# Access to Care for Cardiometabolic Diseases in Low- and Middle-Income Countries

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# 1. Introduction

## 1.1. Background and Motivation

Cardiovascular diseases (CVD) are the most common cause of death globally (GBD Compare 2022). However, while in high income countries the share of deaths attributable to CVD has decreased over the past decades, low- and middle-income countries (LMICs) have seen a steady incline in CVD mortality (GBD Compare 2022). The heaviest burden is carried by upper-middle-income countries (UMICs), where 41% of all deaths in 2019 were caused by CVD (GBD Compare 2022) – leading to far-reaching effects on population welfare, health system structures, social protection schemes, labor markets, and overall economic development (World Economic Forum and Harvard School of Public Health 2011).

One approach to curbing this health burden is to target diabetes, hypertension, and hypercholesterolemia – leading metabolic CVD risk factors, which significantly increase the likelihood of experiencing ischemic heart disease, strokes, and other CVD events (Fuchs and Whelton 2020; Grundy et al. 1999; National Cholesterol Education Program 2001). These conditions share several features that facilitate promising policy interventions: First, they are quickly detectable by health practitioners, requiring minimal training and increasingly affordable equipment (Hu et al. 2016). Secondly, these conditions can be prevented, treated, and, if caught early enough, even reversed by lifestyle modification (McCombie et al. 2017; WHO 2020a). Lastly, medication for each of these conditions exists and is becoming more readily available due to expired patents, declining prices, and internationally recognized relevance, as signified by their inclusion in the WHO List of Essential Medicines (WHO 2016).

At the same time, several important challenges to successfully target diabetes, hypertension, and hypercholesterolemia care as means of CVD prevention in LMICs exist. At the health systems level, more evidence on the state of care for these conditions is needed in order to guide policy towards achieving universal health coverage and to serve as a marker for progress. At the individual level, health behavior is shaped by limited CVD awareness (Khatib et al. 2014) and care seeking behavior, in which individuals underinvest on preventive health (Pascaline Dupas 2011b), often visiting health professionals only once feeling ill (Risso-Gill et al. 2015; Gong et al. 2020) – a behavior particularly detrimental for CVD prevention, as

diabetes, hypertension, and hypercholesterolemia may begin symptomless and become apparent to the affected only once severe complication develop.

Based on this, the objective of this dissertation is to contribute to evidence on access to CVD care by a) describing the state of hypercholesterolemia care in a large range of LMICs and b) testing the effectiveness of two individual-level interventions aimed at increasing CVD screening behavior in Indonesia and South Africa.

## 1.2. Literature and Contribution

At the health systems level, this dissertation adds to the evidence on the global state of care for CVD prevention in LMICs. Such work is vital for the identification of systematic patterns in care gaps and underserved population groups; it serves as an input in economic costing studies (Basu et al. 2021; Kostova et al. 2020); it can offer insights for national and international policy design of clinical guidelines, insurance schemes, efficient health system structures, and target setting (Gregg et al. 2021; Kirschbaum et al. 2021); and it provides an evidence basis for health intervention studies (Ciancio et al. 2021), including for those presented in this doctoral thesis.

More specifically, this dissertation adds to the literature brought forward by the "Global Health and Population Project on Access to Care for Cardiometabolic Diseases (HPACC)", which contributes to gaining a comprehensive understanding of the global state of care for the leading metabolic risk factors of CVD in LMICs. Such comprehensive overview is of particular importance, as care structures are found to achieve higher efficiency when built on integrated CVD care rather than on the assessment of singular risk factors alone (WHO 2018). Hence, in the HPACC studies, coauthors and I set out to first assess the state of care for diabetes, hypertension, and – as presented in this thesis – hypercholesterolemia. Secondly, we describe the state of care when incorporating multiple CVD risk factors simultaneously. We do so by analyzing data from up to 1.2 million adults from 76 LMICs between 2005 and 2019 using nationally representative, population-based surveys pooled at the individual level (Manne-Goehler et al. 2022).

In our analyses, we find that access to both diabetes and hypertension care is poor across many LMICs. Specifically, we estimated that less than two-thirds of individuals with diabetes ever had a blood glucose screening prior to the survey (Manne-Goehler et al. 2019). While in

Geldsetzer et al. (2019), we found that 73% of individuals with hypertension have ever had a blood pressure screening, both studies showed that further drops along diagnosis and treatment care stages led to a retention of less than one fourth of all individuals in control of their condition. Upper-middle income countries were found to generally perform better, yet most countries still exhibited a large unmet need for care. Adding to these findings, this dissertation presents the state of care for hypercholesterolemia.

Furthermore, HPACC studies show large gaps in integrated CVD care. In Peiris et al. (2021), we found that overuse of hypertensive treatment occurs in individuals with otherwise low CVD risk. At the same time, Flood et al. (2021) found that fewer than 5% of people with diabetes receive all recommended treatments when also incorporating their care needs for additional CVD risk factors. Underlining this, our findings in Basu et al. (2021) showed the most cost-effective method for reducing diabetes complications is to scale up blood pressure and statin medication, a type of drug that reduces blood cholesterol levels, rather than focusing on glycemic treatment alone. Adding to these findings, this dissertation presents evidence on care gaps in the recommended use of statins among individuals with high overall CVD risk.

Following the insights on CVD screening gaps from HPACC studies, this dissertation adds to the evidence on how to increase screening take-up in LMICs at the individual level. In this, the presented work builds on the literature of how individuals decide on health investments. Economic theory describes individual's health investments in screening as a function of costs and benefits over time, with initial health stocks, uncertainty over incidence of illness and treatment success, as well as time and risk preferences predicting health decisions (P. Dupas and Miguel 2017; Grossman 1972; Picone, Sloan, and Taylor, Jr. 2004a; Becker 1974a). Given a functioning health care supply structure – in which screening acts as the first stage in a referral system that leads to diagnosis, treatment, and control – the benefit of getting tested for diabetes, hypertension, and hypercholesterolemia can accrue from three sources. First, it allows for early treatment, which can lessen the complications associated with the condition and in some cases even revert them altogether. Secondly, by providing medical advice and a personalized risk assessment, screening can prevent these conditions in individuals with not yet abnormal measurements. Third, by preventing and treating these conditions, screening acts as a preventive mechanism also for CVD and other downstream health outcomes. Costs of screening can occur in monetary form, e.g. in screening fees or transport costs, as well as in non-monetary form, e.g. in psychological stress caused by the testing procedure or its outcome.

Empirical literature has identified several effective interventions that alter this cost-benefit structure and address informational, behavioral, or cost barriers to health screening take-up. Examples of successful interventions aimed at lowering cost barriers include the use of cash incentives to increase take-up of HIV testing services (Thornton 2008), and subsidies towards treatment options after cervical cancer screenings (Okeke, Adepiti, and Ajenifuja 2013). Take-up of cervical cancer screening, as well as breast and colorectal cancer screenings, have also been shown to be affected by informational interventions, such as the provision of educational materials, one-on-one education, or group teachings (R. C. Baron et al. 2008; Everett et al. 2011). Mass media campaigns as another form of an informational intervention have also been shown to increase HIV screenings (Vidanapathirana et al. 2005). Examples of successful behavioral interventions for increased screening take-up include reminders via mail, phone call, or SMS for cancer screenings (R. C. Baron et al. 2008; Eibich and Goldzahl 2020; Everett et al. 2011; Kerrison et al. 2015), prompting individuals to schedule screening appointments (Milkman et al. 2013), as well as using vouchers as means of reframing already free screening services (Kacker et al. 2021). As this evidence focuses primarily on high income country settings or on conditions other than diabetes, hypertension, and hypercholesterolemia, this dissertation applies and adapts such policy tools into the CVD sphere in LMICs.

## 1.3. Chapter Overview

The second chapter of this dissertation is dedicated to providing evidence on the global state of CVD care. In this, Essay 1 will give an overview of the comprehensive care continuum for hypercholesterolemia, while in Essay 2 we examine the treatment stage of hypercholesterolemia and CVD prevention by assessing statin use. Both essays are observational, cross-country studies based on HPACC's nationally-representative, individual-level data from up to 41 LMICs, which combines biomarkers and physical measurements with self-reported access to care items. Following this, the third chapter presents evidence on the effectiveness of interventions aimed at increasing the demand for CVD risk factor care at the individual level. In this, Essay 3 examines the effect of SMS reminders on diabetes and hypertension screening uptake in Indonesia, while Essay 4 examines the effect of survey-based referral letters on hypertension care and blood pressure outcomes in South Africa. While both essays are based on primary data collection using in-person and telephone surveys, Essay 3 follows a randomized control trial design, whereas Essay 4 utilizes a quasi-experimental regression discontinuity design for causal impact analysis.

### 1.3.1. Essay 1: Unmet Need for Hypercholesterolemia Care in 35 Low- and Middle-Income Countries: A Cross-Sectional Study of Nationally-Representative Surveys

As the prevalence of hypercholesterolemia is increasing in LMICs, detailed evidence on the state of care for this condition is needed to guide the response of health systems to this epidemic. The objective of this study is to quantify unmet need for hypercholesterolemia care among adults in 35 LMICs.

In joint work with the HPACC team, we pooled individual-level data from 129,040 respondents aged 15 years and older from nationally representative surveys conducted between 2009 and 2018. Hypercholesterolemia care was quantified using cascade of care analyses in the pooled sample as well as by region, country income group, and country. Hypercholesterolemia was defined as high total or LDL cholesterol (TC and LDL-C), identified in the survey's biomarker measurements, or self-reported lipid-lowering medication use. Stages of the care cascade for hypercholesterolemia were defined as follows: screened (prior to the survey), aware of diagnosis, treated (lifestyle advice and/or medication), and controlled TC or LDL-C. We further estimated how age, sex, education, body mass index (BMI), current smoking, having diabetes, and having hypertension was associated with cascade progression using modified Poisson regression models with survey fixed effects.

We estimated a high TC prevalence of 7.1% and a high LDL-C prevalence of 7.5% in this set of LMICs. The cascade analysis shows that 43% of study participants with high TC and 47% with high LDL-C have ever had their cholesterol measured prior to the survey. 31% and 36% were aware of their diagnosis; 29% and 33% were treated; 7% and 19% were controlled. We find substantial heterogeneity in cascade performance across countries and higher performances in UMICs and the Eastern Mediterranean, Europe, and Americas. Lipid screening was significantly associated with older age, female sex, higher education, higher BMI, comorbid diagnosis of diabetes, and comorbid diagnosis of hypertension. Awareness of diagnosis was significantly associated with older age, higher BMI, comorbid diagnosis of diabetes, and comorbid diagnosis of hypertension. Lastly, treatment of hypercholesterolemia was significantly associated with comorbid hypertension and diabetes, and control of lipid measures with comorbid diabetes.

We conclude that cascade performance was poor across all stages, indicating large unmet need for hypercholesterolemia care in this sample of LMICs – calling for greater policy and research attention towards this NCD risk factor and highlighting opportunities for improved prevention of cardiovascular disease. A closer examination of the better performing countries in our study, such as Sri Lanka, Costa Rica, Iran, and Morocco, could yield important policy lessons.

### 1.3.2. Essay 2: Use of Statins for the Prevention of Cardiovascular Disease in 41 Low- and Middle-Income Countries: A Cross-Sectional Study of Nationally Representative, Individual-Level Data

In the prevention of CVD, a World Health Organization (WHO) target is that at least 50% of eligible people use statins. The objectives of this study are to benchmark statin use in 41 LMICs and to investigate country-level and individual-level characteristics associated with statin use.

In joint work with the HPACC team, we pooled individual-level data from 116,449 respondents aged 40 to 69 years from nationally representative surveys conducted between 2013 and 2019. Primary outcomes are the proportion of eligible individuals self-reporting use of statins for the primary and secondary prevention of CVD. Eligibility for statin therapy for primary prevention was defined among individuals with a history of diagnosed diabetes or a 10-year CVD risk >20%. Eligibility for statin therapy for secondary prevention was defined among individuals with a self-reported history of CVD. At the country level, we estimated statin use by per-capita health spending, per-capita income, burden of CVD, and noncommunicable disease policy commitment. At the individual level, we used modified Poisson regression models to assess statin use along individual-level characteristics of age, sex, education, and rural versus urban residence. Countries were weighted in proportion to their population size in pooled analyses.

We estimated that 9.7% of individuals in our sample were eligible for a statin for primary prevention of CVD and 7.9% were eligible for secondary prevention of CVD. Among the eligible individuals, statin use was 8.0% for primary prevention of CVD and 21.9% for secondary prevention of CVD. The WHO target that at least 50% of eligible individuals receive statin therapy to prevent CVD was achieved by no region or income group. At the country level, statin use was less in countries with lower health spending. At the individual level, there

was generally lower statin use among men (primary prevention only) and individuals who were younger, less educated, and lived in rural areas.

In a diverse sample of LMICs, statins are used by approximately one in ten eligible people for the primary prevention of CVD and one in five eligible people for the secondary prevention of CVD. There is an urgent need to scale up statin use in low- and middle-income countries to achieve WHO targets. Policies and programs that facilitate implementation of statins into primary health systems in these settings – such as those put forward by the WHO HEARTS Technical Package for Strategic Approaches to Improving Cardiovascular Health in Countries – should be explored.

### 1.3.3. Essay 3: The Effect of SMS Reminders on Health Screening Uptake: A Randomized Experiment in Indonesia

Despite rising CVD prevalences, the uptake of screening for such conditions can remain low even in contexts where free, village-level care structures are available. The objective of this study is to assess the effectiveness of a personalized SMS intervention aimed at increasing diabetes and hypertension screening demand in Indonesia.

In joint work with Anna Reuter, Lisa Rogge, and Sebastian Vollmer, we conducted a randomized controlled trial on 1,386 respondents aged 40 years or older between 2019 and 2020. Participants were randomly sampled from two districts in Aceh, Indonesia in a two-stage stratified design and randomly assigned to a treatment or control group. The treatment group received two sets of three text messages about the risk of diabetes and hypertension as well as the necessity, benefits, and logistics of free, village-based screening services. We estimated intention-to-treat and local-average-treatment-effects on screening uptake, diabetes and hypertension-related knowledge, and spillover effects. Additionally, we assessed heterogeneous treatment effects along time and risk preferences as well as discussed implications for scale-up.

We found that the intervention increased the uptake of screening services from 33% to 40%, which is a 6.6 percentage point or a 20% increase compared to the control group. For respondents who received at least one full set of messages and could remember any message

content, the effect size increased to 17 percentage points. The text messages seemed to work as a reminder for screening: While there was an overall increase in the uptake of screening, there was no impact on knowledge related to the text message or general disease knowledge. Respondents primarily remembered the content on the logistics and the advice to get screened. The only new information, which was remembered by a quarter of the respondents who recalled any content, was that their age group implies a higher risk for hypertension and diabetes. In addition, the treatment effect was driven by attending screening at the community health center (Puskesmas) rather than the specific village screening meeting (Posbindu). The treatment effect did not differ across time and risk preferences. We could not detect any spillovers to other household members.

We conclude that text messages can be a cheap and easily scalable tool to reduce testing gaps in a middle-income country setting, working primarily as a reminder to seek out screening services for diabetes and hypertension.

### 1.3.4. Essay 4: The Effect of Survey-Based Referral Letters for Hypertension on Care and Health Outcomes in South Africa

Referral letters issued for high blood pressure measurements taken during survey collection has the potential to increase hypertension screening directly through research itself. The objective of this study is to assess the effectiveness of such referral letters on care and health outcomes as well as to identify whether physical and mental health act as determining factors in the impact of the intervention.

In joint work with Carlos Riumallo Herl, we estimated the causal effects of referrals letters using a regression discontinuity design, which exploits the deterministic referral rule based on whether individuals fall above or below established thresholds in their systolic and diastolic blood pressure (SBP and DBP) measurements. We pooled survey data from two longitudinal data sources on South African adults aged 40 or older from 2008 to 2019: the "Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa" (HAALSI) project and the nationally-representative National Income Dynamics Study (NIDS). We estimated the effect of a referral letter issued at baseline for high SBP and high DBP separately on the outcomes of i) awareness of diagnosis, ii) being currently under treatment, iii) and being hypertensive at follow-up; as well as on the change in iv) SBP and v) DBP between baseline and follow-up. Additionally, we aimed to identify whether physical and mental health act as determining factors in the impact of the intervention. We did so by estimating RD specifications using covariate adjustment, which include self-rated health as a proxy for both physical and mental health as well as depressive symptomology as one specific dimension of mental health.

We found that overall referral letters do not have a significant effect on the awareness of diagnosis, treatment, and most blood pressure outcomes after two to four years. Receiving a letter for high SBP significantly and robustly affected the change in DBP between baseline and endline, however the effect was of small magnitude and no impact on hypertension rates at follow-up could be identified. Furthermore, in our analysis of physical and mental health, we found self-rated health and depressive symptomology to significantly affect care and BP outcomes. While worse self-rated health was generally associated with better care and BP

outcomes, these effects were alleviated when individuals with better self-rated health receive the treatment. We further provide descriptive evidence suggesting that this may be due to individuals seeking care according to their actual health status and that respondents with better self-rated health may update their beliefs when presented with contrasting personalized risk information in the form of the letter. Additionally, we found that referral letters lead to worse health outcomes in respondents with depressive symptoms – potentially reinforcing negative sentiments on self-efficacy and a sense of hopelessness.

We conclude that survey-based referral letters for high blood pressure have little effect on care and health outcomes in this sample, but that differential effects may occur depending on the physical and mental health of the recipients. More research should be devoted to identifying how surveys can maximize the benefit of delivering collected personalized risk information to their participants in an impactful, responsible, and sustainable manner.

## 1.4. General Summary and Conclusion

This dissertation concludes that access to CVD care is poor in many LMICs. We showed that especially for diabetes and hypercholesterolemia, large shares of affected individuals are never screened for their conditions. Furthermore, across all diabetes, hypercholesterolemia, and hypertension, we found large drops along diagnosis, treatment, and control stages of care. As a marker for integrated CVD care, the analysis of statin use for primary and secondary prevention of CVD additionally showed that no examined LMIC met WHO treatment targets. These findings suggest that large population shares remain without appropriate care for the global leading cause of death – calling for greater policy and research attention towards facilitating improved CVD care in LMICs.

Highlighting opportunities for improvement, we found that substantial heterogeneities in access to care across regions and countries exist. Some countries, such as Costa Rica, were found to consistently perform better across multiple studies and conditions, potentially offering important policy lessons upon closer inspection. Also at the individual level, patterns in the associations with care outcomes suggest that targeting mechanism for identifying respondent at higher risk of presenting with CVD may partially be in place; with older individuals and those presenting with comorbidities being more likely to achieve care outcomes. At the same

time, also differences in key socioeconomic characteristics, such as education, became apparent – requiring solutions that expand on efficient, but equitable target mechanisms.

While solutions must be found on all levels of the health system, this dissertation specifically points to two interventions aimed at increasing individual-level screening demand for CVD risk factors, namely SMS reminder and survey-based referral letters. Both interventions aimed at increasing the salience of CVD risk factors by instructing and reminding individuals to seek care; as well as aimed at altering risk perceptions of individuals by offering different degrees of personalized risk information. They showed that health behavior can be affected by such light-touch interventions, as SMS reminders induced greater screening uptake, and survey-based referral letters induced small changes in health outcomes in certain population groups (yet left no impact on others). In the SMS intervention, this seemed to have worked primarily through a reminder effect. In the referral letter intervention, impact varied by physical and mental health status, potentially addressing perceptions of risk of illness and of screening and treatment benefits. Overall, these interventions show that CVD health behavior can be affected by such light-touch interventions, but to an extent that still left large care gaps remaining.

# 2. The State of Cardiovascular Care in Low- and Middle-Income Counties

## 2.1. Essay 1:

### Unmet Need for Hypercholesterolemia Care in 35 Low- and Middle-Income Countries: A Cross-Sectional Study of Nationally-Representative Surveys

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### 2.1.1. Abstract

**Background:** As the prevalence of hypercholesterolemia is increasing in low- and middle-income countries (LMICs), detailed evidence is urgently needed to guide the response of health systems to this epidemic. This study sought to quantify unmet need for hypercholesterolemia care among adults in 35 LMICs.

**Methods and Findings:** We pooled individual-level data from 129,040 respondents aged 15 years and older from 35 nationally-representative surveys conducted between 2009 and 2018. Hypercholesterolemia care was quantified using cascade of care analyses in the pooled sample and by region, country income group, and country. Hypercholesterolemia was defined as (i) total cholesterol (TC) ≥ 240 mg/dL or self-reported lipid-lowering medication use, and alternatively as (ii) low density lipoprotein cholesterol (LDL-C) ≥160 mg/dL or self-reported lipid-lowering medication use. Stages of the care cascade for hypercholesterolemia were defined as follows: screened (prior to the survey), aware of diagnosis, treated (lifestyle advice and/or medication), and controlled (TC<200 mg/dL or LDL-C<130 mg/dL). We further estimated how age, sex, education, body mass index (BMI), current smoking, having diabetes, and having hypertension is associated with cascade progression using modified Poisson regression models with survey fixed effects.

High TC prevalence was 7.1% (95% CI: 6.8 to 7.4%) and high LDL-C prevalence was 7.5% (95% CI: 7.1 to 7.9%). The cascade analysis showed that 43% (95% CI: 40 to 45%) of study participants with high TC and 47% (95% CI: 44 to 50%) with high LDL-C ever had their cholesterol measured prior to the survey. 31% (95% CI: 29 to 33%) and 36% (95% CI: 33 to 38%) were aware of their diagnosis; 29% (95% CI: 28 to 31%) and 33% (95% CI: 31 to 36%) were treated; 7% (95% CI: 6 to 9%) and 19% (95% CI: 18 to 21%) were controlled. We found substantial heterogeneity in cascade performance across countries and higher performances in upper-middle income countries and the Eastern Mediterranean, Europe, and Americas. Lipid screening was significantly associated with older age, female sex, higher education, higher BMI, comorbid diagnosis of diabetes, and comorbid diagnosis of hypertension. Awareness of diagnosis was significantly associated with older age, higher BMI, comorbid diagnosis of diabetes, and comorbid diagnosis of hypertension. Lastly, treatment of hypercholesterolemia was significantly associated with comorbid hypertension and diabetes, and control of lipid measures with comorbid diabetes. The main limitations of this study are a potential recall bias

in self-reported information on received health services as well as diminished comparability due to varying survey years and varying lipid guideline application across country and clinical settings.

**Conclusions:** Cascade performance was poor across all stages, indicating large unmet need for hypercholesterolemia care in this sample of LMICs – calling for greater policy and research attention towards this NCD risk factor and highlighting opportunities for improved prevention of cardiovascular disease.

### 2.1.2. Introduction

Cardiovascular disease (CVD) is already the leading cause of death in low- and middle-income-countries (LMICs) and is projected to increase rapidly in the coming decades (GBD 2017 Causes of Death Collaborators 2018; IHME n.d.). Hypercholesterolemia – defined as abnormal levels of blood lipids, such as high fasting total cholesterol – is the second leading physiological risk factor for CVD after high blood pressure ("GBD Results Tool | GHDx" n.d.; National Cholesterol Education Program 2001). High cholesterol was estimated to cause 3.5 million deaths and 81.4 million disability-adjusted life years (DALYs) in LMICs in 2019 ("GBD Results Tool | GHDx" n.d.). Importantly, the disease burden caused by hypercholesterolemia is eminently preventable with lifestyle modification and low cost, off-patent medications (Gaziano et al. 2017; R. Collins et al. 2016; Cholesterol Treatment Trialists' (CTT) Collaboration 2015; National Cholesterol Education Program 2001). The fact that a high burden persists suggests that many health systems in LMICs are still ill-equipped to address this important condition.

Despite the importance of rigorous evidence to guide health policy and improve healthcare delivery, the current empirical evidence remains weak and offers only a limited understanding of the state of care for hypercholesterolemia in LMICs (Roth et al. 2011; Farzadfar et al. 2011). Research is mainly confined to single countries, often based on a subnational level with a focus on specific subpopulations, or to single health care indicators, such as access to essential medicines (Roth et al. 2011; Jingi et al. 2014b; Khatib et al. 2016; Shanthi Mendis et al. 2005; F.-L. Zhang et al. 2017). To our knowledge, nationally representative studies analyzing broader health system performance at the individual-level across a larger number of LMICs have been altogether absent.

Our analysis aims to address this dearth of evidence by identifying the unmet need for hypercholesterolemia care using a pooled dataset of nationally representative, population-based surveys that includes 129,040 individuals from 35 LMICs. We assess the unmet need for care by applying the cascade of care approach, a quantitative depiction of the screening, diagnosis, treatment, and control stages within the care system of the affected population groups. This methodology has been widely used to monitor care responses to the HIV epidemic and is increasingly applied to examine the management of chronic diseases, such as diabetes or hypertension (Ali et al. 2014; Manne-Goehler et al. 2019; Geldsetzer et al. 2019; Haber et al.

2016). We estimate the cascade of care for individuals, separately for high total cholesterol (TC) and high low-density lipoprotein cholesterol (LDL-C), (i) in a pooled sample across all 35 LMICs and (ii) disaggregated at the World Health Organization's (WHO) epidemiological subregion (WHO n.d.), World Bank country income classification (World Bank 2020), and country level. We then estimate the associations between individual-level characteristics and cascade completion – yielding insights into the overall unmet need for care as well as into potentially underserved subpopulations in this group of LMICs.

### 2.1.3. Methods

*Data sources*

The included datasets were obtained through a systematic request approach. We first targeted surveys following the WHO's Stepwise Approach to Surveillance of Noncommunicable Disease (NCD) Risk Factors (STEPS). We identified responsible contacts for each survey via the WHO STEPS website, expert contacts, a web search, and the WHO NCD Microdata repository (WHO n.d.). Inclusion criteria were: surveys had to be conducted during or after 2008; had to come from an upper-middle, lower-middle or low-income country per World Bank definition during the survey year (World Bank 2020), be nationally representative with a response rate of over 50%; have data available at the individual-level; include biomarkers for hypercholesterolemia (TC or LDL-C); and include questions that assess the access to health services for diagnosis, preventive counselling, and treatment of hypercholesterolemia. Whenever STEPS surveys were not available, we searched for complementing data meeting the inclusion criteria. A detailed protocol and outcome of the search process is provided in Appendix A.1.

This process yielded 32 STEPS surveys from 2010 to 2018 to be included in our analysis: Algeria, Azerbaijan, Bangladesh, Belarus, Benin, Bhutan, Botswana, Burkina Faso, Costa Rica, Ecuador, Eswatini, Guyana, Iran, Iraq, Kiribati, Kyrgyzstan, Lebanon, Moldova, Mongolia, Morocco, Myanmar, Solomon Islands, Sri Lanka, St. Vincent and the Grenadines, Sudan, Tajikistan, Timor-Leste, Tokelau, Tonga, Tuvalu, Vietnam, and Zambia. Supplementary to these, we added the 2009/10 National Health Survey from Chile, the 2013 National Survey of Noncommunicable Diseases from Seychelles, and the 2017 HYBRID Survey from the Marshall Islands. All surveys used multi-stage cluster random sampling to select participants. Details on data access can be found in Appendix A.2 and details on sampling strategies can be found in Appendix A.3.1.

*Cascade construction*

The cascade-of-care methodology first requires the identification of individuals with hypercholesterolemia to serve as the overall sample. Our definition of hypercholesterolemia is contingent upon a collected biomarker sample and self-reported medication use. We used two lipid biomarkers to establish a set of hypercholesterolemia definitions – total cholesterol and LDL-C. Total cholesterol is significantly and positively associated with ischemic heart disease mortality as well as other CVDs, and is the most commonly measured lipid biomarker in the LMIC literature (National Cholesterol Education Program 2001; Prospective Studies Collaboration 2007). LDL-C is the primary target for cholesterol-lowering therapy according to the Adults Treatment Panel III (ATP III) guidelines of the National Cholesterol Education Program and therefore holds particular relevance for the analysis of unmet need for care (National Cholesterol Education Program 2001; Jeemon et al. 2017). The biomarker cut-offs for classifying hypercholesterolemia are based on the ATP III guidelines, which are frequently used in the literature ("NCDs | STEPS Country Reports" n.d.; Joshi et al. 2014; Lee et al. 2014; Muntner et al. 2013). The guidelines specify three classifications of TC – namely desirable, borderline high, and high – and five for LDL-C – optimal, near optimal/above optimal, borderline high, high, and very high.[1] We defined hypercholesterolemia as high and very high lipid values. We opted for this classification for two reasons. First, high TC and LDL-C values have been shown to be associated with an increased lifetime risk of coronary heart disease justifying clinical therapies and necessitating care (National Cholesterol Education Program 2001). Second, treatment guidelines are usually based on CVD risk scores rather than on lipid measures alone and often vary across countries (National Cholesterol Education Program 2001; Jeemon et al. 2017). In order to not evaluate health systems by care standards that are in fact unapplied, we chose to be conservative in our definition of hypercholesterolemia. Thus, we defined hypercholesterolemia based on respondents with (i) a TC measurement of 240 mg/dL or higher or who were taking lipid-lowering medication, and alternatively (ii) a LDL-C measurement of 160 mg/dL or higher or taking lipid-lowering medication. However, in

[1] The ATP III provides three classifications of TC and five classifications of LDL. The three TC classifications are: (i) TC<200 mg/dL is classified as desirable, (ii) 200≤TC≤239 is classified as borderline high, and (iii) TC≥240 is classified as high. The five LDL classifications are: (i) LDL-C<100 is classified as optimal, (ii) 100≤ LDL-C ≤129 is classified as near or above optimal, (iii) 130≤ LDL-C ≤159 is classified as borderline high, (iv) 160≤ LDL-C ≤189 is classified as high, and (v) LDL-C ≥129 is classified as very high.(National Cholesterol Education Program 2001)

supplemental analyses, we redefine hypercholesterolemia to further include borderline high values as well as apply a definition based on the American College of Cardiology / American Heart Association Task Force on Clinical Practice Guidelines (AHA/ACC)[2].

Bangladesh, Chile, Costa Rica, Guyana, Iran, Iraq, and Lebanon measured lipid biomarkers via blood samples sent to a laboratory. Belarus, Benin, Bhutan, Burkina Faso, Ecuador, Eswatini, Kiribati, Moldova, Morocco, Solomon Islands, Sri Lanka, St. Vincent and the Grenadines, Sudan, Timor-Leste, Tonga, Vietnam, and Zambia used the CardioCheck PA point-of-care (POC) device. Seychelles used the Konelab 30i, Mongolia the Prima Home Test, Myanmar the SD Lipido Care Analyzer, Tokelau the Accutrend GC, and Tuvalu the Accutrend Plus (see Appendix A.3.2). For the remaining six countries, we could not identify whether biomarkers were measured via a laboratory or a POC machine.

In Algeria, Bangladesh, Burkina Faso, Chile, Costa Rica, Iran, Iraq, Lebanon, Mongolia, Morocco, Myanmar, Seychelles, and St. Vincent and the Grenadines both TC and LDL-C records were collected, while the remaining countries measured only TC. We took TC records directly from the survey and derived LDL-C from total cholesterol, triglycerides, and HDL cholesterol records using the Friedewald equation (Friedewald, Levy, and Fredrickson 1972). Individuals without a biomarker record were excluded from the analysis (Appendix A.4). A sensitivity analysis that includes individuals with no biomarker measurement, in which hypercholesterolemia is defined purely based on the self-reported medication status, can be found in Appendix A.6.1 (Figure A.6 - 1). We further excluded observations with TC records above 300 mg/dL, because even though physiologically very high TC values may occur, POC devices are not always well-equipped to reliably measure these (Appendix A.4) (pts Diagnostics n.d.; Panz et al. 2005). Supplementary analyses including TC values above 300 mg/dL can be found in Appendix A.6.1 (Figure A.6 - 2).

In a next step, the cascade-of-care analysis requires the measurement of the sample respondents' met need for hypercholesterolemia care prior to the survey. For this, we defined the following four cascade stages expressing each step in the care continuum: (1) ever received a cholesterol measurement ("Lipids Measured"); (2) ever been told by a health care professional

[2] AHA/ACC uses an LDL-C cutoff of 70 mg/dL as a threshold for statin therapy in adults 40 to 75 years of age with diabetes or with a 10-year atherosclerotic cardiovascular disease risk of over 7.5%. In our definition, we classify everyone with an LDL-C measurement of 70 mg/dL or higher as having hypercholesterolemia.

about one's hypercholesterolemia diagnosis ("Aware of Diagnosis"); (3) received lifestyle advice or currently taking medication for high cholesterol ("Advice or Medication"); and (4) has lipid measure in controlled ranges ("Controlled Disease"). Our definition of the last cascade stage was again based on biomarker measurements. We recognize that there usually are no clinical target ranges for cholesterol alone and thus we chose to define "controlled" lipid ranges based on the ATP III guidelines' definition of desirable, optimal, and near optimal values, as was done in related literature (He et al. 2004; Primatesta and Poulter 2006; Mindell et al. 2011). Hence, according to our definition an individual had controlled lipid values whenever TC was lower than 200 mg/dL and LDL-C was lower than 130 mg/dL (National Cholesterol Education Program 2001). Supplementary cascade analyses based on a definition that further considers borderline high values (≥200 and <240 mg/dL TC; ≥130 and <160 mg/dL LDL-C) as "controlled" lipid values can be found in Appendix A.6.1 (see Figure A.6 - 3 and Figure A.6 - 4).

The cascade stages *Lipids Measured, Aware of Diagnosis, Advice or Medication* were measured with self-reported interview data. Across surveys, the question phrasing of these cascade measures was almost identical as is shown in Appendix A.4. *Lipids Measured* refers to lipid measurements that had taken place prior to the survey. For *Advice or Medication* (3), advice refers to lifestyle advice about physical activity, body weight, fruit and vegetable intake, special diets, reduction of fat, or tobacco consumption. Medication refers to any oral treatment.

*Statistical analysis*

In the cascade-of-care analysis, we calculated the share of respondents that reach each consecutive cascade stage over the denominator of all individuals with hypercholesterolemia defined either as high TC or as high LDL-C. We estimated the cascades of care for the pooled sample as well as at the WHO epidemiological subregion, World Bank country income classification, and country level for both hypercholesterolemia definitions. In addition to this, we carried out a pooled cascade analysis on a restricted sample of individuals with hypercholesterolemia for whom cholesterol screening is recommended according to international guidelines. This allows an examination of health system performance in relation to adherence to approved care guidelines. We derived the screening recommendation guidelines from the WHO Package of Essential Noncommunicable (PEN) Disease Interventions for Primary Health Care in Low-Resource Settings. The PEN protocol specifies that individuals exhibiting any one of the following risk factors should be included in the routine management

of CVD risk and undergo cholesterol screening: age>40 years; current smoking; waist circumference ≥90 cm in males or ≥100 cm in females; having diabetes; or having hypertension (WHO 2020a).

We adjusted all cascade estimations for survey sampling designs using the 'svy set' command with subpopulation specifications in Stata 16.1 (StataCorp, College Station, Texas, US), used R's ggplot2 package for the disaggregated cascade graphics, and R's geepack package as well as Stata 16.1 for regression estimations (Wickham 2016).

In addition to the cascade analyses, we estimated individual-level correlates of cascade progression. We regressed the proportion of respondents with high TC or high LDL-C that reached each cascade stage on age, sex, education, smoking, body mass index (BMI), diabetes, and hypertension status. In this, we adjusted our standard errors for clustering at the primary sampling unit level and included survey fixed effects (for mathematical equations see Appendix A.5.1). The regression analyses were not weighted (Abadie et al. 2017). We used a modified Poisson regression model yielding risk ratios (RR) as our main specification and supplemented our analysis with additional univariable and multivariable models and an analysis of deviance in Appendix A.6.2 (Zou 2004).

*Covariate measurement*

Age, smoking status, and education were self-reported. Sex was recorded as observed. We calculated respondents' BMI from height and weight measurements that were taken alongside waist circumference measurements. The hypertension status was derived from blood pressure readings and the diabetes status from collected blood glucose measurements. Hypertension was defined as a systolic blood pressure of at least 140 mm Hg, diastolic blood pressure of at least 90 mm Hg, or reported use of medication for hypertension. Diabetes was defined as fasting plasma glucose of at least 7.0 mmol/l (126 mg/dl), random plasma glucose of at least 11.1 mmol/l (200 mg/dl), HbA1c of at least 6.5%, or reporting to be taking medication for diabetes. More details on the definition and measurement of these comorbidities are provided elsewhere (Manne-Goehler et al. 2019; Geldsetzer et al. 2019).

*STROBE guidelines*

This study is reported as per the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guideline (see Appendix A.7.1).

### 2.1.4. Results

*Sample characteristics*

Our sample included 129,040 individuals from 35 LMICs over a 9-year period (2009-2018). Details on country-specific sample characteristics can be found in Appendix A.6.2 (Table A.6 - 1). Socio-demographic characteristics of the respondents are displayed in Table 2.1-1 stratified by biomarkers. We found that 7.1% (95% CI: 6.8 to 7.4%) of individuals had high TC and 7.5% (95% CI: 7.1 to 7.9%) had high LDL-C (also see Table A.6 - 2). The mean age of the overall sample was around 40 to 41 years (SD:  14 years), whereas the mean age in those with either form of hypercholesterolemia was around 49 years (SD: 13-14 years). Secondary schooling or higher education was completed by 41% of those with high TC and 31% of those with high LDL-C. Around 59-61% of those with hypercholesterolemia were overweight or obese and approximately 16-17% were current smokers. Comorbid diabetes occurred in 23-24% of those with hypercholesterolemia and hypertension in 49-52%. Around 87-89% of those with hypercholesterolemia exhibited at least one associated risk factor, indicating that cholesterol screening was recommended for them. Sample characteristics of respondents, who had TC and LDL-C measures in normal ranges and who reported not taking lipid-lowering medication can be found in Table A.6 - 3.

Table 2.1-1. Socio-demographic sample characteristics by hypercholesterolemia definition

| | TC Sample* | | | | LDL-C Sample** | | | |
|---|---|---|---|---|---|---|---|---|
| | Overall Sample | | Sample With High TC | | Overall Sample | | Sample With High LDL-C | |
| | Number of Observations† | Percentage or Mean‡ | Number of Observations† | Percentage or Mean‡ | Number of Observations† | Percentage or Mean‡ | Number of Observations† | Percentage or Mean‡ |
| Hypercholesterolemia Prevalence*** | 128,998 | 7 | 10,737 | 100 | 58,332 | 7 | 6,315 | 100 |
| Female | 128,996 | 51 | 10,732 | 51 | 58,330 | 52 | 6,314 | 59 |
| Age(mean) | 128,998 | 40 | 10,733 | 49 | 58,332 | 41 | 6,315 | 49 |
| 15–24 y/o | 12,290 | 15 | 194 | 3 | 3,184 | 12 | 88 | 3 |
| 25–34 y/o | 29,555 | 26 | 820 | 13 | 12,882 | 26 | 512 | 14 |
| 35–44 y/o | 30,445 | 23 | 1,713 | 19 | 14,278 | 24 | 1,024 | 19 |
| 45–54 y/o | 26,964 | 18 | 2,967 | 28 | 12,824 | 19 | 1,689 | 27 |
| 55–64 y/o | 20,757 | 13 | 3,328 | 26 | 9,728 | 13 | 1,842 | 24 |
| 65+ y/o | 9,029 | 5 | 1,715 | 11 | 5,436 | 6 | 1,160 | 13 |
| Education | | | | | | | | |
| Less than primary school | 25,566 | 21 | 1,906 | 24 | 12,719 | 26 | 1,456 | 29 |
| Less than secondary school | 39,406 | 34 | 3,470 | 35 | 20,784 | 39 | 2,376 | 39 |
| Secondary completed or higher | 62,086 | 45 | 5,064 | 41 | 23,767 | 35 | 2,292 | 31 |
| BMI | | | | | | | | |
| Normal | 53,969 | 52 | 2,750 | 38 | 22,596 | 48 | 1,584 | 36 |
| Underweight | 8,323 | 10 | 231 | 3 | 3,538 | 9 | 113 | 3 |
| Overweight | 36,438 | 25 | 3,790 | 37 | 18,591 | 28 | 2,385 | 38 |
| Obese | 28,024 | 13 | 3,715 | 22 | 12,465 | 15 | 2,068 | 23 |
| Smoking# | 128,329 | 20 | 10,699 | 16 | 57,974 | 20 | 6,292 | 17 |
| Diabetic | 121,887 | 8 | 10,062 | 24 | 57,288 | 9 | 6,190 | 23 |
| Hypertensive | 127,755 | 27 | 10,650 | 52 | 57,766 | 27 | 6,265 | 49 |
| Screening recommended§ | 128,998 | 68 | 10,733 | 89 | 58,332 | 70 | 6,315 | 87 |
| **Total Number of Observation** | 128,998 | | 10,737 | | 58,332 | | 6,315 | |

Note:
* Includes respondents from all 32 countries with a valid TC measurement (see A.4); columns "Sample With High TC" restricted to respondents with high TC (defined by exceeding ATP III guideline cutoffs, i.e., TC ≥6.21 mmol/L, or respondent taking lipid medication).
** Includes respondents from Algeria, Bangladesh, Burkina Faso, Chile, Costa Rica, Iran, Iraq, Lebanon, Mongolia, Morocco, Myanmar, Seychelles, and St. Vincent and the Grenadines with a valid LDL-C measurement (see A.4); columns "Sample With High LDL-C" restricted to respondents with high LDL-C (defined by exceeding ATP III guideline cutoffs, i.e., LDL-C ≥4.14 mmol/L, or respondent taking lipid medication).
*** Refers to high TC in columns 1–4 and high LDL-C in columns 5–8. See Table A.6 - 2 for 95% confidence intervals.
† Unweighted.
‡ Values account for sampling design with survey weights rescaled by the survey's sample size such that all countries contribute to estimates according to their population size.
# Respondents that are currently smoking or were smoking within past 12 months are classified as smoking (as per WHO PEN disease interventions for primary healthcare in low-resource settings (WHO PEN) Protocol 1).
§ According to the PEN protocol, screening is recommended whenever the respondent exhibits at least one of the following risk factors: age >40; smoking; diabetic; hypertensive; waist circumference ≥90 in males; waist circumference ≥100 in females.
ATP III, Adults Treatment Panel III; BMI, body mass index; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; WHO PEN, World Health Organization package of essential noncommunicable disease interventions for primary healthcare in low-resource settings.

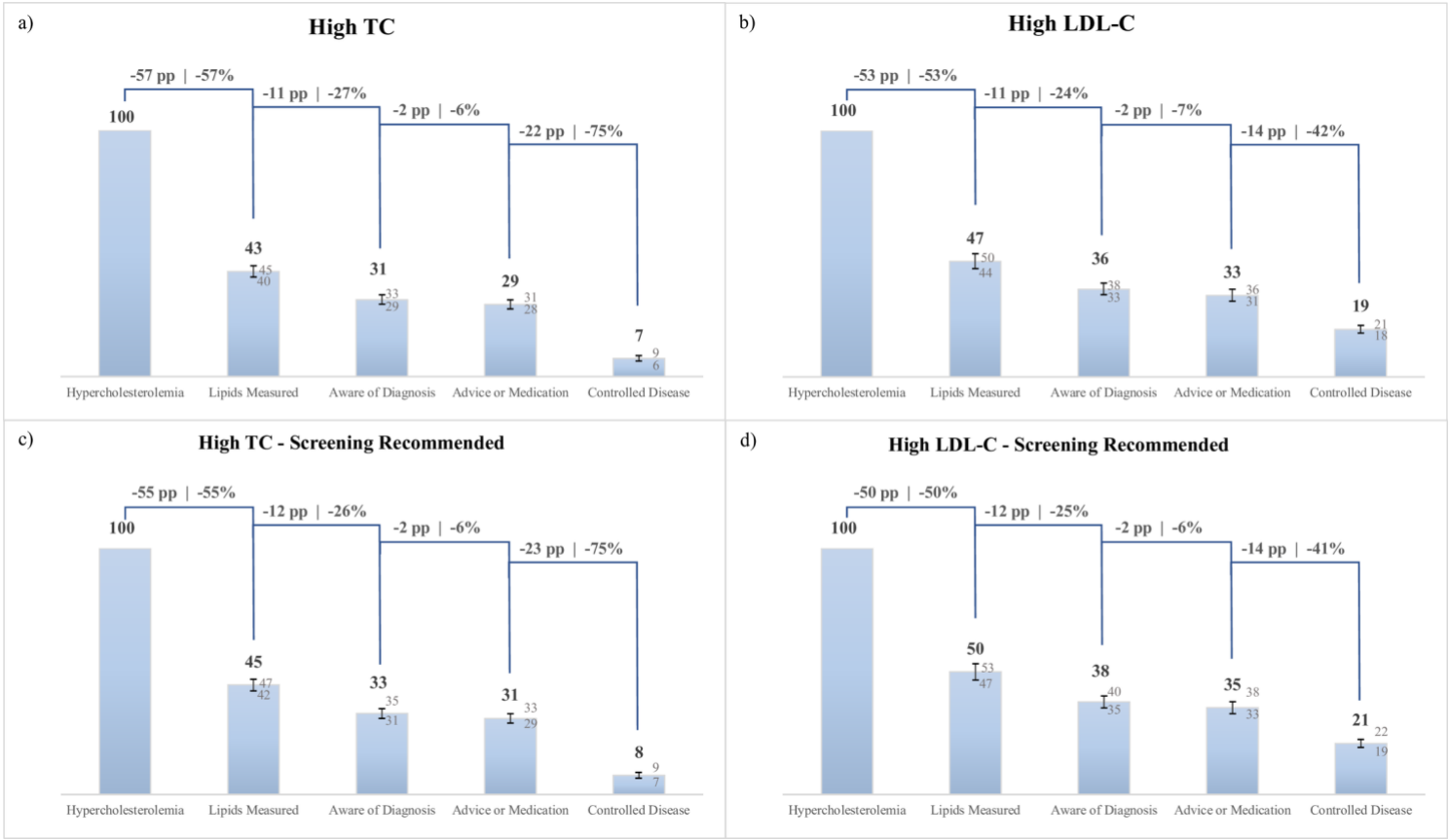
### *Pooled cascades of care*

The cascades of care for the pooled country sample are displayed in Panel a) and b) of Figure 2.1-1. Only 43% (95% CI: 40 to 45%) of those with high TC and 47% (95% CI: 44 to 50%) with high LDL-C had had their blood lipids measured prior to the survey. In those with high TC (Panel a)), 31% (95% CI: 29 to 33%) were diagnosed and 29% (95% CI: 28 to 31%) were

treated. Only 7% (95% CI: 6 to 9%) of individuals with high TC achieved control. Of those with high LDL-C (Panel b)), less than half were diagnosed (36%, 95% CI: 33 to38%), 33% (95% CI: 31 to36%) were treated, and 19% (95% CI: 18 to21%) achieved control.

Panel c) and d) of Figure 2.1-1 display cascade results for individuals meeting PEN criteria for lipid screening. Cascade performance was found to be similar compared to the previous analyses: only 45% of respondents with high TC and for whom screening was recommended according to PEN guidelines had undergone a cholesterol measurement.

Figure 2.1-1: Cascades of Care by Biomarker




Note: Bars represent point estimates; numeric form can be viewed above bars. Whiskers represent 95% confidence intervals; numeric form of upper and lower bounds can be viewed above and below whiskers. On top, the absolute percentage point drops of each cascade step are shown on the left-hand side and the relative percentage drop on the right-hand side. All calculations incorporate Primary Sampling Units (PSU) and strata to account for the different survey designs of included countries, as well as use sampling weights rescaled such that all countries contribute equally. Percentage and percentage point drops are calculated with unrounded point estimates. Panel a) only considers TC and the self-reported medication status in the classification of having hypercholesterolemia. Panel b) only considers LDL-C and the self-reported medication status in the classification of having hypercholesterolemia. Included are all countries that measured LDL-C, namely Algeria, Bangladesh, Burkina Faso, Chile, Costa Rica, Iran, Iraq, Lebanon, Mongolia, Morocco, Myanmar, Seychelles, and St. Vincent and the Grenadines. Panel c) again considers TC and the self-reported medication status in the classification of hypercholesterolemia. It further restricts the sample to those respondents with hypercholesterolemia for which screening is recommended based on the exhibition of at least one of the following risk factors: age>40; current smoking; having diabetes; having hypertension; waist circumference≥90 in males and ≥100 in females. Panel d) again considers LDL-C and the self-reported medication status in the classification of having hypercholesterolemia. It further restricts the sample again to those respondents with hypercholesterolemia for which screening is recommended (as in Panel c). Included are all countries that measured LDL-C, namely Algeria, Bangladesh,

Burkina Faso, Chile, Costa Rica, Iran, Iraq, Lebanon, Mongolia, Morocco, Myanmar, Seychelles, and St. Vincent and the Grenadines.

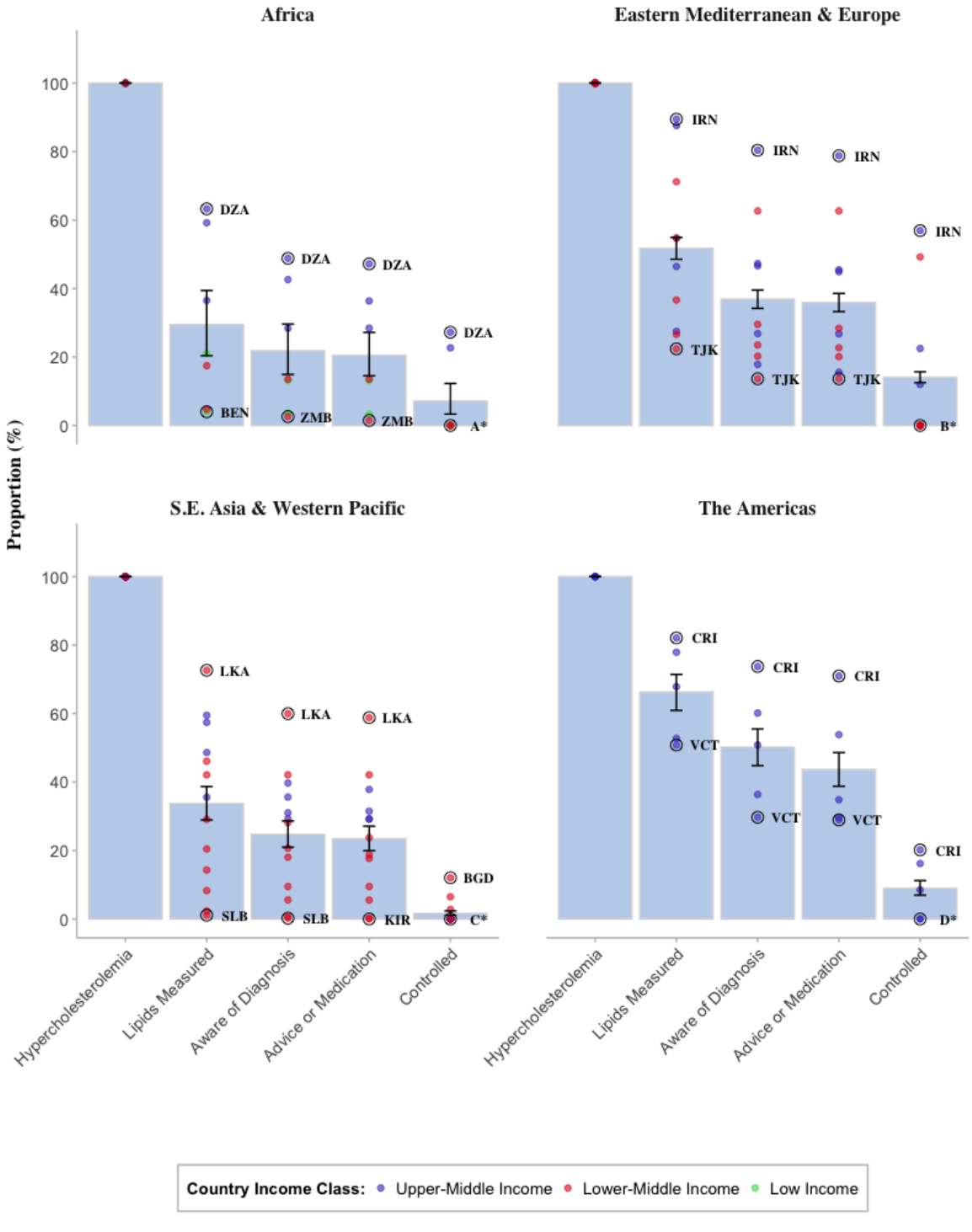
Furthermore, Appendix A.6.1 shows a range of supplementary analyses. The cascade of care based on a definition that also classifies borderline high TC as hypercholesterolemia shows by design a substantially poorer performance (see Figure A.6 - 3). Similarly, cascade performance is markedly worse when basing the hypercholesterolemia definition on cutoffs from the AHA/ACC guidelines (see Figure A.6 - 5 and Figure A.6 - 6). The cascades of care for high TC restricted to the countries that collected both TC and LDL-C records mirrored those for high LDL-C care (see Figure A.6 - 6). The cascade of care restricted to respondents aged 40 or older mirrors the cascade results for individuals meeting PEN criteria for lipid screening (see Figure A.6 - 8 and Figure A.6 - 9). The cascade of care disaggregated at the medication and lifestyle advice stage shows that majority of respondents receive both medication and lifestyle advice (see Table A.6 - 4). Finally, neither estimates including TC records over 300 mg/dL (see Figure A.6 - 2) nor those using a more inclusive definition of controlled lipid values (see Figure A.6 - 10) show substantial differences in cascade performance in comparison to the cascade of care presented in Figure 2.1-1.

*Disaggregated cascade of care*

Figure 2.1-2 displays the cascades of care disaggregated by WHO epidemiological subregion, World Bank country income class, and country (for results in table format see Table A.6 - 5 to Table A.6 - 7). The Americas and Eastern Mediterranean & Europe regions achieved comparatively high cascade of care levels: 66% (95% CI: 61 to 71%) of individuals with hypercholesterolemia in the Americas and 52% (95% CI: 49 to 55%) of those in the Eastern Mediterranean & Europe regions have ever had their cholesterol measured. Examining the same cascade stage for Africa and South-East Asia & Western Pacific, we found shares of 29% (95% CI: 21 to 40%) and 34% (95% CI: 30 to 38%), respectively. As the cascade progresses, all regions converge to under 15% at the control stage. We found substantial heterogeneity across countries. Iran displayed the best cascade performance – 89% (95% CI: 88 to 91%) of individuals with hypercholesterolemia have had their cholesterol measured prior to the survey and around 57% (95% CI: 54 to 60%) were still retained at the control stage. Other high performing countries included Costa Rica, Belarus, Ecuador, Morocco, and Sri Lanka (see Table A.6 - 7). Benin, Bhutan, Eswatini, Kiribati, Myanmar, Solomon Islands, and Zambia exhibited the greatest unmet need for care. In each case, fewer than 20% of those with hypercholesterolemia ever had their cholesterol measured leaving the consecutive cascade

stages at very low levels. Achieved levels of control were low almost in all of the 32 countries, with less than 10% in 26 countries. Next to Iran, only Morocco achieved comparably high levels of control, where 49% (95% CI: 41 to 58%) of those with high TC reached the last cascade stage. Cascade performance was found to be consistently higher in upper-middle-income countries.

Figure 2.1-2: Cascade of Care for High TC by WHO Epidemiological Subregion and World Bank GDP Income Classification



Note: Bars represent pooled region point estimates. Whiskers represent pooled region 95% confidence intervals. Dots represent country point estimates; dots are color coded by GDP income classification; highest and lowest performing country of each region is indicated by country abbreviation. Several countries have point estimates of zero at the control stage, in which case they were abbreviated by the letters A*, B*, and C*:
A* :Benin, Botswana, Burkina Faso, Eswatini, and Zambia
B* :Azerbaijan, Belarus, Kyrgyzstan, Moldova, Sudan, and Tajikistan
C* :Bhutan, Kiribati, Marshall Islands, Solomon Islands, Sri Lanka, Timor-Leste, Tokelau, Tonga, Tuvalu, and Vietnam
D* :Ecuador and Guyana
The country abbreviations follow the ISO 3166-1Alpha-3 codes:
BEN Benin, BGD Bangladesh, CRI Costa Rica, DZA Algeria, GUY Guyana, IRN Iran, KIR Kiribati, LKA Sri Lanka, SLB Solomon Islands, TJK Tajikistan, VCT St. Vincent and the Grenadines, ZMB Zambia
Other abbreviations: S.E. Asia = South-East Asia
For more details, see Note Figure 2.1-1: Cascades of Care by Biomarker
.

*Individual-level characteristics and cascade progression*

In estimating the association between individual-level characteristics and cascade progression, we found a significant age gradient for reaching the first and second cascade stages – for instance, over-65-year-olds were 2.09 times (95% CI: 1.67 to 2.60; p-value: <0.001) more likely to have had their cholesterol measured in comparison to the youngest age group (see Table 2.1-2). The age gradient disappeared in the treatment cascade stage and was found to be insignificant in the control stage. We further observed that women were significantly more likely to have been screened than men (RR: 1.06; 95% CI: 1.03 to 1.10; p-value: <0.001), but less likely reach the control stage (RR: 0.92; 95% CI: 0.86 to 0.98; p-value: 0.007). Individuals with secondary education or higher were also significantly more likely to have been screened compared to those who did not complete primary schooling (RR: 1.25; 95% CI: 1.20 to 1.30; p-value: <0.001), but showed no significant association with reaching other cascade stages. Being a smoker showed only weakly significant, negative associations with having undergone a lipid screening (RR: 0.96; 95% CI: 0.92 to 1.00; p-value: 0.07) and treatment (RR: 0.97; 95% CI: 0.94 to 1.00; p-value: 0.03). Individuals, who were overweight or obese were significantly (p-value: <0.001) more likely to have been screened and diagnosed in comparison to individuals with a normal BMI. Moreover, having diabetes or hypertension were found to have risk ratios significantly (p-value: <0.001) greater than 1 for reaching the lipid measurement, diagnosis, or treatment stage. Diabetes further had a significant and positive association with having had a lipid measure in controlled ranges. Additional univariable and multivariable regression models, an analysis of deviance, and the missingness of predictor variables by country can be viewed in Table A.6 - 8 to Table A.6 - 12.

Table 2.1-2 Correlates of Cascade Progression

| | Measured | | | Diagnosed | | | Treated | | | Controlled | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RR | | *p* | RR | | *p* | RR | | *p* | RR | | *p* |
| **Age** | | | | | | | | | | | | |
| 15–24 years | REF | | | REF | | | REF | | | REF | | |
| 25–34 years | 1.17 | [0.93,1.48] | 0.18 | 1.12 | [0.85,1.49] | 0.41 | 0.91 | [0.82,1.01] | 0.07 | 1.19 | [0.62,2.29] | 0.61 |
| 35–44 years | 1.63 | [1.30,2.03] | <0.001 | 1.31 | [1.01,1.71] | 0.04 | 0.95 | [0.87,1.03] | 0.22 | 1.34 | [0.72,2.49] | 0.35 |
| 45–54 years | 1.86 | [1.49,2.32] | <0.001 | 1.41 | [1.09,1.83] | 0.009 | 0.96 | [0.89,1.04] | 0.33 | 1.39 | [0.75,2.57] | 0.30 |
| 55–64 years | 2.04 | [1.64,2.55] | <0.001 | 1.46 | [1.13,1.89] | 0.004 | 0.97 | [0.90,1.06] | 0.54 | 1.43 | [0.78,2.65] | 0.25 |
| 65 or older | 2.09 | [1.67,2.60] | <0.001 | 1.43 | [1.10,1.85] | 0.007 | 0.99 | [0.91,1.07] | 0.73 | 1.61 | [0.87,2.98] | 0.13 |
| Sex | | | | | | | | | | | | |
| Male | REF | | | REF | | | REF | | | REF | | |
| Female | 1.06 | [1.03,1.10] | <0.001 | 1.01 | [0.98,1.04] | 0.53 | 0.99 | [0.97,1.01] | 0.22 | 0.92 | [0.86,0.98] | 0.007 |
| Education | | | | | | | | | | | | |
| Less than primary school | REF | | | REF | | | REF | | | REF | | |
| Less than secondary school | 1.06 | [1.02,1.10] | 0.004 | 1.02 | [0.98,1.05] | 0.35 | 1.01 | [0.99,1.02] | 0.41 | 1.03 | [0.96,1.11] | 0.45 |
| Secondary school completed or higher | 1.25 | [1.20,1.30] | <0.001 | 1.01 | [0.97,1.05] | 0.52 | 1.00 | [0.98,1.02] | 0.97 | 1.01 | [0.93,1.10] | 0.74 |
| Smoking | | | | | | | | | | | | |
| Past or Never | REF | | | REF | | | REF | | | REF | | |
| Current | 0.96 | [0.92,1.00] | 0.07 | 0.96 | [0.92,1.01] | 0.13 | 0.97 | [0.94,1.00] | 0.03 | 1.02 | [0.93,1.12] | 0.71 |
| BMI | | | | | | | | | | | | |
| Normal | REF | | | REF | | | REF | | | REF | | |
| Underweight | 0.74 | [0.62,0.88] | <0.001 | 1.01 | [0.87,1.17] | 0.89 | 0.98 | [0.91,1.06] | 0.65 | 1.16 | [0.90,1.50] | 0.26 |
| Overweight | 1.08 | [1.04,1.12] | <0.001 | 1.08 | [1.04,1.12] | <0.001 | 0.99 | [0.97,1.01] | 0.20 | 1.03 | [0.96,1.12] | 0.39 |
| Obese | 1.15 | [1.11,1.20] | <0.001 | 1.08 | [1.04,1.12] | <0.001 | 0.99 | [0.97,1.01] | 0.45 | 1.01 | [0.93,1.09] | 0.86 |
| Diabetes | 1.19 | [1.15,1.22] | <0.001 | 1.10 | [1.07,1.13] | <0.001 | 1.02 | [1.01,1.04] | <0.001 | 1.21 | [1.14,1.28] | <0.001 |
| Hypertension | 1.15 | [1.12,1.19] | <0.001 | 1.09 | [1.05,1.13] | <0.001 | 1.04 | [1.02,1.06] | <0.001 | 1.04 | [0.98,1.11] | 0.18 |
| *N* | 10,575 | | | 6,073 | | | 4,601 | | | 4,283 | | |

Note: Multivariable modified Poisson regression models with robust error structure, clustering at Primary Sampling Unit (PSU), including binary country variables (survey-level "fixed effects"), and "Lipids Measured", "Aware of Diagnosis", "Advice or Medication", and "Controlled Disease" as dependent variables. Each cascade stage estimation is conditioned on completion of prior cascade stages. The coefficients indicate risk ratios. 95% confidence intervals in brackets. The regression samples do not include Tokelau, due to information on education not being available, nor Tonga, due to unavailable blood glucose measurements. Survey fixed effect estimates can be viewed in Figure A.6 - 11. Respondents that are currently smoking or were smoking within past 12 months are classified as current smokers (as per World Health Organization's Package of essential noncommunicable disease interventions for primary health care in low-resource settings (WHO PEN) Protocol 1)

### 2.1.5. Discussion

In a pooled sample of 129,040 individuals from 35 LMICs, we found that less than one out of every three respondents with hypercholesterolemia had been treated and less than one in five had achieved control. By using nationally representative data that combines individual-level biomarkers with self-reported health service utilization, our study shows that cascade performance, while poor overall, is characterized by large declines at the screening and control stage in particular. To our knowledge, this is a first application of the cascade of care methodology to such an extensive evaluation of the unmet need for hypercholesterolemia care, yielding novel insights into the shortcomings of health services in this geographically diverse group of countries.

The results of this study have several important policy implications for health system strengthening. We found that screening for hypercholesterolemia constitutes a major barrier to meeting care needs, as this stage was consistently found to have the largest or second largest

amount of loss along the cascade of care. In the United States and Europe, where cholesterol screening rates varied in ranges comparable to our study, screening appeared to be influenced by structural health system inequities and was found to be lower in disadvantaged groups – such as racial minorities or those with low education (CDC 2019; Rodin et al. 2012; Carroll and Sug 2013). Our results show that in this set of LMICs education was also positively associated with screening. We estimated that individuals with secondary education or higher had a 25% higher likelihood of being screened relative to individuals with less than primary education. Potential reasons for this could be that additional schooling results in better health literacy and greater awareness of CVD risk or – as a proxy for wealth and social status – better access to the health system. In addition to sociodemographic characteristics, we also found the presence of other CVD risk factors, such as age, high BMI, or comorbid diabetes or hypertension, to be associated with screening. This suggests that health systems are – in accordance with WHO guidance – targeting high-risk individuals for screening. However, while many individuals with hypercholesterolemia who were included in this study presented with at least one other CVD risk factor, cascade performance did not improve overall when examining this group only. This suggests that a large proportion of high-risk individuals were still left out of screening efforts. In cases where this relates to a lack of laboratory infrastructure and equipment as well as accessibility and affordability of care, POC machines may have the potential to increase screening rates amongst all population groups (Yager, Domingo, and Gerdes 2008).

We also found large losses at the stage of diagnosis, as approximately only one third of all individuals with hypercholesterolemia was found to be aware of their high cholesterol. Our results further showed that age, high BMI, having diabetes, and having hypertension were significantly associated with being aware of one's high cholesterol level. This suggests that health care workers may appropriately prioritize those at greatest risk of CVD across the cascade, not only at the screening stage as described above. In the case of diabetes, this significant effect persisted through the final "control" stage of the cascade of care. This is an encouraging finding given the markedly worse CVD outcomes of patients with diabetes in comparison to those without (Anjana et al. 2020). Our results are in line with the current evidence base, as studies undertaken in several high and upper-middle income countries also found age and high CVD risk to be associated with greater awareness of having hypercholesterolemia (Muntner et al. 2013; C. Murphy et al. 2017; Roth et al. 2011). Furthermore, while we did not find sex to be significantly associated with having received a

hypercholesterolemia diagnosis, it is worth noting that prior studies have reported significant, albeit inconsistent patterns of sex differences (Roth et al. 2011; Lee et al. 2014; He et al. 2004).

The smallest loss in the care cascade – both in absolute and relative terms – occurred between the diagnosis and treatment stages. This is consistent with lifestyle advice essentially being cost-free and previous evidence that found declining costs of cholesterol-lowering medications in LMICs (Roth et al. 2011) Nonetheless, a loss in care at this stage suggests that obstacles to treatment delivery persist. Here, previous evidence points toward a lack of access to and affordability of medicines, as well as the variation in treatment guidelines that influence clinical decisions (Roth et al. 2011; Jingi et al. 2014b; Khatib et al. 2016; Byrne et al. 2015). On the international scale, this is reflected in the WHO's List of Essential Medicines, which currently only includes simvastatin for mixed hyperlipidemia. However, given the low treatment rates, expanding this list to include other statins, such as atorvastatin, pravastatin, fluvastatin, or lovastatin – which are currently only listed as therapeutic equivalents to simvastatin – could be one potential approach to increase their uptake (WHO n.d.).

Finally, a drop of 42-75% from all that received treatment for hypercholesterolemia to those that achieved control marked the largest relative loss in the care cascade. Both in the pooled analysis and at the country-level, control rates were found to be low, ranging from virtually zero to 27% in all but two countries – Iran (57%) and Morocco (49%). This finding should be interpreted with the understanding that common treat-to-target ranges for lipids are not universally applied and are often combined with coronary heart disease risk levels, which could not be included in this study due to a lack of data availability (Nelson 2013). Nonetheless, this finding is also reflected in other studies, where control rates in China, Thailand, and Jordan also ranged between 10% and 25% (Roth et al. 2011; He et al. 2004). Such low control rates may reflect both insufficient treatment options available to providers, for instance due to a lack of access to affordable medication as described above, or due to poor treatment adherence by respondents. While improvements in medication availability may improve the former, a large literature base is currently forming around policy interventions such as mobile health or peer and community education to improve uptake and adherence to lipid-lowering therapy (Watkins et al. 2018; Fottrell et al. 2019).

Generally, we found that the Americas, the Eastern Mediterranean and European regions achieved higher cascade performance than Africa, South East Asia, and the Western Pacific

regions. We further showed that upper-middle income countries were consistently better at retaining individuals throughout the cascade than lower-middle income or low income countries. This pattern may reflect that hypercholesterolemia care requires a level of attention that countries with low health system capacity may not be able or willing to achieve yet. Because hypercholesterolemia care is embedded in a framework of comprehensive CVD care, it is shaped by several clinical complexities of calculating risk scores, still comparably expensive screening and treatment options, and an international context that focuses on policies to target each of the cardiometabolic risk factors individually, for instance through initiatives such as the WHO Global Diabetes Compact (Khatib et al. 2016; WHO n.d.; n.d.; Jingi et al. 2014a).

Within these patterns, we still found very large heterogeneity at the country level across all cascade stages, which is mirrored in the literature (Lee et al. 2014; Muntner et al. 2013; He et al. 2004; Gregory A Roth et al. 2011). It is particularly noteworthy that Sri Lanka and Morocco were amongst the highest performing countries – despite their lower-middle income status. Sri Lanka has been shown to be highly engaged in fighting non-communicable diseases. They have a national NCD agenda, a high share of primary health care facilities that offer CVD risk management, cardiac rehabilitation programs, as well as policies targeting tobacco, alcohol and salt reductions, and NCDs generally (Tuangratananon et al. 2019; Sri Lanka Ministry of Health 2018; Turk-Adawi, Sarrafzadegan, and Grace 2014). Sri Lanka was also found to have the highest number of full-time equivalent professional staff in an NCD unit within the Ministry of Health in comparison to six other Asian countries (Tuangratananon et al. 2019). The high performance of Morocco on the other hand was not mirrored in prior, yet limited literature. These studies have shown that while Morocco is already undergoing the epidemiological transition, the awareness of ischemic heart disease and cardiovascular disease risk remained low in the population (Turk-Adawi et al. 2018; Kharbach et al. 2019; Chadli et al. 2018). Hence, future research may yield valuable insights into the strengths and weaknesses of the Moroccan NCD care system. After Morocco and Sri Lanka, Costa Rica and Iran stood out as particularly high-performing, upper-middle income countries. Notably, Costa Rica performed similarly well in corresponding analyses of the cascades of care for diabetes and hypertension, which also further discuss potential reasons for its high performance (Manne-Goehler et al. 2019; Geldsetzer et al. 2019). In the cascade analysis for Iran, the high rates of controlled lipid values stood out in particular – which could be due to increasing statin prescriptions and food industry improvements, and further speaks to Iran's high capacity for CVD control as well as

its leading commitment in the Eastern Mediterranean region to fighting NCDs (Turk-Adawi et al. 2018; Aryan et al. 2018).

This study had several limitations. First, several measures may be subject to measurement biases. For one, our data on health services received was self-reported and thus may be subjected to a recall bias. For instance, individuals that were taking medication could have been more likely to remember ever being screened for hypercholesterolemia, affecting the absolute probability of reaching each cascade stage. Similarly, recalling the provision of light-touch treatment interventions, such as having received lifestyle advice, may be difficult for respondents. In addition, our definition of hypercholesterolemia was based on biomarkers that, in some countries, were measured with point-of-care devices. While these may be less accurate than lab-based testing, studies have shown that they can be reliably used for lipid screening (Gialamas et al. 2010; Panz et al. 2005; Plüddemann et al. 2012; Ferreira et al. 2015). A study by Ferreira et al. (2015) found a 94.6%-97.7% agreement between the CardioCheck PA – which is used by the majority of countries – and the laboratory when sorting lipid records into the ATP III lipid classifications used in our analysis (Ferreira et al. 2015). Moreover, our disaggregated cascade analysis should be considered with the following caveats in mind. First, the comparability between countries is to some extent limited as the time span of 9 years across surveys potentially introduced period effects into our analysis. While a cascade analysis by year showed no observable time trend (see Figure A.6 - 12), this must be viewed in light of the fact that the estimates are based on a small number of surveys per year and that they are likely heavily enmeshed with country effects. In addition, some country-level estimates have very small sample sizes due to low prevalence rates and are thus shown only for the purpose of completion. Relatedly, in our cascade regression analysis, we note that as we conditioned each cascade stage estimation on completion of prior cascade stages, increasing losses in sample size reduced the statistical power to detect significant associations – potentially explaining our findings. Finally, we chose to define hypercholesterolemia and achieving control based on the ATP III guidelines due to their frequent use in the literature. However, these are relatively conservative in comparison to some national guidelines, as is apparent when examining the markedly lower cascade performance when applying AHA/ACC guidelines (see Figure A.6 - 5). The comparability of countries is generally limited by a lack of universally used guidelines, as different guidelines are applied across countries and clinical settings and may even include geographical parameters, as is the case in the European Society of Cardiology (ESC) and European Atherosclerosis Society (EAS) guidelines (Lee et al. 2016; Mach et al. 2020). Despite

this, such a comparison still offers important insights into national and global care gaps and can be used for identifying effective policy as well as serve as markers of progress in tackling the burden of hypercholesterolemia.

### 2.1.6. Conclusion

We found low levels of access to hypercholesterolemia care in this group of LMICs, with especially large levels of unmet screening and control needs across all countries. Further work is required to understand the underlying causes for this underperformance. A closer examination of the better performing countries in our study – such as Sri Lanka, Costa Rica, Iran, and Morocco – could yield important policy lessons, especially as the lipid cascade offers a potentially important tracer of unmet need for chronic disease care. Given its increasing relevance as one of the major, yet eminently preventable CVD risk factors, hypercholesterolemia deserves more attention both from a health-services and a research perspective, globally.

## 2.2. Essay 2:

# Use of Statins for the Prevention of Cardiovascular Disease in 41 Low- and Middle-Income Countries: A Cross-Sectional Study of Nationally Representative, Individual-Level Data

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### 2.2.1. Abstract

**Background:** In the prevention of cardiovascular disease (CVD), a World Health Organization (WHO) target is that at least 50% of eligible people use statins. Robust evidence is needed to monitor progress toward this target in low- and middle-income countries (LMICs) where most CVD deaths occur. The objectives of this study were to benchmark statin use in LMICs and to investigate country-level and individual-level characteristics associated with statin use.

**Methods and Findings:** We conducted a cross-sectional analysis of pooled, individual-level data from nationally representative health surveys conducted in 41 LMICs between 2013-2019. Our sample consisted of non-pregnant adults aged 40-69 years. Primary outcomes were the proportion of eligible individuals self-reporting use of statins for the primary and secondary prevention of CVD. Eligibility for statin therapy for primary prevention was defined among individuals with a history of diagnosed diabetes or a 10-year CVD risk of at least 20%. Eligibility for statin therapy for secondary prevention was defined among individuals with a history of self-reported CVD. At the country level, we estimated statin use by per-capita health spending, per-capita income, burden of CVD, and noncommunicable disease policy commitment. At the individual level, we used modified Poisson regression models to assess statin use along individual-level characteristics of age, sex, education, and rural versus urban residence. Countries were weighted in proportion to their population size in pooled analyses.

The final pooled sample included 116,449 non-pregnant individuals. 9229 individuals reported a previous history of cardiovascular disease (7·9% [95% CI 7·4–8·3] of the population-weighted sample). Among those without a previous history of cardiovascular disease, 8453 were eligible for a statin for primary prevention of cardiovascular disease (9.7% [95% CI 9.3-10.1] of the population-weighted sample). For primary prevention of cardiovascular disease, statin use was 8.0% (95% CI, 6.9% to 9.3%) and for secondary prevention statin use was 21.9% (95% CI, 20.0% to 24.0%). The WHO target that at least 50% of eligible individuals receive statin therapy to prevent CVD was achieved by no region or income group. Statin use was less common in countries with lower health spending. At the individual level, there was generally higher statin use among women (primary prevention only, risk ratio [RR] 1·83 [95% CI 1·22–2·76), and individuals who were older (primary prevention, 60–69 years, RR 1·86 [1·04–3·33]; secondary prevention, 50–59 years RR 1·71 [1·35–2·18]; and 60–69 years RR 2·09 [1·65–2·65]), more educated (primary prevention, RR 1·61 [1·09–2·37]; secondary prevention, RR 1·28 [0·97–1·69]), and lived in urban areas (secondary prevention only, RR 0·82 [0·66–1·00]).

**Conclusion:** In a diverse sample of LMICs, statins are used by approximately one in ten eligible people for the primary prevention of CVD and one in five eligible people for the secondary prevention of CVD. There is an urgent need to scale up statin use in low- and middle-income countries to achieve WHO targets. Policies and programs that facilitate implementation of statins into primary health systems in these settings should be explored.

### 2.2.2. Introduction

Ischemic heart disease and stroke are responsible for more than a fifth of all deaths worldwide (G. A. Roth et al. 2020). In low-income and middle-income countries (LMICs), where 80% of these deaths occur, improving outcomes for cardio- vascular diseases (including heart disease and stroke) is necessary to achieve Sustainable Development Goal (SDG) target 3.4 outlined in 2015: a reduction of a third in premature mortality from non-communicable diseases by 2030 (N. C. D. Countdown collaborators 2020). The use of statins to prevent cardiovascular diseases is an important strategy for health systems to reduce the population burden of cardiovascular diseases and to achieve this SDG target (Wirtz et al. 2016).

Statins are a type of drug that reduce cholesterol concentration through inhibition of the HMG-CoA reductase enzyme. According to evidence from clinical trials demonstrating effectiveness and safety, statins are widely recommended for the primary and secondary prevention of cardiovascular diseases (Cholesterol Treatment Trialists et al. 2010) and have been included in WHO clinical practice guidelines for cardiovascular disease prevention and control since 2007 (WHO 2007).

In high-risk individuals, statins are considered cost- effective for primary health systems and among a package of drugs considered the so-called best buys for non-communicable disease prevention and control (WHO 2017). A key target in the WHO non-communicable disease Global Monitoring Framework is that by 2025, at least 50% of eligible people with existing cardiovascular diseases or at high risk of these diseases receive effective drug therapies including statins (WHO 2014a). This high frequency of statin use in patients with cardiovascular diseases has been achieved in high-income countries (HICs) (Leino, Dorsch, and Lester 2020; Patel et al. 2019; Shah et al. 2015; Ueda et al. 2018; Salim Yusuf et al. 2011).

There is a need for rigorous monitoring of population- based estimates of statin use in LMICs. However, to our knowledge, there has been no comprehensive evaluation of statin use in LMICs using nationally representative samples. Important previous studies assessing statin use in LMICs used non-representative samples and included data collected before 2007 (Chow et al. 2020; Shanthi Mendis et al. 2005; A. Murphy et al. 2018; Salim Yusuf et al. 2011) when statins were added to the WHO Essential Medicines List and became more affordable via

increased generic production (Kishore et al. 2018). The present study addresses a crucial evidence gap in the current understanding of global cardiovascular disease prevention by aiming to estimate statin use in LMICs to track progress towards the WHO target, and investigate the country-level and individual-level characteristics associated with statin use.

### 2.2.3. Methods

*Study design and participants*

In our cross-sectional study, we analyzed individual-level data from national health surveys done between 2013 and 2019 in 41 LMICs. Our comprehensive methodology for pooling surveys has been previously described (Geldsetzer et al. 2019; Manne-Goehler et al. 2019). We first identified all LMICs in which a WHO Stepwise Approach to Surveillance (STEPS) survey had been done. We prioritized STEPS surveys because they are WHO's recommended method for population monitoring of non-communicable disease targets. To identify other surveys in countries in which no STEPS survey was available, we did a systematic internet search in April, 2020, for each country using search terms and other details described in Appendix A.1.

We included surveys that met the following criteria: (1) were done in an LMIC as classified by the World Bank in the survey year; (2) were done in 2013 or later; (3) were nationally representative; (4) had individual-level data available; and (5) asked questions on statin use and previous history of cardiovascular disease. We chose 2013 as the first year of survey eligibility because this was the year that STEPS surveys introduced questions on statin use and cardiovascular disease history. Additional details on the search process, data availability, and methodology of the underlying surveys are available in Appendix A.1 - A.3. Our sample consisted of non-pregnant respondents aged 40–69 years. We chose this age range to align with the WHO non-communicable diseases Global Monitoring target for drug therapy to prevent cardiovascular diseases (aged 40 years and older) (WHO 2014a) and to encompass the upper age of 69 years in most surveys.

This study was judged to be exempt from institutional review board approval by the University of Michigan (HUM00199295), because the research involved survey data that could not be linked to a specific individual.

*Outcomes and procedures*

Our outcomes were the proportion of eligible individuals self-reporting use of statins for the primary and secondary prevention of cardiovascular diseases. We defined these outcomes to align with the monitoring indicator recommended in the WHO non-communicable diseases Global Monitoring Framework and WHO HEARTS Technical Package for cardiovascular diseases management in primary health care: "Proportion of eligible persons receiving drug therapy...to prevent heart attacks and strokes" (WHO 2014a). We defined statin use among respondents on the basis of the answer to the following question in STEPS surveys: "Are you currently taking statins regularly to prevent or treat heart disease?" We defined cardiovascular disease history on the basis of the answer to the following question in STEPS surveys: "Have you ever had a heart attack or chest pain from heart disease (angina) or a stroke (cerebrovascular accident or incident)?"

Eligibility for statin therapy for primary prevention was defined among individuals without a history of self-reported cardiovascular disease and with either: (1) a history of diagnosed diabetes or (2) a 10-year cardiovascular disease risk of more than 20% using the 2019 WHO laboratory-based risk equations (Kaptoge et al. 2019; WHO 2020b). These equations use individual-level inputs of age, smoking status, systolic blood pressure, history of diabetes, and total cholesterol. The measurement of biological variables across surveys is summarized in Appendix A.3.2. Eligibility for statin therapy for secondary prevention was defined among individuals with a history of self-reported cardiovascular disease.

*Statistical Analysis*

We calculated the proportion of individuals using statins for the primary and secondary prevention of cardiovascular disease in the overall pooled sample, by WHO region and World Bank income group, and by country. We compared these results with the WHO non-communicable diseases Global Monitoring Framework's 2025 target that at least 50% of eligible individuals in the population receive statin therapy to prevent heart attacks and strokes (WHO 2014a).

To investigate predictors of statin use across countries, we then plotted statin use for primary and secondary prevention of cardiovascular disease against four country- level characteristics: (1) per-capita health spending in the year the survey was done; (2) per-capita gross national

income using World Bank estimates in the year the survey was done; (3) burden of atherosclerotic cardiovascular disease, as assessed by the sum of disability-adjusted life-years per 100000 people for ischemic heart disease and ischemic stroke, as estimated by the Global Burden of Disease study (Vos et al. 2020); and (4) political commitment to non- communicable diseases, as assessed by a 2019 version of the non-communicable diseases policy implementation score. The non-communicable diseases implementation score ranges from 0–100%, with higher scores reflecting greater political commitment to these diseases. Country-specific external data included in our analysis are presented in Appendix A.5.2.

To investigate individual-level predictors of statin use within each country and across the pooled sample, we regressed statin use on age, sex, education as a marker of socioeconomic status, and rural versus urban residence. In the within-country models, we restricted the regressions to the secondary prevention outcome due to the low number of individuals using statins for primary prevention. We used Zou's modified Poisson regression with robust error variance because it facilitates interpretation of model output as risk ratios (RRs) and is a valid approach for analyzing binary outcomes (Zou 2004). We also report the absolute difference in predicted probabilities using average marginal effects.

We did multiple sensitivity analyses. First, we assessed statin use for primary prevention only among individuals aged 40 years and older with no previous history of cardiovascular disease and estimated 10-year cardiovascular disease risk of at least 20% (i.e., not adhering to the WHO recommendation for statin therapy among all people aged ≥40 years with diabetes). Second, because the 2019 WHO risk equations were published after most surveys were done, we reanalyzed the primary prevention outcome using the 2007 WHO/ International Society of Hypertension cardiovascular disease risk charts and a 10-year cardiovascular disease risk threshold of at least 30% (WHO 2017; 2014a; 2007). Third, we re-estimated the pooled regressions without the rural versus urban residence covariate, because this information was missing in about a third of the countries (n=14 surveys). Fourth, we rescaled individual survey weights such that each country was equally weighted in the pooled analyses.

In all analyses, we accounted for complex survey design by adjusting for stratification and clustering at the primary sampling unit using the Stata "svyset" command with subpopulation specification. Additionally, we applied sampling weights, which adjust for the probability of selection, non-response, and differences between the sample population and the target

population. In the main pooled analyses, we rescaled survey weights using each country's 2019 population of people aged 40–69 years and used country-level fixed-effects. Whenever survey weights were missing, the country-average weight was assigned to observations with missing weight values. For all other data, a complete case analysis was used. Analyses were done in Stata version 16.1 and R version 4.0.5. Additional methodological details are provided in Appendix A.5.2.

*Role of the funding source*

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

### 2.2.4. Results

*Sample characteristics*

The final pooled sample included 116449 non-pregnant individuals, 50383 men (49·6% [95% CI 49·0–50·2] of the population-weighted sample) and 66066 women (50·4% [49·8–51·0] of the population-weighted sample). In the overall sample, 9229 reported a previous history of cardiovascular disease (7·9% [95% CI 7·4–8·3] of the population-weighted sample). Among those without a previous history of cardiovascular disease, 8453 were eligible for a statin for primary prevention of cardiovascular disease (9·7% [95% CI 9·3–10·1] of the population-weighted sample); Table 2.2-1; Table A.6 - 13; Table A.6 - 14).

Among the 41 included surveys, there were at least four countries in each WHO region. Nine surveys were done in low-income countries, 17 in lower-middle-income countries, and 15 in upper-middle-income countries. In the pooled sample, self-reported statin use and previous history of cardiovascular disease were missing in 0·4% of the sample (Table A.6 - 15).

Table 2.2-1 Survey Characteristics

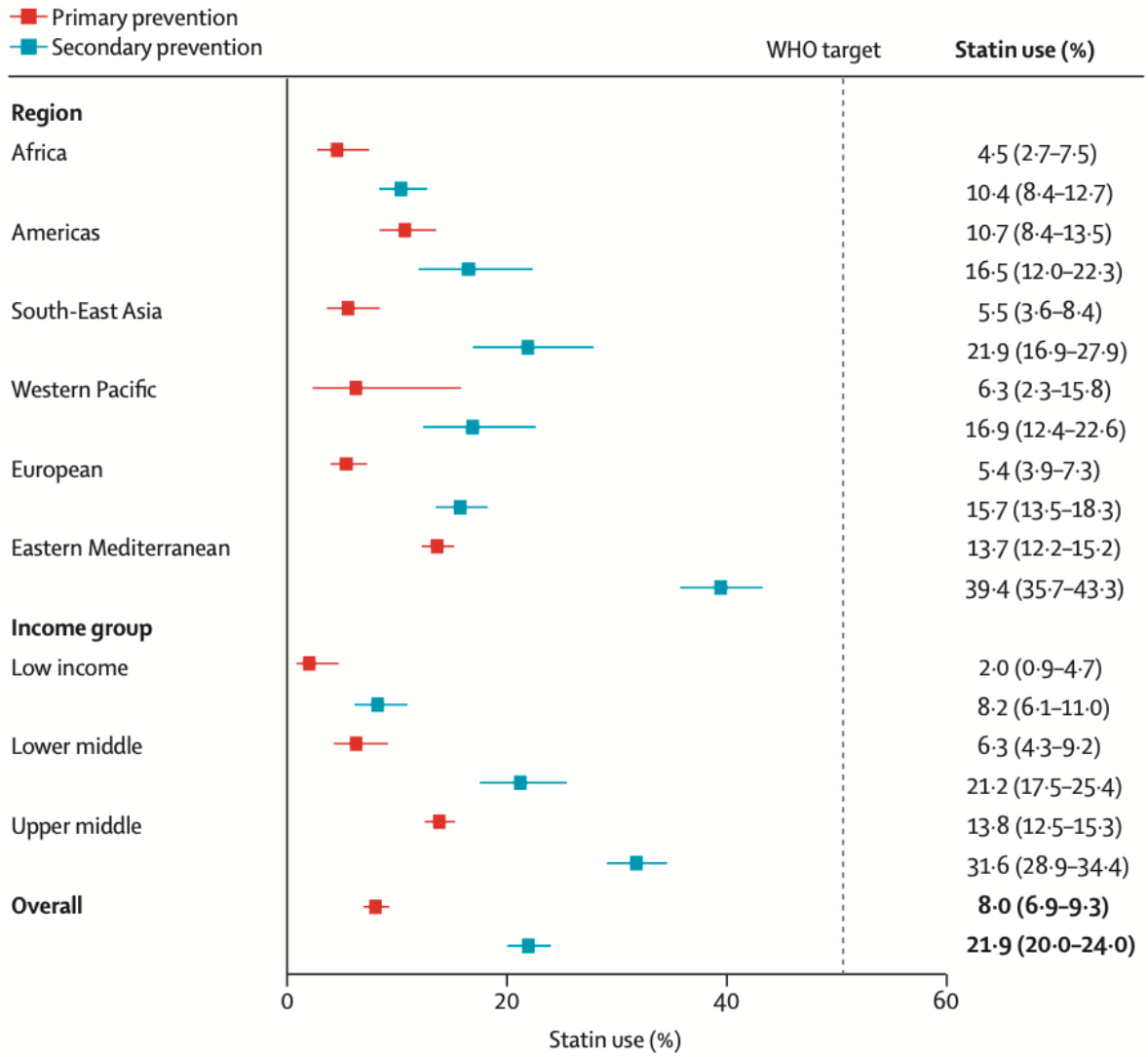
| Country[a] | ISO code | Income group[b] | Year[c] | Response rate[d] | Sample size, n[e] | Female, % | Median age (IQR) |
|---|---|---|---|---|---|---|---|
| Africa | | | | | | | |
| Algeria | DZA | UMIC | 2016-17 | 93.8 | 3,648 | 54 | 50 (44-58) |
| Benin | BEN | LIC | 2015 | 98.5 | 2,010 | 48 | 50 (44-56) |
| Botswana | BWA | UMIC | 2014 | 64 | 1,511 | 70 | 51 (45-58) |
| Burkina Faso | BFA | LIC | 2013 | 97.2 | 1,936 | 48 | 49 (44-55) |
| Eswatini | SWZ | L-MIC | 2014 | 70 | 1,360 | 69 | 52 (45-60) |
| Ethiopia | ETH | LIC | 2015 | 95.5 | 3,236 | 54 | 50 (42-56) |
| Kenya | KEN | LIC | 2015 | 93 | 1,750 | 59 | 51 (44-59) |
| Uganda | UGA | LIC | 2014 | 92.2 | 1,337 | 60 | 50 (44-57) |
| Zambia | ZMB | L-MIC | 2017 | 65 | 1,597 | 62 | 50 (44-59) |
| Americas | | | | | | | |
| Ecuador | ECU | UMIC | 2018 | 69.4 | 2,352 | 57 | 52 (45-60) |
| Guyana | GUY | L-MIC | 2016 | 77 | 1,370 | 57 | 52 (46-60) |
| Mexico | MEX | UMIC | 2018-19 | 98 | 20,287 | 55 | 51 (45-59) |
| St. Vincent & the Grenadines | VCT | UMIC | 2013 | 67.8 | 1,965 | 52 | 52 (46-58) |
| Eastern Mediterranean | | | | | | | |
| Afghanistan | AFG | LIC | 2018 | N/A | 1,621 | 42 | 50 (45-60) |
| Iran | IRN | UMIC | 2016 | 98.4 | 14,378 | 52 | 52 (45-59) |
| Iraq | IRQ | UMIC | 2015 | 93.5 | 1,839 | 58 | 50 (44-59) |
| Jordan | JOR | UMIC | 2019 | 63 | 2,595 | 59 | 51 (45-59) |
| Lebanon | LBN | UMIC | 2017 | 65.9 | 1,301 | 58 | 53 (47-59) |
| Morocco | MAR | L-MIC | 2017 | 89 | 2,782 | 63 | 52 (45-59) |
| Sudan | SDN | L-MIC | 2016 | 88 | 3,267 | 57 | 50 (45-58) |
| Europe | | | | | | | |
| Armenia | ARM | L-MIC | 2016 | 42 | 1,399 | 70 | 55 (48-61) |
| Azerbaijan | AZE | UMIC | 2017 | 97.3 | 1,783 | 60 | 55 (48-60) |
| Belarus | BLR | UMIC | 2016 | 87 | 3,453 | 60 | 54 (47-61) |
| Georgia | GEO | L-MIC | 2016 | 75.7 | 2,938 | 71 | 56 (49-62) |
| Kyrgyzstan | KGZ | LIC | 2013 | 100 | 1,602 | 63 | 51 (46-57) |
| Moldova | MDA | L-MIC | 2013 | 83.5 | 3,133 | 62 | 55 (49-61) |
| Tajikistan | TJK | L-MIC | 2016 | 94 | 1,330 | 57 | 50 (45-57) |
| Turkmenistan | TKM | UMIC | 2018 | 93.8 | 2,005 | 58 | 50 (44-58) |
| South East Asia | | | | | | | |
| Bangladesh | BGD | L-MIC | 2018 | 83.8 | 3,666 | 47 | 49 (44-56) |
| Bhutan | BTN | L-MIC | 2014 | 89.9 | 1,343 | 57 | 50 (45-57) |
| Myanmar | MMR | LIC | 2014 | 90 | 5,506 | 65 | 51 (45-57) |
| Nepal | NPL | LIC | 2019 | 86.4 | 2,662 | 58 | 51 (45-60) |
| Sri Lanka | LKA | L-MIC | 2014 | 72 | 3,148 | 59 | 53 (46-60) |
| Timor-Leste | TLS | L-MIC | 2014 | 96.3 | 1,334 | 53 | 51 (44-61) |
| Western Pacific | | | | | | | |
| Kiribati | KIR | L-MIC | 2015 | 55 | 943 | 54 | 50 (44-57) |
| Mongolia | MNG | L-MIC | 2019 | 98 | 3,415 | 56 | 52 (45-59) |
| Nauru | NRU | UMIC | 2015-16 | 74.5 | 461 | 55 | 50 (44-56) |
| Solomon Islands | SLB | L-MIC | 2015 | 58.4 | 1,155 | 50 | 50 (44-57) |
| Tokelau | TK | UMIC | 2014 | 70 | 266 | 53 | 51 (46-57) |
| Tuvalu | TUV | UMIC | 2015 | 76 | 615 | 55 | 53 (47-59) |
| Vietnam | VNM | L-MIC | 2015 | 79.8 | 2,150 | 55 | 52 (45-59) |
| Total | | | | 86.7 (70.0-93.9)[f] | 116,449[g] | 57 (54-60)[f] | 51 (50-52)[f] |

Note: [a] World regions are defined by the World Health Organization. [b] Income groups are defined by the World Bank fiscal year categories in the year the survey was conducted. [c] Year reflects the year(s) of survey data collection. [d] Values are the response rate for biochemical measurements, if available, as reported by the survey. [e] The sample includes non-pregnant individuals ages 40-69 years of age (40-64 years of age for Burkina Faso, Kyrgyzstan, Myanmar, and Tokelau). [f] This is the median value and interquartile range with each country having the same weight. [g] This is the sum across all countries. Abbreviations: CI, confidence interval; IQR, interquartile range; ISO, International Organization for Standardization; LIC, low-income country; L-MIC, lower-middle-income country; UMIC, upper-middle-income country.

*Estimates of statin use across countries*

In the pooled sample across countries, statin use for primary prevention was 8·0% (95% CI 6·9–9·3) and for secondary prevention was 21·9% (20·0–24·0; Figure 2.2-1). By region, statin use for both primary and secondary prevention was highest in the Eastern Mediterranean region (primary prevention, 13·7% [95% CI 12·2–15·2]; secondary prevention, 39·4% [35·7–43·3]) and lowest in Africa (primary prevention, 4·5% [2·7–7·5]; secondary prevention, 10·4% [8·4–12·7]. By World Bank income group, there was a positive gradient between statin use and country-level economic development, including a seven-fold greater use of statins for primary prevention (from 2·0% [95% CI 0·9–4·7] to 13·8% [12·5–15·3]) and four-fold greater use for secondary prevention (from 8·2% [6·1–11·0] to 31·6% [28·9–34·4]) within upper- middle-income countries than in low-income countries. No region or income group achieved the WHO target of 50% use of statins among eligible individuals in the population. At the country level, only Iran achieved the WHO target for secondary prevention, and no country achieved the target for primary prevention (Table A.6 - 16).

Figure 2.2-1: Pooled estimates of self-reported use of statins for the primary and secondary prevention of cardiovascular disease in 41 low-income and middle-income countries



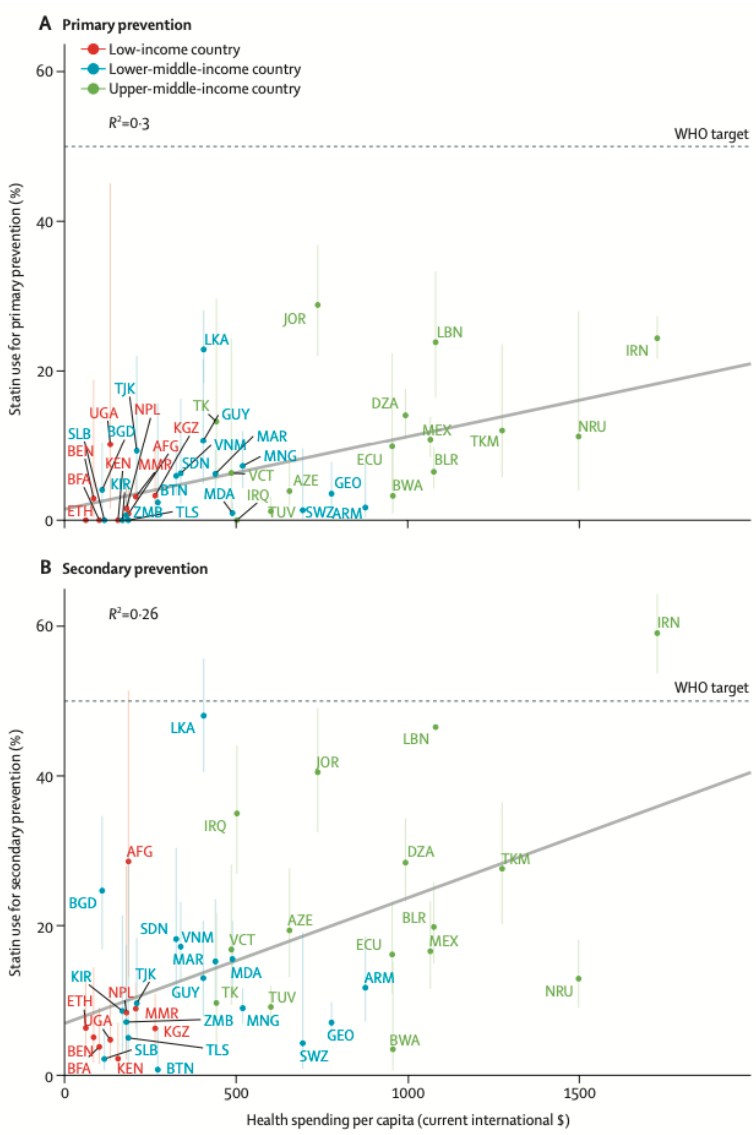

Note: The sample includes non-pregnant individuals aged 40–69 years (age 40–64 years for Burkina Faso, Kyrgyzstan, Myanmar, and Tokelau). Estimates account for survey design and weighting by each country's 2019 population of individuals who were aged 40–69 years. The error bars represent 95% CIs. The vertical dashed line represents the WHO target that at least 50% of eligible people use statins.

*Country-level characteristics associated with statin use*

Of country characteristics examined, per-capita health spending accounted for most statistical variation in the observed statin use (R2=0·30 for primary prevention and R2=0·26 for secondary prevention; Figure 2.2-2; Figure A.6 - 13 to Figure A.6 - 15). Examples of countries that appeared to have greater than predicted statin use based on health spending included Iran, Jordan, Lebanon, and Sri Lanka. Per-capita income (primary prevention, R2=0·21; secondary prevention, R2=0·19), non-communicable diseases policy commitment (primary prevention, R2=0·05; secondary prevention, R2=0·11), and estimated burden of cardiovascular disease

(primary prevention, R2<0·01; secondary prevention, R2=0·01) accounted for less statistical variation in observed statin use.

Figure 2.2-2: Self-reported statin use for primary prevention (A) and secondary prevention (B) by per-capita health spending

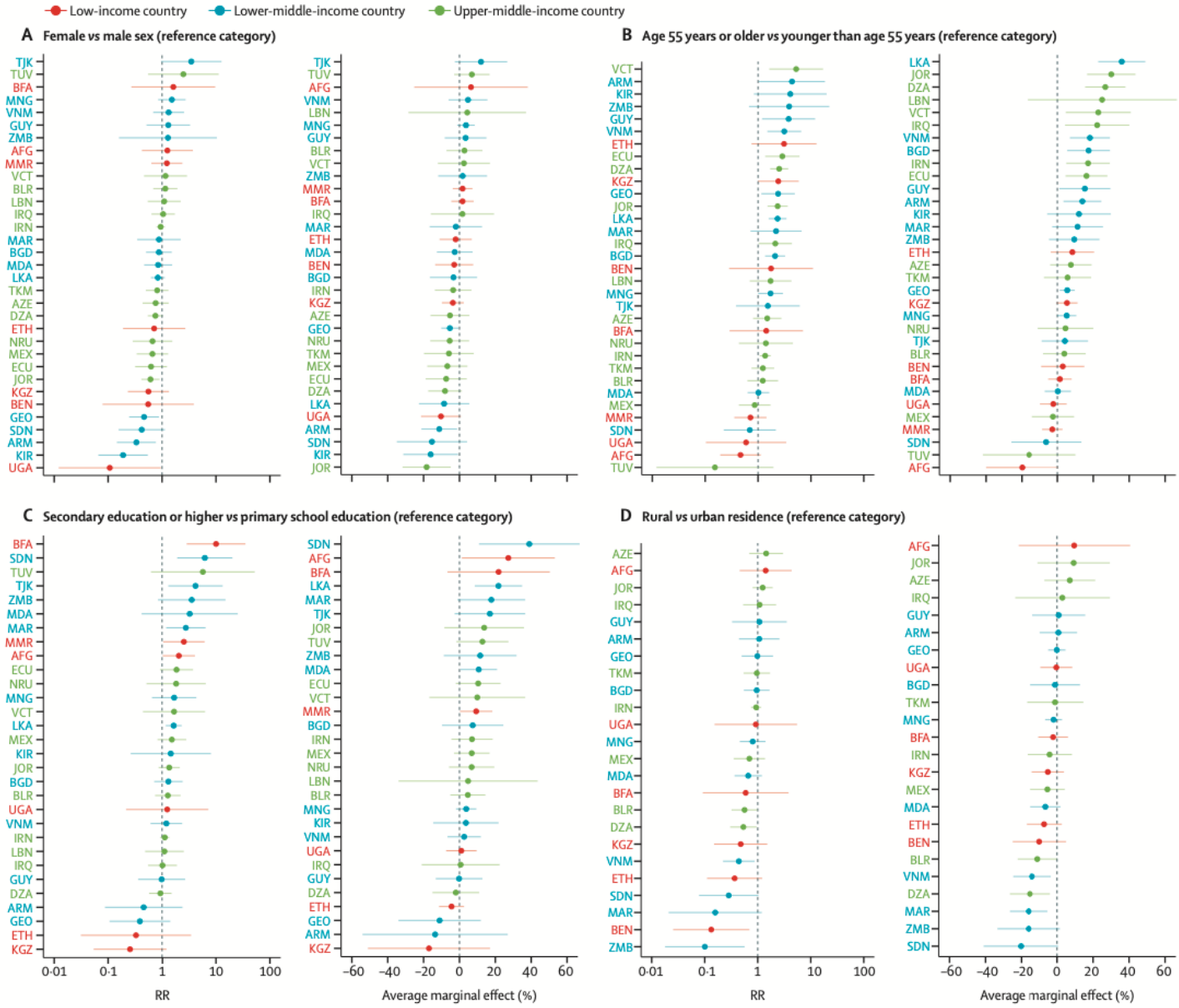



Note: The sample includes non-pregnant individuals aged 40–69 years (aged 40–64 years for Burkina Faso, Kyrgyzstan, Myanmar, and Tokelau). Per-capita health spending is in current international dollars in the year the survey was done. Estimates account for survey design and weighting. The vertical error bars represent 95% CIs. The horizontal dashed line represents the WHO target that at least 50% of eligible people use statins. The diagonal line depicts an ordinary least-squares regression with each country having the same weight. The Iraq survey is excluded from the primary prevention analysis because use of statins was asked only among people self-reporting previous cardiovascular disease. The standardized regression coefficients were 0·55 (95% CI 0·28–0·82) for primary prevention and 0·51 (0·23–0·79) for secondary prevention. AZE=Azerbaijan. BEN=Benin. BFA=Burkina Faso. BGD=Bangladesh. BLR=Belarus. BTN=Bhutan. BWA=Botswana. DZA=Algeria. ECU=Ecuador. ETH=Ethiopia. GEO=Georgia. GUY=Guyana. IRN=Iran. IRQ=Iraq. JOR=Jordan. KEN=Kenya. KGZ=Kyrgyzstan. KIR=Kiribati. LBN=Lebanon. LKA=Sri Lanka. MAR=Morocco. MDA=Moldova. MEX=Mexico. MMR=Myanmar. MNG=Mongolia. NPL=Nepal. NRU=Nauru. SDN=Sudan. SLB=Solomon Islands. SWZ=Eswatini. TJK=Tajikistan. TK=Tokelau. TKM=Turkmenistan. TLS=Timor-Leste. TUV=Tuvalu. UGA=Uganda. VCT=St Vincent and the Grenadines. VNM=Vietnam. ZMB=Zambia.

*Individual-level characteristics associated with statin use*

Although there was heterogeneity across countries, characteristics of older age, higher educational attainment, and urban residence were associated with greater use of statins for secondary prevention in the within-country models (Figure 2.2-3; Table A.6 - 17 to Table A.6 - 20).

Figure 2.2-3: Relative and absolute differences in statin use for secondary prevention of cardiovascular disease by country using modified Poisson regressions for sex (A), age (B), education (C), and residence (D)

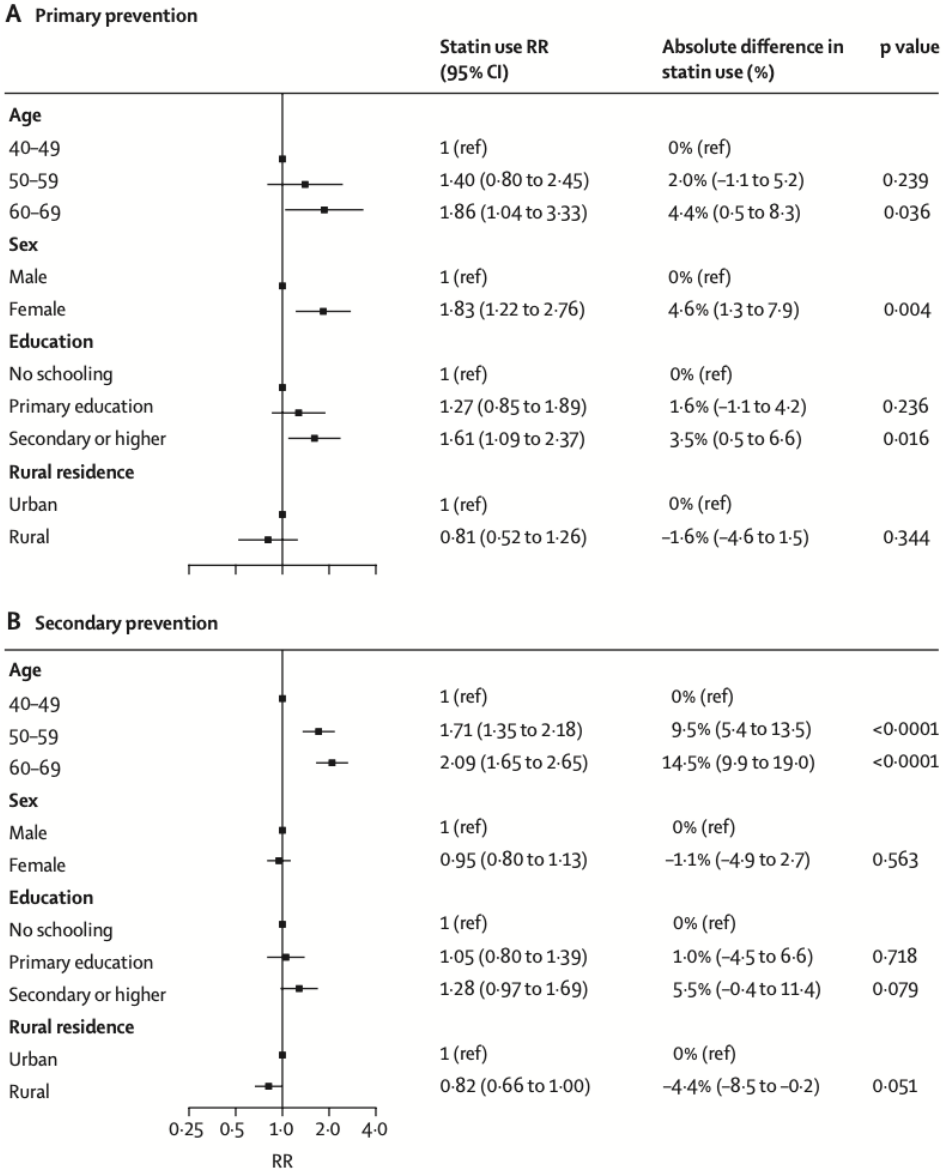



Note: All regressions were adjusted for sex and age. Age was included in three categories (40–49 years, 50–59 years, and 60–69 years) for all the regressions except for in (B) age, in which it was dichotomized as age 55 years or older versus younger than age 55 years. The regressions account for sample weights, stratification in survey design, and clustering at the level of the primary sampling unit. Error bars show the 95% CIs. Education was not available in the survey from Tokelau. Rural versus urban residence was unavailable in 14 surveys (Botswana, Ecuador, Eswatini, Kiribati, Lebanon, Myanmar, Nauru, Solomon

Islands, Sri Lanka, St Vincent and the Grenadines, Tajikistan, Timor-Leste, Tokelau, and Tuvalu). Differences in the ordering of countries by RRs versus average marginal effects is due to the difference in baseline statin use among countries. RR=risk ratio. For country abbreviations see Note Figure 2.2-2

In the multivariable regressions of statin use in the pooled sample, older age was associated with higher statin use for both primary prevention (60–69 years RR 1·86 [95% CI 1·04–3·33]) and secondary prevention (50–59 years RR 1·71 [1·35–2·18] and 60–69 years RR 2·09 [1·65–2·65];Figure 2.2-4). Women were more likely than were men to use statins for primary prevention (RR 1·83 [95% CI 1·22–2·76]) but not secondary prevention (RR 0·95 [0·80–1·13]). Individuals with secondary or higher education were more likely to use statins than were those with no schooling (primary prevention, RR 1·61 [95% CI 1·09–2·37]; secondary prevention, RR 1·28 [0·97–1·69]). Rural residence was associated with lower use of statins than was urban residence for secondary prevention (RR 0·82 [95% CI 0·66–1·00]) but not primary prevention (RR 0·81 [0·52–1·26]).

Figure 2.2-4: Relative and absolute differences in statin use across the pooled sample using modified Poisson regressions for primary prevention (A) and secondary prevention (B)




Note: Results are presented as RRs (95% CIs) and average marginal effects weighting each country by its 2019 population of individuals aged 40–69 years. The models include each of the covariates listed in the plot, country- level fixed effects, and account for clustering at the level of the primary sampling unit. Due to incomplete data, the surveys from Botswana, Ecuador, Eswatini, Kiribati, Lebanon, Myanmar, Nauru, Solomon Islands, Sri Lanka, St Vincent and the Grenadines, Tajikistan, Timor-Leste, Tokelau, and Tuvalu were excluded from the pooled regression analysis. The Iraq survey only contributes to the analysis of secondary prevention of cardiovascular disease. p values refer to the output from the modified Poisson regression model rather than p value of the average marginal effect. RR=risk ratio.

### *Sensitivity analyses*

The sensitivity analyses assessing statin use for primary prevention among individuals aged 40 years and older with 10-year cardiovascular disease risk of more than 20% (i.e., removing the universal indication for statins among people with diabetes), using the 2007 WHO/International Society of Hypertension cardiovascular disease risk charts with 10-year

cardiovascular disease risk threshold of at least 30%, and excluding the rural versus residence variable, were consistent with the main analyses. The sensitivity analysis using equal country weights showed slightly lower estimates for overall statin use for primary (6·7% [95% CI 5·8–7·7]) and secondary (15·9% [14·7–17·2]) prevention of cardiovascular disease. The remainder of the results from this sensitivity analysis mirrored the patterns of individual-level associations with statin use that were observed in the main analyses. Full results from these sensitivity analyses are provided in Figure A.6 - 16 to Figure A.6 - 22.

### 2.2.5. Discussion

In a geographically and economically diverse sample of nationally representative surveys from 41 low-income and middle-income countries, we found that statins were used by approximately one in ten eligible people for the primary prevention of cardiovascular disease and one in five eligible people for the secondary prevention of cardiovascular disease. The WHO target that at least 50% of eligible individuals receive statin therapy to prevent cardiovascular disease was achieved by no region or income group and by just a single country (and only for secondary prevention) in this set of LMICs. At the country level, statin use was lower in countries with lower health spending. At the individual level, there was generally lower statin use among men (primary prevention only) and individuals who were younger, less educated, or lived in rural areas. These estimates provide the first nationally representative and most geographically expansive evidence about the patterns of statin use in many LMICs. Our findings can serve to evaluate progress towards global non-communicable disease targets and to guide health systems' responses to the large and rising cardiovascular disease burden in LMICs.

Statins are widely recommended in clinical practice guidelines and were added to the WHO Essential Medicine List in 2007 (Kishore et al. 2018; WHO 2007). Nevertheless, we find that statin use for cardiovascular disease has remained very low (Salim Yusuf et al. 2011). By contrast, in surveys done in the USA and other high- income countries, statin use is 60–70% for secondary cardiovascular disease prevention (Shah et al. 2015; Salim Yusuf et al. 2011) and approximately 50% for primary cardiovascular disease prevention in people with diabetes or a 10-year cardiovascular disease risk of at least 20% (Leino, Dorsch, and Lester 2020; Patel et al. 2019; Ueda et al. 2018). Statin use is much higher in the upper-middle-income countries than in the lower- middle-income or low-income countries included in our study. Previous work using pooled surveys from LMICs has demonstrated that about three quarters of people

with diagnosed hypertension take antihypertensive medications (Geldsetzer et al. 2019), and 85% of people with diagnosed diabetes take glucose-lowering medications (Flood et al. 2021). Given the disproportionate burden of cardiovascular disease in LMICs and the strong clinical evidence supporting statin therapy, our findings emphasize the urgent need to scale up statin use relative to other medicines to prevent and control non-communicable diseases.

Important previous studies assessing the use of statins in multiple LMICs include the WHO study on Prevention of REcurrences of Myocardial Infarction and StrokE (WHO-PREMISE) (Shanthi Mendis et al. 2005) and the Prospective Urban Rural Epidemiology (PURE) study (Chow et al. 2020; A. Murphy et al. 2018; Salim Yusuf et al. 2011). WHO-PREMISE was a cross-sectional study at health facilities in ten LMICs from 2002 to 2003 in which 20% of patients with a previous history of cardiovascular disease reported using statins (Shanthi Mendis et al. 2005). PURE is a prospective cohort study done in more than 20 high-income, middle-income, and low- income countries. In baseline data collected between 2003 and 2009, statin use for secondary prevention was reported by 3·3% of individuals in low-income countries, 4·3% in lower-middle-income countries, 17·6% in upper-middle-income countries, and 66·5% in high-income countries (Salim Yusuf et al. 2011). Most of the variation in statin use was explained by between-country differences (Salim Yusuf et al. 2011), but there were differences observed by individual-level characteristics such as socioeconomic position (A. Murphy et al. 2018).

Our study adds to the evidence previously provided by WHO-PREMISE and PURE to substantially advance the understanding of statin use globally for many LMICs. First, previous studies used sampling frames that were not strictly representative compared with nationally representative data used in the current study. Such nationally representative estimates are preferred by WHO to monitor progress in meeting non-communicable disease targets (WHO 2014a). Second, we compiled the most recently available survey data (2013 or later) on statin use in LMICs. By contrast to previous studies, all surveys included in our study were done after simvastatin was added to the WHO Essential Medicine List in 2007 and after statin patents expired in the USA (2006–12), which was associated with large decreases in international prices for statins (Kidd 2006; Kishore et al. 2018). Third, we include a much larger sample of countries than did WHO-PREMISE or PURE. Fourth, a novel aspect of our study is that we estimate statin use not only for secondary prevention of cardiovascular disease, but also for primary prevention by applying eligibility criteria from recently updated WHO clinical

guidelines and risk equations (Kaptoge et al. 2019; WHO 2020b). Finally, our study uses the most up-to-date data available to track progress towards the stated target for statin therapy in the WHO Global Monitoring Framework for non- communicable diseases (WHO 2014a).

An important finding in our study was the substantial variation in statin use between countries. We found that country-level characteristics explained only a modest amount of the observed between-country differences in statin use. For example, the variation in per-capita health spending explained approximately a quarter of the variance in statin use for secondary prevention (R2=0·26) in our study, which is substantially lower than in the PURE study (R2=0·77), although PURE also included data from high-income countries (Salim Yusuf et al. 2011). Our comparisons also allowed us to identify countries where statins were more commonly used than what would be predicted on the basis of health spending or other country characteristics alone. Examples included several countries in the Eastern Mediterranean WHO region, including Iraq, Iran, Jordan, and Lebanon. The results from Iran are notable because it was the only country in our sample that has already achieved the 2025 WHO non-communicable disease target of 50% statin use for secondary prevention of cardiovascular disease, although this was not the case for primary prevention. Potential explanations for these observations in Iran include the country's political commitment to non-communicable diseases, establishment of a multisectoral national non-communicable diseases committee, and prioritization of interventions classified by WHO as so-called best buys (Bakhtiari et al. 2020). Our findings can inform subsequent health system research investigating the underlying reasons why some health systems – including those in countries with low per-capita health spending – are more likely to offer statin therapy to eligible individuals.

At the individual level, although there was heterogeneity among surveys, we found greater statin use among individuals who were older, had greater educational attainment, and lived in urban rather than rural areas, which was generally consistent with previous studies (Shanthi Mendis et al. 2005; Salim Yusuf et al. 2011). In previous research on hypertension and diabetes care in LMICs, older age and higher education have emerged as strong predictors of diagnosis, treatment, and control of these conditions (Geldsetzer et al. 2019; Manne-Goehler et al. 2019). The greater use of statins for primary prevention of cardiovascular disease among women has also been reported in the PURE study (Walli-Attaei et al. 2020). However, unlike in the PURE study, women with a previous history of cardiovascular disease had similar rates of statin use to those of men in our study.

Several reasons might explain the lower use of statins relative to other cardiovascular disease medicines in LMICs. Cholesterol measurements are typically more costly than measurements of other risk factors such as blood pressure or blood glucose. Previous clinical guidelines focused on cholesterol target concentrations for statin initiation and monitoring, so these higher measurement costs might have led clinicians and policy makers to focus less on statins. Additionally, the burden of cardiovascular disease attributable to elevated cholesterol has been lower than that attributable to elevated blood pressure in cohort studies (S. Yusuf et al. 2020). As a result, national policies might have prioritized blood pressure medications over statins even though the relative risk reduction for statin therapy is similar to that of anti-hypertensive therapy (Karmali et al. 2016). An example demonstrating this dynamic is that statins were added to the WHO Essential Medicine List in 2007 (Kishore et al. 2018), yet statins are included in national essential medicines lists in only two thirds of LMICs—a lower proportion than other essential cardiovascular disease medicines (Husain et al. 2020; Wirtz et al. 2016). Finally, statins are less affordable in LMICs than are other medicines used to prevent and control cardiovascular disease, as documented by PURE's finding that statins cost 17% of discretionary household income in urban areas and 49% in rural areas of low-income countries (Khatib et al. 2016). International prices for statins are similar to those of these other medicines (Management Sciences for Health 2016), suggesting that procurement prices alone are probably insufficient to explain the low statin use observed in our study.

The WHO HEARTS Technical Package provides a template for implementing multilevel strategies to scale up statin use in LMICs (WHO 2016). Along with structural enabling factors such as health system capacity for point-of-care lipid testing and political buy-in to harness necessary investments, relevant HEARTS package components include simplified clinical protocols, secure procurement of quality-assured medications and measurement devices, task-sharing among clinical teams, community-based delivery of care, and strengthened information systems (WHO 2016). In settings with limited laboratory capacity, greater use of non-laboratory risk scores could support a risk-based approach to cardiovascular disease prevention, as recommended in HEARTS. Finally, fixed-dose combination medications (i.e., so-called polypills), which are effective in reducing cardiovascular disease (Joseph et al. 2021), also have the potential to increase appropriate use of both statins and blood pressure medications.

Our study has several limitations. First, we rely on self- reported measures of a previous history of cardiovascular disease and statin use. We justify using these self-reported measures as they are the recommended methodology in the WHO non-communicable disease Monitoring Framework (WHO 2014a). To our knowledge, there is no research validating self-reported medical history or medication use in STEPS surveys. Previous studies support the reliability of self-reports of cardiovascular disease history, including accuracy of 89% in the PURE study (Salim Yusuf et al. 2011). Self-reports for cardiovascular disease medications have also been found to have high levels of accuracy in previous studies (Hafferty et al. 2018; Richardson et al. 2013). Second, we were unable to capture important details of medication use such as the specific statin agent or dose, whether the statin was generic or branded, and whether the respondent had taken statins in the past but stopped them due to side-effects. Although these details would not have affected our estimates of statin eligibility as defined by WHO, it would have allowed us to comment on the appropriateness of statin intensity, cost, and other factors. Third, our findings are mainly generalizable to the countries in which surveys were done, and we were unable to include surveys from some large LMICs, such as China and India. Results at the country level should be interpreted with caution. However, our study is unique in its use of nationally representative, individual-level data from surveys done in a diverse set of countries that collectively represent a total population of more than 1 billion people. In future research, we hope to assess statin use using harmonized data from countries of all income levels. Fourth, we did not assess statin use by target lipid concentrations – an approach recommended in previous guidelines and applied in our group's previous work (M. E. Marcus et al. 2021) – because low-density lipoprotein cholesterol data were unavailable in approximately two-thirds of surveys. Finally, our analyses of statin use for primary prevention rely on cardiovascular risk scores developed by WHO that might not be accurately calibrated to all countries in our analysis.

In conclusion, our results emphasize the urgent need to scale up statin use in LMICs, where most of the global cardiovascular risk burden occurs. Policies and programs that facilitate the successful implementation of statins into primary health systems in these settings must be investigated in future research and advocacy.

# 3. The Effectiveness of Selected Individual-Level Interventions Aimed at Increasing Care Seeking Behavior for CVD Screenings

## 3.1. Essay 3:

### The Effect of SMS Reminders on Health Screening Uptake: A Randomized Experiment in Indonesia

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and
Study pre-registration: Marcus, Maja E. et al. 2019. "A Mobile Phone-based Intervention to Improve Health Screening Uptake: A Randomized Experiment in Indonesia." AEA RCT Registry. November 2019. (https://doi.org/10.1257/rct.5047-1.0.)

### 3.1.1. Abstract

While the burden of non-communicable diseases is rising in low- and middle-income countries, the uptake of screening for these diseases remains low. We conducted a randomized controlled trial in Indonesia to assess whether personalized and targeted text messages can increase the demand for existing public screening services for diabetes and hypertension in the at-risk population. Our intervention increased screening uptake by approximately 6.6 percentage points compared to the pure control group. Among those, who received and read the messages, the effect size is 17 percentage points. The intervention appears to work through a reminder rather than a knowledge effect. We conclude that text messages can be a cheap and easily scalable tool to reduce testing gaps in a middle-income country setting.

### *3.1.2.* Introduction

The ongoing epidemiological transition in low- and middle-income countries (LMICs) raises new challenges for their health systems. While the burden of infectious diseases remains high, non-communicable diseases (NCDs) are on the rise. Many of these diseases require a care very different from infectious diseases: They can be tackled effectively many years before individuals notice symptoms, and before severe complications develop. At the same time, individuals must be aware of this "invisibility" and take up preventive health behavior early on.

Diabetes and hypertension screening can be seen as a special case of preventive health behavior, for which it is not the aim to avoid an illness altogether but to detect a prevalent condition early enough to avoid or postpone complications. Screening is possible at very low costs, and at very early stages, behavioral changes can be sufficient to control these conditions. Yet, screening for diabetes and hypertension is underutilized in many LMICs (Geldsetzer et al. 2019; Manne-Goehler et al. 2019), even in settings with a free and easily accessible screening infrastructure, such as Indonesia.

In this study, we test whether a low-cost, light-tough text message intervention can increase the uptake of hypertension and diabetes screening in Indonesia. To understand the potential effect better, we explicitly test whether the intervention can transport new information, and whether risk aversion and patience are mediating the effect. Lastly, we examine household spillover effects to see whether the intervention can be effective beyond the direct message recipient.

We assessed these research questions via a randomized controlled trial in the general at-risk population, in which half of the participants received the full intervention and half is the pure control group. The treatment group received two sets of three text messages, with each set sent before one of the monthly village screening dates between January and March 2020. The messages called upon the recipients to attend screening at the specified time and place and gave short information on their elevated risk, the necessity, and the benefit of screening. The intervention was targeted at individuals over the age of 40, who are at increased risk to develop diabetes or hypertension and should be screened once a year in accordance with WHO PEN screening guidelines (WHO 2010). We randomly sampled 2,006 participants from two districts

in Aceh province in a two-stage stratified design. Baseline data was collected in November and December 2019 and endline data was collected approximately one month after the last screening date via telephone surveys as the COVID-19 outbreak did not allow for in-person interviews.

We find that the intervention increased the uptake of screening services from 33% to 40%, which is a 6.6 percentage point or a 20% increase compared to the control group. For respondents who received at least one full set of messages and could remember any message content, the effect size increases to 17 percentage points. The text messages seem to work as a reminder for screening: While there is an overall increase in the uptake of screening, there is no impact on knowledge related to the text message or general disease knowledge. Respondents primarily remembered the content on the logistics and the advice to get screened. The only new information, which is remembered by a quarter of the respondents who recall any content is the fact that their age group implies a higher risk for hypertension and diabetes. In addition, the treatment effect is driven by attending screening at the community health center (Puskesmas) rather than the specific village screening meeting (Posbindu) that was mentioned in the messages. The treatment effect does not seem to differ across time and risk preferences. We cannot detect any spillovers to other household members.

In a standard model, investment in preventive health care such as screening would be the result of the monetary and non-monetary costs and benefits of each health option, as well as the time horizon over which they occur (P. Dupas and Miguel 2017). In such a world, the individual's investment in preventive health care is optimal for the individual, and the societal optimum could be reached by changing the cost structures. However, in reality, an underinvestment in preventive health care is observed (Kremer, Rao, and Schilbach 2019). This underinvestment can be the result of various factors, such as inaccurate or motivated beliefs, trust, present bias, or limited attention.

Previous studies showed that preventive health behavior can be improved by both new information and reminders conveyed via text messages. Our work builds on and contributes to this literature in the following ways. First, previous literature showed that text messages can be effective in targeting complex and sustained behavior changes for preventive health, such as smoking cessation or increased physical activity (Cole-Lewis and Kershaw 2010). These studies usually use text messages with high frequency and over long durations, or in

combination with other more intensive treatments. Complementing this, we employ a light-tough intervention, where only 6 messages were sent out over the course of two months, and examine one specific health action, which needs to be carried out only once over long time periods. This health action further differs from the aforementioned, as NCD screening not only aims at preventing the disease altogether, but also serves as detection for already existing cases – introducing additional factors into the individual's cost-benefit analysis in comparison to purely preventive behaviors. Second, other light-tough interventions for one-time health actions showed that text messages can be an effective tool for the scheduling or reminding of health care appointments, including health check-ups or the adherence to vaccination schedules (Jacobson Vann et al. 2018; McLean et al. 2014). Our study goes beyond such settings by addressing community-wide NCD screening outside of the direct health practitioner-patient relationship and by targeting a population that is less connected to NCD care. Third, studies focusing on NCD screening services were primarily conducted in high-income countries, which typically have a longer history of NCDs as the leading health burden and of NCD care structures (McLean et al. 2014; Sallis et al. 2019). We complement this evidence by studying Indonesia – a middle-income country setting, in which screening for NCDs might be less habitual, as they have caused the majority of deaths only since the 1990s (IHME 2018). To our knowledge, the only studies examining NCD screening in LMICs targeted cervical cancer screening (D. Zhang et al. 2020), which exclusively occurs in female population groups and is a separate noncommunicable disease class from diabetes and hypertension. Apart from text messages, other interventions to increase screening demand specifically for diabetes and hypertension in LMICS are also rare; the only other study we know of uses again a more intensive treatment, namely in-person scripts and pharmacy vouchers (de Walque et al., 2020; Gong et al., 2020). Lastly, beyond the main treatment effect, we contribute to the scarce evidence base of spillover effects, particularly within the household, of preventive health interventions (Dupas & Miguel, 2017).

In the following chapter, we summarize the current prevalence of and screening for diabetes and hypertension in Indonesia. Then, we describe the experiment in detail by deriving the hypotheses from previous evidence and our own pre-studies, presenting the intervention design, estimation strategy, data collection and outcome definitions. The fourth chapter displays the experiment's results as well as implications for a potential scale-up. Finally, we conclude and give an outlook for further research.

### 3.1.3. Context

Similar to other LMICs, the burden of NCDs is rising in Indonesia. From 1990 to 2017, the share of NCDs in causes of death rose from 48% to 75% (IHME 2018). In 2017, hypertension and diabetes were among the top three risk factors for morbidity (IHME 2018). The most recent national health survey from the Ministry of Health revealed that diabetes prevalence has risen to 11% and hypertension to 34% (Riskesdas 2018), both above the global average. To battle this trend, the national government has started implementing targeted prevention programs. In the last decade, nationwide programs were established to integrate a division responsible for NCD needs in every community health center (*Puskesmas*) (Mahendradhata et al. 2017).

One main effort is the village screening program *Posbindu (Pos binaan terpadu*). Once per month, trained nurses from the local *Puskesmas* offer information as well as screening and monitoring services for various NCDs to the general population at a central place within each village. This basic service is free of charge for the user and financed through a combination of the *Puskesmas* and village budget. At the village level, community health workers (*kader*) are responsible for organizing and advertising the meetings. In addition to *Posbindu*, it is possible to get free screening at the district's *Puskesmas* at all times, and for a charge of approximately 50,000 IDR[3] at private practices. However, the national health survey shows that the general population has rarely used the NCD screening services so far. About one third of those aged above 45 report that they never had their blood pressure checked, and around 70% never had their blood sugar level checked (Riskesdas 2018).

This pattern of high diabetes and hypertension prevalence and low screening uptake is also observed in our study region in Aceh province: the diabetes and hypertension prevalence is slightly above the national mean, and reported screening rates were below the national average in 2018 (Riskesdas 2018). A focus group discussion with 12 *kaders* from our study area revealed that *Posbindu* tends to be visited by elderly women and those who were already diagnosed[4]. The *kaders* perceive it as more difficult to motivate the general population to attend the meetings even though sufficient time and equipment would be available. In addition, the

[3] 3.56 USD at an exchange rate of 14032.02 IDR/USD, this charge includes blood pressure, blood glucose and additionally cholesterol and uric acid measurement.

[4] The focus group discussion was part of our pre-study to gather information on the supply-side perspective.

province has close to universal health insurance coverage for over a decade, which makes it a suitable setting to study the demand-side barriers to screening uptake.

### 3.1.4. Method

*The Intervention*

Our intervention is a repeated set of SMS text messages on the necessity and logistics of diabetes and hypertension screening. It was designed to address disease misperceptions as well as behavioral barriers to screening uptake. The intervention was piloted in mid-January 2020 (see appendix B.4) and fielded from late January until March 2020.

Targeted mechanisms

As a high prevalence of NCDs is a rather new phenomenon in LMICs, individuals might not yet be aware of the role of screening as preventive health behavior, or might not have internalized regular check-ups. Text messages on screening dates might tackle several of these barriers: They might convey new information, thus update beliefs, make the screening decision more salient to the individual, thus serving as a reminder, or introduce a deadline to be screened.

To find out which factors keep at-risk individuals from taking up screening in the Acehnese context, we conducted a qualitative and a quantitative pre-study[5] (see Table B.2 - 1 for the detailed study timeline). For the qualitative arm, twelve in-depth semi-structured interviews with individuals from the target population were conducted in November 2019. These findings were quantified and extended in the quantitative baseline data collection from late November until December 2019 (see chapter B.2 for data collection details).

These pre-studies showed that the majority of our respondents were informed about the main characteristics of hypertension and diabetes, as well as the possibility to screen free of charge. There are some perceived non-monetary costs such as fear of diagnosis and the notion that preventive health programs are designed for the elderly or women, but no strong stigmatization. On the other hand, respondents are aware that early treatment initiation can help and that especially diabetes likely leads to high treatment costs. However, to most respondents it was

[5] The detailed design and findings will be made available in a separate paper.

not salient that their age implied a higher risk for both conditions, and most did not know that one could have them without feeling any symptoms. Studies from other parts of Indonesia confirm that even if individuals could identify risk factors, the own susceptibility was underestimated (Pujilestari et al. 2014), and even diagnosed respondents did not yet internalize that the need for screening does not depend on feeling ill (Rahmawati and Bajorek 2018). Informing individuals about the need for screening independent of symptoms and their age-based risk might thus increase screening uptake.

Furthermore, forgetfulness and limited attention might prevent screening uptake. Reminders and fixed dates might simply make the decision for screening more salient and induce planning (Milkman et al. 2013), or increase the perceived urgency of screening. Similarly, evidence from other LMICs suggests that present bias can be a substantial barrier to screening uptake, as individuals postpone the health investment infinitely (Kremer, Rao, and Schilbach 2019). Deadlines can be efficient countermeasures as they signal that on the deadline, individuals cannot decide between now or later, but only between now or never (Kremer, Rao, and Schilbach 2019). Hence, individuals might not procrastinate the health investment any longer, but might be inclined to take up screening at the deadline. While the screening date is a non-binding deadline, the mere notion that missing the date implies a waiting period of one month might be effective to reduce naïve procrastination (O'Donoghue and Rabin 2015).

Previous studies showed that impatient individuals are less likely to seek screening (Picone, Sloan, and Taylor, Jr. 2004a), resulting in a higher risk of underdiagnoses (Kim and Radoias 2016). Increasing the salience of the time dimension might reinforce this heterogeneity, while deadline setting might help especially impatient individuals to take up screening. Similarly, more risk-averse individuals invest more in preventive health in some cases (Tsaneva 2013), but not in all (Goldzahl 2017; Picone, Sloan, and Taylor, Jr. 2004a), depending on how uncertain the outcomes of screening and treatment are perceived (Selden 1993). Thus, the information conveyed in text messages might impact screening demand differently for relatively more and relatively less risk-averse individuals.

Finally, text messages could impact individuals beyond the targeted respondents due to information sharing, social learning, or mere convenience when respondents are accompanied to the screening facility. Spillovers of health interventions are rarely examined (P. Dupas and

Miguel 2017), but are of interest when analyzing the overall impact of an intervention. In the case of text messages, this might be particularly relevant, as they can be shared easily.
Thus, to assess the effectiveness of the intervention, we test the following hypotheses:
H1: The intervention increases screening uptake of the message recipient.
H2: The intervention increases screening and disease knowledge.
H3: There is a heterogeneous treatment effect along risk and time preferences.
H4: The intervention increases screening uptake of other household members.

Content & personalization

The messages' content included the village-level *Posbindu*[6] screening date and location as well as selected information about hypertension and diabetes. We opted to emphasize the benefits of early screening uptake, in order to positively frame the messages, rectify respondents' misconceptions, and confirm their correct beliefs. Furthermore, as very few respondents were aware of age being a significant risk factor for diabetes and hypertension, we included this information to increase relevance and urgency for the recipients. Also, we included a note that the community health worker (*kader*) or the community health center (*Puskesmas*, abbreviated to PKM) can be contacted for further information. This aimed at increasing the trustworthiness and legitimacy of the messages, while at the same time providing respondents with contacts should any questions arise. To maximize their potential impact (e.g. Head et al. (2013)), the messages were personalized by providing village-level information, addressing the age of the recipient, as well as including the recipient's name in the greeting.

Based on these considerations, we formulated the following messages (see Table B.1 - 1 in the appendix for the translation of each message):

Message 1: Greetings [Mr/Ms name], do you know that [diabetes|hypertension| does not always show symptoms but can be treated better if detected earlier. Check for FREE at POSBINDU [date].
Message 2: Greetings [Mr/Ms name], do you know that people over 40 years old have a high risk of diabetes & hypertension? Ask kader / PKM & check for FREE at POSBINDU [date].

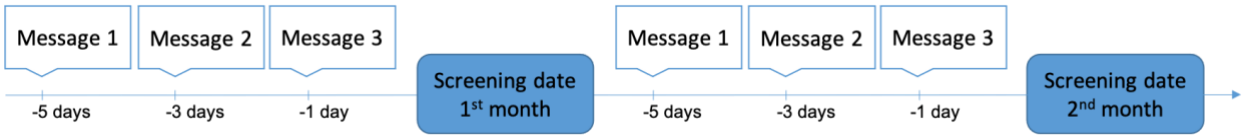
[6] 17 out of 146 villages did not have a *Posbindu* screening during our study period. In these cases, participants were invited to the *Posbindu* in a neighboring village as participation is not restricted to village residents.

Message 3: Greetings [Mr/Ms name], remember to benefit from a FREE diabetes and hypertension CHECK in POSBINDU tomorrow morning at [place within the village]. Contact nearest kader or PKM.

Implementation

Each individual in the treatment group received six SMS messages to the telephone number that s/he chose to be his/her contact number at baseline. The respondent did not have to be the owner of the phone, but s/he needed to be accessible through the phone number. As depicted in Figure 3.1-1, three messages were sent before the first village screening date and three were sent before the second date one month later. In the first cycle, the first message addressed diabetes, while in the second cycle, it addressed hypertension. In both screening cycles, messages were sent five days, three days and one day before the screening date. For 12 respondents in the treatment group, the first screening date took place end of January 2020, whereas for everyone else in the treatment group it took place in February.[7] The screening dates were enquired by our local research assistants from the respective *Puskesmas* up to two weeks before the start of the intervention to ensure their accuracy. As the *Puskesmas* only coordinates the screening services for all the villages in their catchment area, and the organization at the village level is done by the village health worker, we do not expect this enquiry to have any supply side effects. Most of the intervention period was not affected by the COVID-19 pandemic as *Posbindu* typically takes place in the beginning of a month and the second treatment cycle was therefore finished for most participants in early March. Puskesnas records show that at this time, Posbindu still took place regularly and attendance did not drop compared to the previous months.

Figure 3.1-1: Intervention timeline




[7] To not interfere with newly implemented recommendations of social distancing, SMS were no longer sent after March 24, 2020, such that 10 people did not receive the full second cycle of the text messages. In early March case numbers were still very low in Indonesia (and none in Aceh) and there were no restrictions in place.

The messages were sent out by the research team using the bulk SMS gateway provider *bulkgate*. We received delivery reports from the portal stating which messages failed to be delivered.

Treatment assignment was done in a random draw after baseline data collection in Stata 14 using the procedure proposed in DIME (2019). Half of the phone numbers were randomly allocated to the treatment group, which received the full intervention, while the control group received no intervention. Interviewers were fully blinded to treatment assignment, and could only infer treatment status from the answers the respondents gave at endline (in which the reception of messages was assessed after the screening behavior). Respondents were not aware of the existence of a control and treatment group throughout the study.

*Estimation strategy*

We assess the impact of our intervention using intention-to-treat and local-average-treatment-effect estimates. Our regression specifications include the following outcome, treatment, and control variables, all of which were specified in the pre-analysis plan and implemented accordingly (M. E. Marcus et al. 2020).

*Outcome variables*

Our primary outcome is screening uptake, which is measured in two ways. First, we use self-reported data at endline on whether respondents went to any diabetes or hypertension screening within the intervention period.[8] Secondly, we measure whether respondents went to at least one of the two *Posbindu* dates specified in our text message intervention.

Secondary outcomes are SMS-related knowledge, broader diabetes and hypertension knowledge, and household spillovers. SMS-related knowledge aims to capture the direct effect of the information that is transmitted in the messages. This is measured by a count index from 0 to 7, which increases by one for each correctly answered question that relates to the message content. All dimensions are measured by separate survey items that are part of the larger block of knowledge and screening questions (refer to Table B.3 - 1 for the list of questions). We

[8] We further pre-specified the aim to measure screening uptake across all villages in the sample districts using *Posbindu* attendance rates from administrative data, but full access could not yet be granted.

assess broader diabetes and hypertension knowledge to evaluate any knowledge impacts beyond the pure message content, for example through information obtained from the health staff during screening, or through information seeking. We measure broader diabetes and hypertension knowledge with an index derived from a model of the determinants of health seeking behavior (Becker 1974b; Janz and Becker 1984). The index includes items that can be influenced by information into a clear direction. An increase in the index therefore reflects both an increase in knowledge and should, as the model hypothesizes, increase the propensity to take up screening services. We measure the individual dimensions using the survey items displayed in Table B.3 - 2. For the main results, we use a count index that increases by one with each correctly answered knowledge question. To test the sensitivity of this result, we employ principal component analysis to reduce the dimensions to one variable, weighted by their explanatory power. This index gives a holistic picture of health knowledge with a focus on diabetes and hypertension.

We measure household spillovers through a binary variable indicating whether any other household members went for diabetes or hypertension screening within the intervention period.

*Treatment status*

Treatment is defined in two ways. First, we categorize respondents into treatment and control group according to their randomized status. Secondly, we define a "treatment exposure" variable, which indicates whether the respondent received all three messages in one month and can recall the content of at least one message. The former is measured using delivery reports from the bulk SMS provider. The latter is a self-reported measure collected at endline. It is based on listing at least one of the elements of our text messages when asked about the content of the NCD/ screening related message in an unaided recall question, if the respondent claims to have received such a message.

*Variables for heterogeneous treatment effects*

We measure risk and time preferences with one self-reported baseline survey question each, taken from and validated by the Global Preferences Survey (Falk et al. 2018; 2016). Patience is elicited by asking respondents to indicate how generally willing they are to give up something today in order to benefit from it in the future (on a scale from 0 to 10). Willingness-

to-take risks is elicited by asking respondents to indicate on a scale from 0 to 10 how generally willing they are to take risks.

*Control variables*

We measure age, sex, education, and phone ownership using self-reported survey questions. Furthermore, we construct a wealth index based on self-reported asset ownership using the standard DHS approach. All control variables were elicited at baseline.

*Regression specifications*

We estimate treatment effects on primary and secondary outcomes in the following framework:

a) Intention-to-treat (ITT)

$$Y_i = \alpha + \beta Treat_i + \delta Control_i + \varepsilon_i \quad (1)$$

where *Y* is our outcome variable (screening uptake in the main specifications and household spillover effects, SMS-related knowledge, and broader hypertension and diabetes knowledge in secondary analyses), *Treat* is an indicator variable for treatment status, and *Control* denotes the variables age (continuous), sex (indicator for female), education (none as base category, indicators for primary, lower secondary, upper secondary, tertiary education), wealth (in quintiles, with lowest as base category), and phone ownership[9].

b) Local Average Treatment Effect (LATE)

Additionally, we estimate the local average treatment effect using an instrumental variable approach (Imbens and Angrist 1994). Specifically, we use assigned treatment status to instrument the treatment exposure variable.

$$Exposed_i = \eta + \theta Treat_i + \pi Control_i + \upsilon_i \quad (2)$$

$$Y_i = \alpha + \beta \widehat{Exposed}_i + \delta Control_i + \varepsilon_i \quad (3)$$

We explore potential heterogeneities in treatment uptake along time and risk preferences using the following specification:

[9] Due to a technical problem, phone ownership was not elicited for 7 individuals. We created a separate indicator for missing phone ownership information to keep them in the estimation sample. Neither phone ownership nor the indicator are significantly different from zero in the regressions.

$$Y_i = \alpha + \beta Treat_i + \gamma Trait_i + \theta Trait_i * Treat_i + \delta\, Control_i\ + \varepsilon_i \quad (4)$$

Where $Trait$ is the respective continuous indicator of baseline risk or time preference.

Standard errors are clustered by phone number. For all main hypothesis, p-values will be adjusted for multiple hypothesis testing following the Benjamini-and-Hochberg method (Benjamini and Hochberg 1995) as a robustness check.

*Data and sample characteristics*

The baseline sample was drawn in a two-stage stratified random sampling procedure. First, we randomly drew 147 villages from a complete list of villages in the districts Aceh Besar and Banda Aceh. This draw was stratified by district to have an equal number of villages from the mostly rural Aceh Besar and the mostly urban provincial capital Banda Aceh (refer to Figure B.2 - 1 for a map of the sampled villages). Within the villages, we selected households using a random walk following the procedure described in appendix B.2.2. Around half of the identified houses were found to be occupied, out of which 85% agreed to undergo the short eligibility check. The eligibility criteria ensured that the respondent would be recommended to be screened on a yearly basis (being over the age of 40[10]), and is neither diagnosed with diabetes or hypertension nor adheres to the recommended screening schedules. Out of those who did the eligibility check, one third of households was eligible[11]. If several household members met the inclusion criteria, one was randomly chosen as respondent. This yielded a sample of 2,006 individuals[12]. The survey was introduced as a research study on the health of people over 40 in Aceh province, and respondents were asked to give a phone number through which they can be reached over the next months.

[10] We set the upper age limit of 70 to ensure that the respondent is able to complete the interview. Refer to appendix B.2.1 for a detailed list and reasoning for each in- and exclusion criterion.

[11] Out of those ineligible, 36% did not have a member between the ages of 40 and 70, 28% had a member with a prior diabetes or hypertension diagnosis, 15% went for regular screening, in 8% of households eligible members were not at home and only 6% of households had to be excluded because they did not have any mobile phone (Table B.2 - 2).

[12] An additional 94 baseline respondents were excluded before randomization as they had not supplied us with a valid telephone number until the end of data collection. This also led to the drop-out of one village in the final sample.

The endline survey was conducted from end of March until beginning of May 2020 and was shifted to phone interviews due to the outbreak of the COVID-19 pandemic (call pattern described in Figure B.2 - 2). The analysis sample comprises of 1,386 individuals, 704 of the control and 682 of the treatment group. This implies a re-contact rate of slightly more than 70%[13], which is high for a telephone survey, but lower than we expected from the planned in-person endline data collection. The endline sample is hence slightly smaller than was deemed necessary in the power calculation (see appendix B.2.3).

We depict endline sample characteristics across treatment and control group in Table 3.1-1. The average age of the respondents is 50 years, slightly more than 60% of the sample population is female, and 73% have at least lower secondary education. Literacy in Bahasa Indonesia is over 90%. About two thirds of the respondents owned the phone which was used to contact them, the remainder were reachable through a phone owned by a family member or someone else. Compared to the same age group living in households with a mobile phone in the representative national socio-economic survey (SUSENAS 2017), our respondents are to a higher proportion female and slightly less educated, but generally similar across basic sociodemographic characteristics (see Table B.5 - 2).

[13] 1,412 respondents could be re-interviewed. Due to missing information on whether screening happened after the start of the intervention (the month of screening was not reported) for 23 respondents, and missing information on age, gender and wealth quintile for one respondent each, the final analyses sample consists of 1,386 respondents.

Table 3.1-1 Endline sample characteristics across treatment and control group

| | Control group | | | Treatment group | | | |
|---|---|---|---|---|---|---|---|
| | Mean | Standard deviation | N | Mean | Standard deviation | N | p-value |
| Age | 50.26 | 8.22 | 704 | 49.52 | 7.85 | 682 | 0.088 |
| Female | 0.64 | 0.48 | 704 | 0.61 | 0.49 | 682 | 0.285 |
| Highest level of schooling | | | | | | | 0.850 |
| None | 0.04 | 0.19 | 704 | 0.03 | 0.18 | 682 | |
| Primary | 0.23 | 0.42 | 704 | 0.24 | 0.42 | 682 | |
| Junior Secondary | 0.23 | 0.42 | 704 | 0.21 | 0.41 | 682 | |
| Senior Secondary | 0.35 | 0.48 | 704 | 0.36 | 0.48 | 682 | |
| Tertiary | 0.15 | 0.36 | 704 | 0.17 | 0.37 | 682 | |
| Literacy | 0.91 | 0.29 | 568 | 0.93 | 0.26 | 555 | 0.160 |
| Wealth quintile | | | | | | | 0.389 |
| 1 | 0.22 | 0.41 | 704 | 0.19 | 0.39 | 682 | |
| 2 | 0.19 | 0.39 | 704 | 0.18 | 0.38 | 682 | |
| 3 | 0.19 | 0.39 | 704 | 0.22 | 0.41 | 682 | |
| 4 | 0.20 | 0.40 | 704 | 0.19 | 0.39 | 682 | |
| 5 | 0.20 | 0.40 | 704 | 0.22 | 0.42 | 682 | |
| Own phone | 0.64 | 0.48 | 700 | 0.68 | 0.47 | 679 | 0.101 |
| Joint F-test | | | | | | | 0.277 |

Means, standard deviation and number of observations of main respondent characteristics by treatment group; p-values based on t-tests of difference in mean between treatment and control group, except in the case of education, wealth quintile, and the total, where we used F- tests on joint significance of the different levels respectively variables.

Treatment and control group were balanced across all key variables of interest at baseline, except for phone ownership, which was slightly higher in the treatment group (see Table B.5 - 1). At endline, respondent age is slightly lower in the treatment group and the share of phone owners remains slightly higher. As displayed in Table B.5 - 3 to

Table B.5 - 5, there was no differential attrition between treatment and control group. There are no statistical differences in the demographics between the individuals of the treatment and

control group lost to follow-up, except for a lower baseline disease knowledge in the treatment group at 10% significance. However, independent of treatment status, respondents who were lost to follow-up seem to be to a higher proportion female, less educated and knowledgeable about NCDs, less wealthy, and to a lesser proportion phone owners. These differences likely occur due to the need to shift the administration of the survey to the phone: Additional analyses reveal that phone ownership is more likely across younger, male and better educated individuals from households in the fifth wealth quintile. If controlling for all base characteristics simultaneously, having no educational degree and not being the phone owner are the only significant drivers of attrition (see Table B.5 - 6).

According to the delivery reports, at least one full cycle of intervention messages was delivered in 97% of cases before one of the Posbindu dates. For 84% of our sample, we have also self-reported measures of exposure[14]: Out of those who received at least one full cycle, 30% could correctly recall at least one item of the message content, indicating that the messages were not only delivered, but also received, read, and understood. Consequently, around 28% of the treatment group constitute the exposed group in the LATE estimation.

### 3.1.5. Results

*Screening uptake*

We find that our intervention had a positive effect on screening uptake of the message recipient (Figure 3.1-2). In the intention-to-treat analysis, treatment increased screening uptake from 33% in the control to 40% in the treatment group. This is an increase by around 6.6 percentage points (p.p.) or 20% at a statistical significance level of less than 1%. This effect is robust in all pre-specified model specifications (Table B.6 - 1), adjustments for multiple hypothesis testing (
Table B.6 - 2) or alternative estimation strategies (
Table B.6 - 4).

When treatment exposure (having received the full cycle of text messages and being able to recall message content) is instrumented by treatment status, the effect is more than twice as

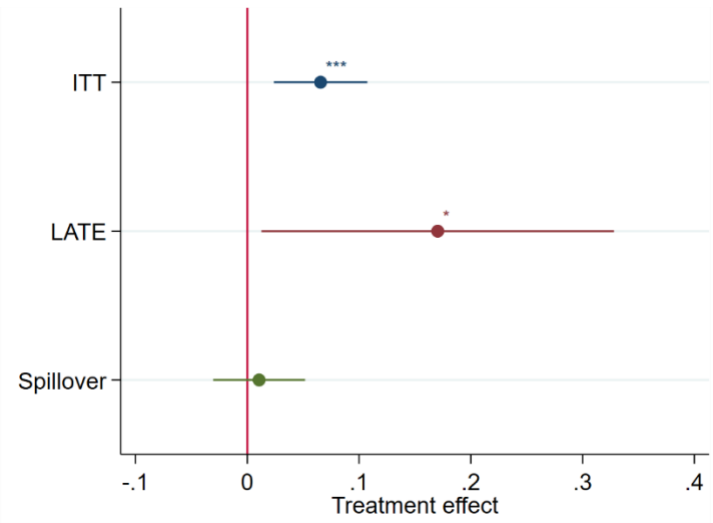
[14] As the questions about message content were asked only in the very end of the interview, the estimation sample for the LATE excludes 204 respondents who terminated the interview before this question. Respondents in this subsample are to a higher proportion male, to a lesser proportion phone owner, but otherwise similar.

high (17 p.p.), which indicates the potential for a higher treatment effect if barriers to message reception are reduced. In the section *Implications for Scale-up*, we explore the main barriers from sending up to acting upon the messages in detail. It needs to be mentioned that the precision of the LATE estimate is lower than for the ITT due to the above-mentioned reduction in the sample and hence a loss in statistical power.

The effect on screening uptake of the message recipient did not lead to within-household spillover effects. We do not find evidence for other household members taking up screening more often, neither in the aggregate as displayed in Figure 3.1-2, nor when restricting the sample to household members in the same age group as our respondents (between the age of 40 and 70). Receiving the messages through another household member's phone or a family phone could have increased other household member's attention to the messages, but even if accounting for phone ownership, we do not find evidence for substantial spillover effects (

Table B.6 - 9).

Figure 3.1-2: Treatment effect on screening uptake of the message recipient and household members.



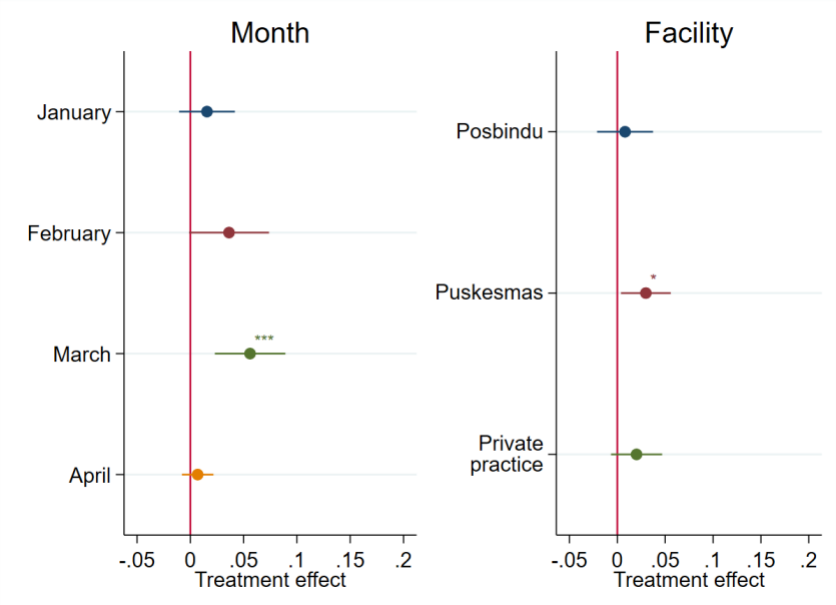

Point estimates of the treatment coefficient from equation 1 (ITT), the instrumented treatment coefficient from equation 3 (LATE) for the message recipient and other household members (ITT), controlling for age, gender, wealth and phone ownership; see Table B.6 - 1 for tabular display with and without covariates; displayed with 90% confidence intervals; * p < 0.1, ** p < 0.05, *** p < 0.01

To understand the treatment effect of the message recipient better, we further examine the timing and location of screening (Figure 3.1-3). For all respondents, we see low screening

uptake in November and December, and increasing visits to testing facilities from January on. Even though treatment is positively correlated with screening uptake in all months, it is only statistically significantly different from zero in March and is comparable to the size of the aggregate treatment effect. This suggests a concentration of the treatment effect after having received the second set of text messages. When disaggregating the treatment effect according to screening provider, we see that the effect is not driven by treatment group respondents going to the specific *Posbindu* meeting that was mentioned in the messages, but rather by going for screening at the *Puskesmas*. Even though the focus of the messages was on the *Posbindu* meeting, the *Puskesmas* was always mentioned as a point of contact, and might have posed a suitable alternative for some respondents.

Apart from merely going for screening, we see that this uptake translated in significantly higher blood pressure testing rates and checks of the medical history in the treatment group. Blood glucose testing, physical measurements, and other blood checks are also positively correlated with treatment, but not statistically significantly different from zero (
Table B.6 - 12).

Figure 3.1-3: Treatment effect on message recipient screening uptake by month and facility




Point estimates of treatment coefficient from equation 1 with different binary screening uptake indicators as outcomes (coded as 1 if the individual indicated to have gone to screening in the respective month/ facility and 0 otherwise); controlling for age, gender, wealth and phone ownership; see
Table B.6 - 10 and
Table B.6 - 11 for tabular display; displayed with 90% confidence intervals; * p < 0.1, ** p < 0.05, *** p < 0.01.

*Channels*

We find that the intervention did not increase knowledge, as shown in Table 3.1-2. We can neither detect a treatment effect for the specific knowledge items mentioned in the text messages, nor for general diabetes and hypertension knowledge. These patterns hold when defining the indices via PCA rather than as a count index (Table B.6 - 5), and for each element of the respective index (Table B.6 - 6 to Table B.6 - 8). In addition, the point estimates are small with rather precise confidence bounds, so that these results can be interpreted as a null effect. It is hence likely that the intervention increased screening uptake of the message recipient purely via a channel that does not imply an updating of beliefs through new information.

Table 3.1-2 Treatment effect on knowledge outcomes

| | (1) SMS knowledge | (2) SMS knowledge | (3) General disease knowledge | (4) General disease knowledge |
|---|---|---|---|---|
| Treated | -0.0009 | -0.0029 | -0.0365 | -0.0570 |
| | (0.0609) | (0.0610) | (0.0616) | (0.0597) |
| Covariates | No | Yes | No | Yes |
| Observations | 1088 | 1088 | 1042 | 1042 |

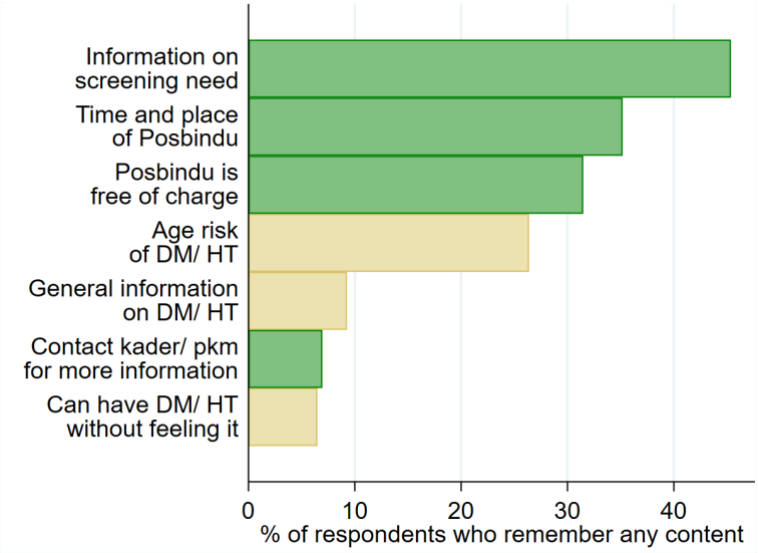
ITT estimates on SMS-related and general disease knowledge indices following equation 1. Both indices are standardized to a sample mean of 0 and a standard deviation of 1. Covariates are age, gender, wealth and phone ownership. Standard errors clustered at the phone-number level in parentheses. $^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.

Figure 3.1-4 displays which information the respondents who report to have received any text message on *Posbindu* are able to recall. We see that these respondents tend to remember the actionable elements of the messages (green), rather than the disease information components (yellow). More precisely, the principal directive that the respondent should be tested for diabetes and hypertension is remembered most frequently – namely by 45% of all respondents, who self-reported being exposed to the treatment. This is followed by logistical components, as 35% and 31% of these respondents remember that the messages contained information on when and where *Posbindu* takes place as well as that it offers free NCD check-ups. We interpret this as evidence for making existing information more salient to the message recipients, as even

in the control group almost all of the 44% of respondents, who knew of the Posbindu program at endline, were aware that it is free of charge and where it takes place.

Similarly, the reported reasons for no screening indicate that our intervention works through increased salience rather than shifts in beliefs: Nearly all respondents who did not attend any screening since the baseline visit reported they did not attend any screening because they were not ill (93%), and only few mentioned time constraints (15%). This pattern is similar to the reasons at baseline and fits the null effect on disease-related knowledge. Hence, more intensive interventions might be needed to alter the beliefs which prevent a large share of the population from regular screening.

Figure 3.1-4: Ability to Recall Text Message Components




*Heterogeneous treatment effects*

We cannot detect any heterogeneous effects across time and risk preferences (Table 3.1-3). In most cases, the standard errors are also too large to retain the original treatment effect. One reason for not detecting any heterogeneous treatment effects might be that these self-reported measures are not strongly correlated with the screening decision in the intervention period. At baseline, we observed a significant correlation between patience and hypertension screening within the last year, but no correlation for willingness to take risk. Another reason might be that the endline sample is too small to detect any heterogeneity.

Table 3.1-3 Analysis of Heterogeneous Effects

| | (1) Screened | (2) Screened | (3) Screened | (4) Screened |
|---|---|---|---|---|
| Treated | 0.055 | 0.082 | 0.090 | 0.118** |
| | (0.051) | (0.051) | (0.057) | (0.057) |
| Willingness to take risk | 0.001 | 0.007 | | |
| | (0.007) | (0.007) | | |
| Treated x Willingness to take risk | 0.001 | -0.004 | | |
| | (0.010) | (0.010) | | |
| Patience | | | 0.005 | 0.008 |
| | | | (0.006) | (0.006) |
| Treated x Patience | | | -0.006 | -0.009 |
| | | | (0.009) | (0.009) |
| Covariates | No | Yes | No | Yes |
| Obs. | 1386 | 1386 | 1386 | 1386 |
| Control group mean | 0.3310 | 0.3310 | 0.3310 | 0.3310 |

Results of regressing the binary screening indicator on the binary treatment indicator, the respective time or risk preference as well as their interaction following equation 4; controlling for message recipient age, gender, wealth, and phone ownership; Standard errors clustered at the phone number in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

*Implications for scale-up*

In the following explorative analyses, we further investigate the scale-up potential and limits to the effectiveness of the intervention. We first focus on what hinders message recipients from reading the messages and hence being exposed to the treatment to shed more light on the potential to reduce the discrepancy between ITT and LATE. Then, we explore differences in

screening experience between the three main facility types to assess the role of accessing a specific screening service. Finally, we provide a cost estimate of this intervention.

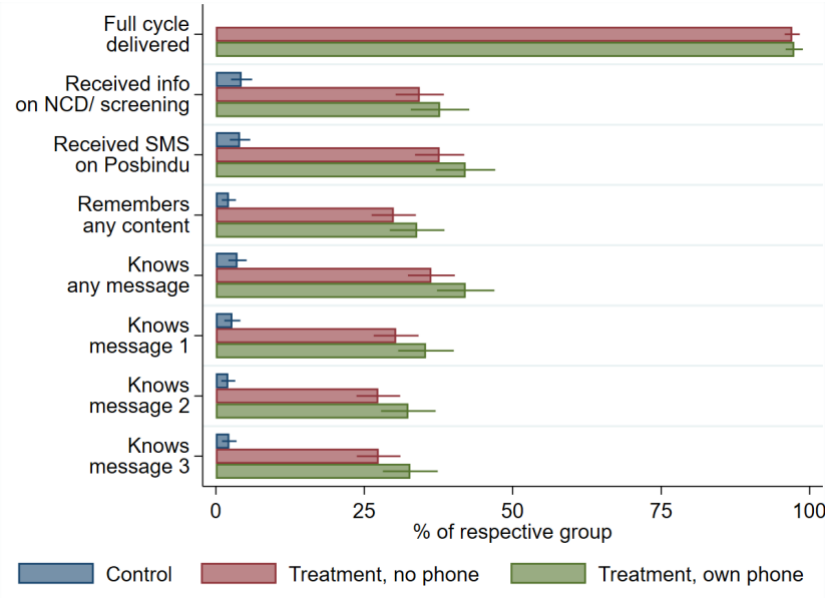
Treatment exposure

For an allocated message recipient to be exposed to the treatment, s/he needs to receive, become aware of, read, understand, and trust the messages. As stated above, message delivery by the provider does not pose a barrier. Rather, being aware or remembering to have received any information on screening appears to be the major barrier (Figure 3.1-5). Phone ownership appears to ease this barrier substantially: While 26% of the treated individuals without a phone remember to have received any information, the share increases to 37% among the treated phone owners. A main issue might be the transfer of the information from the owner to the respondent: 51% of the phone owners who were assigned by the respondents as contact person admitted they transmit messages only sometimes, rarely, or never (response rate: 40%). Once this barrier of becoming aware of the information is overcome, most respondents are able to remember some message content or remember to have received the messages after reading them out. Hence, with an increase in phone ownership over time, the exposure to the intervention can be expected to rise.

We do not find that illiteracy is a binding constraint to reading the messages as only 5% of the sample population reports to be illiterate and 80% face never or only rarely problems when reading Bahasa Indonesia. Alternatively, our messages might be ignored if there is already an overload of information via SMS. We find that around half of the sample receives any text message on a daily basis and on average around four messages per day. Even though this does not seem overly high, phone owners report to receive more messages. We also see that 90% of the respondents who receive SMS in general receive advertisements and 60% would like to receive less advertisement. However, our messages are rather perceived as an official announcement and not an advertisement, thus it is unlikely that our messages are perceived as a burden. This is strengthened by the statement that 68% of respondents, who recall receiving the text messages, report they found the information very relevant to them, and 30% report they found it somewhat relevant. Thus, associating the text messages with the health services might mitigate any information overload.

Taken together, any scale-up needs to consider that even though targeted more broadly, population groups who are more likely to be telephone owners (younger, male and more educated) will be more likely to be exposed to the intervention. See Table B.6 - 13 for a detailed list of socio-demographic and other baseline characteristics by different exposure measures.

Figure 3.1-5: Exposure to Treatment



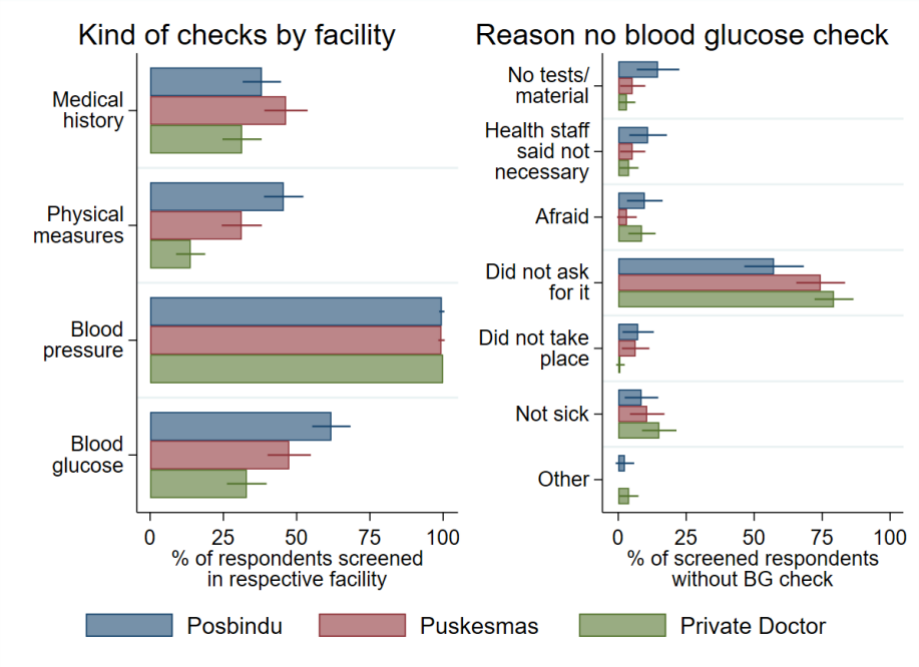

"Full cycle delivered" is based on the provider delivery reports, the remaining indicators are based on the respondent's self report at endline;"Knows any content" indicates whether the respondent could name any message content when asked in an open-ended question (compare Figure 3.1-4); "Knows any message" until "Knows message 3" is based on whether the respondent remembered the respective message when the enumerator read it out.

Screening services across facilities

Increased screening uptake can translate into improved control of the NCD burden the better the screening service. Our treatment effect is driven by respondents screened at the Puskesmas, but their recall of which services and recommendations for future screening were provided to them suggest that currently Posbindu offers the more comprehensive package. As depicted in Figure 3.1-6, nearly all respondents who reported to have undergone a screening report a blood pressure reading. However, which further checks were performed varied across facilities. While 62% of the Posbindu visitors had a blood glucose measurement, this only applies to 47% of the Puskesmas visitors and 33% of the visitors of private practices. In these two facility types, more than two thirds of the visitors who did not get a blood glucose check missed it, because they did not ask for this specifically. This might be caused by different reasons for visiting the respective facility type, but we cannot disentangle this further with our data.

Posbindu visitors were also more likely to report that they were asked to return for blood pressure screening another time, especially compared to visitors of private practices. As our treatment effect is mainly driven by increased use of the Puskesmas services, any potential scale-up might thus consider either increasing awareness towards blood glucose screening to ensure it is actively asked for at the Puskesmas, or stressing the benefits of Posbindu to nudge participants into the more specialized Posbindu.

Figure 3.1-6: Medical checks performed by facilities




Cost estimation

To improve the comparability of our text message reminders with other demand-enhancing interventions, we estimate the costs of our intervention per targeted person and per additionally screened person (Table 3.1-4). In the first column, we consider costs directly related to the intervention, i.e., costs of sending out the text messages and of inquiring the village-specific Posbindu details, assuming that any implementer would be able to target recipients using a register, such as a health insurance database. We base this estimate on the complete treatment group, rather than only the endline sample for a conservative estimate that assumes no treatment effect on the individuals lost to follow-up. In the second column, we additionally provide estimates on the screening costs occurring to the health system in the form of medical staff and material. We assume that a person presenting at a facility would take up 15 minutes of time with a medical practitioner, and price this using wage data from the National Statistical

Office (Badan Pusat Statistik 2021). In addition, we calculate the costs for blood glucose tests with a point-of-care machine, assuming that 47% of the individuals accessing the service are screened for diabetes (as observed in our sample). As every health worker has an own blood pressure monitor, no additional costs are borne for a blood pressure reading. For the scale-up, we assume that Posbindu dates can be transmitted directly to the implementer at a fix cost, such that these costs are not included in the scale-up calculation. On this basis, we estimate that a scale-up would cost IDR 5,277 or USD 0.38 per targeted person, and IDR 129,293 or USD 9.21 per additionally screened person.

Table 3.1-4. Cost estimates

| | Intervention costs | Total costs | Scale-up (per Person) |
|---|---|---|---|
| SMS | 4,651,101 | 4,651,101 | 4,500 |
| Request for Posbindu dates | 1,000,000 | 1,000,000 | |
| Medical staff | | 640,313 | 638 |
| Blood glucose test | | 140,121 | 140 |
| | | | |
| Per targeted person | 5,629 | 6,406 | 5,277 |
| Per additionally screened person | 137,899 | 156,943 | 129,293 |
| Per targeted person (USD) | 0.40 | 0.46 | 0.38 |
| Per additionally screened person (USD) | 9.83 | 11.18 | 9.21 |

All prices denoted in IDR, unless noted differently. Costs are calculated based on the targeted 1,004 respondents of the treatment group after the baseline. SMS costs were EUR 300 and are converted with an exchange rate of 15503.67 IDR/EUR. Costs for medical staff were taken from the National Statistical Office (BPS) as monthly net wages for employees in the health sector with university degree and doubled to receive an upper bound of gross wages to the health system (Badan Pusat Statistik 2021). It was assumed that medical staff would spend about 15 minutes on each examination. It was assumed that point-of-care machines were used for the blood glucose check, as they are used at the Posbindu, such that one test would cost IDR 7,275, including lancet, stick, gloves, and disinfect. Costs for medical staff were calculated for the share of respondents who went to a screening facility due to the intervention (6%) times the share of treatment group respondents who were reached for the endline interview and for whom screening data was non-missing (68%). Costs for blood glucose tests were calculated for the share of respondents who went to a facility due to the intervention (6%) and conducted a blood glucose check (47% of the visitors) times the share of treatment group respondents who were reached for the endline interview and for whom screening data was non-missing (68%). USD were calculated using an exchange rate of 14032.02 IDR/USD. All costs were assessed between November 2019 and February 2020. If the targeted respondents who were not reached for the endline interview or for whom screening data is missing had the same treatment effect as the observed respondents, costs would reduce to USD 6.69 for the intervention costs, USD 8.04 for the total costs, and USD 6.70 for the scale-up costs per additionally screened person.

### 3.1.6. Discussion and Conclusion

Like many other LMICs, Indonesia suffers from a high and increasing burden of diabetes and hypertension. Despite providing opportunities for easily accessible and free screening, uptake remains limited. Diabetes and hypertension screening are specific cases of preventive health behavior that can avoid or postpone complications rather than the disease itself, and are a relatively new component in the Indonesian health system. Thus, it is unclear whether light-touch policy measures proven effective in high-income countries, or for different preventive health behavior work in this context. We conducted an RCT to test whether the uptake of screening programs can be increased with a light-tough text messaging intervention targeted at at-risk individuals.

We find that sending two sets of three text messages before two village-based screening meetings increased screening rates by approximately 6.6 percentage points from 33% in the control group. For participants who received at least one full treatment cycle and remembered any message content, this translates into an increase by approximately 17 percentage points. We do not find a significant difference in the SMS-conveyed or general disease knowledge between treatment and control group. Also, we cannot detect any spillover effects within households, or heterogeneous effects along levels of patience or willingness-to-take-risks.
The intervention appears to work as a reminder rather than conveying new information. Even though our pre-studies revealed gaps in disease knowledge, neither the information that was mentioned in the message nor a larger set of facts and beliefs about diabetes and hypertension changed as a result of the intervention. We find several hints that the intervention might have increased the salience of the decision to take up screening and hence rather works through addressing behavioral barriers related to procrastination or limited attention. First, the elements that respondents remember most from the messages are the general need for screening and its logistics, which were both widely known at baseline already. Secondly, message recipients react more strongly after receiving the second set of text messages and opt to get screened at the Puskesmas rather than the explicitly mentioned Posbindu meeting. Nevertheless, the awareness of a concrete date for screening might have been perceived as a deadline and pushed the recipient to no longer postpone asking for a preventive check-up at the Puskesmas at their convenience.

Possibly, the personalization of the text messages was effective in increasing the relevance for the recipients but did not give them the notion to share this information, such that no spillovers

occurred within households. Alternatively, spillovers might exist but be too small to be detectable in our sample. Similarly, we cannot detect heterogeneous treatment effects based on risk or time preferences. One reason might be the lack of a meaningful update of beliefs on disease risk and treatment efficacy. On the other hand, the countervailing forces of the lotteries of becoming ill and being effectively treated might cancel out any heterogeneous effects. For patience, however, we would have expected that the reminder channel alone would impact respondents with different degrees of patience differently.

The size of our treatment effect is comparable to other SMS interventions on preventive behavior in LMICs: With a risk ratio of 1.174, our findings lie between the results from the systematic reviews on immunization rates by Mekkonen et al. (2019) (RR: 1.11) and Jacobson Vann et al. (2018) (RR: 1.29). With an odds ratio of 1.284, the effect size is slightly lower than the average effect size of studies on STD detection as reported by Taylor et al. (2019) (OR: 1.73). Thus, even though the uptake of immunization or STD screening might underlie very different barriers compared to hypertension or diabetes screening, the impact of text messages can be similar. In addition to finding increased screening attendance after adding SMS reminders to routine invitations in the UK, Sallis et al. (2019) found that adding the prompt to screen in a specific month increased the effectiveness, suggesting that mentioning a concrete deadline might counteract procrastination in this high-income setting. Similar to our results on knowledge transmission, recent evidence on broadcasting SMS to increase COIVD-19 preventive behavior found changes in behavior despite no updates in knowledge (A. Banerjee et al. 2020).

An advantage of text message interventions is their comparatively low cost. We estimate that our intervention costs USD 11.18 per additionally screened person, incorporating the costs of the screening service. A scale-up might decrease these costs even further, especially if screening dates can be centrally collected. Thus, such interventions can be used to reach out to wide parts of the population, such as the population over the age of 40. For people at higher risk due to preconditions, more intensive interventions might be a good addition to push screening rates even more, albeit at higher costs: Using personally delivered invitation letters and pharmacy voucher, de Walque et al. (2020) measure an increase in screening rates by even 15 to 30 percentage points at about 60 USD per screened person. Hence, combining large-scale light-tough interventions as ours with intensive interventions in more selected higher risk groups might be a route to reach the population while keeping the costs balanced.

We conclude that our intervention is cost-effective and has the potential to be scaled up in the Indonesian setting, keeping in mind the limitations that are inherent to SMS interventions. First, being targeted and exposed to the intervention highly depends on owning and regularly using a mobile phone. This implies people who are more likely to own a phone, such as younger, male and more educated individuals are more likely to be reached, and not necessarily the most vulnerable. As mobile phone ownership, network coverage as well as familiarity in usage increases, so does the potential to reach a broader set of the population. As of now, we do not see evidence that our messages induced an overflow of information, but during implementation this needs to be monitored closely and implementers need to bear in mind to target carefully and keep messages to the necessary minimum. Secondly, who is reached by the intervention strongly depends on how the target population is sampled. At scale-up, collecting numbers by visiting households is likely not feasible and would increase the costs substantially. At the same time, previous literature established that personalization matters, such that mere broadcasting might not be advisable. Instead, drawing numbers from an existing register would be ideal. With the expansion of public health insurance in many middle-income countries, health insurances might be suitable implementers. In Indonesia, for example, the recently established, centrally administered health insurance JKN covers the majority of the Indonesian population and could likely target its members based on age and potentially even previous diagnosis.

This study comes with some limitations regarding the recruitment of participants and the telephonic endline data collection. Apart from being unfeasible for scale-up, we cannot rule out that our in-person baseline survey already worked as a reminder to take up screening 2-3 months prior to the intervention. Both treatment and control group saw higher propensities to be screened from January onwards, so that the high control group uptake might in part be driven by our baseline visit. However, we can still detect a systematic difference between treatment and control group, especially as time to the baseline interview increased. Secondly, measuring the main outcome as self-report is subject to the concern of misreporting and social desirability. To minimize this concern, we added detailed follow-up questions on what happened at the screening visit and the consistency of the answers gives us confidence in the main result. Similarly, part of the reason that we do not find an update of beliefs could be that many knowledge questions were posed in a strict way, like asking for the risk factors in an unaided recall question. It might be that more nuanced updates of beliefs happened, but these are unlikely to explain the main treatment effect.

Switching the endline data collection to the telephone was the only possibility after the outbreak of the COVID-19 pandemic, but poses additional limitations. First, we could only re-interview 70% of the sample, with significant attrition across several socioeconomic characteristics. Though we do not expect that the attrition was selective due to factors other than the mode of contact, the true size of the treatment effect might be slightly different when taking the full initial sample into account. To the extent that phone ownership is correlated with both, a higher rate of recall receiving the message and a lower probability to be lost to follow-up, it is likely that our treatment effect would be slightly smaller in this case. Secondly, respondents may be less trusting over a telephone call in comparison to face to face interviews conducted in the privacy of their own home. As our study team visited the respondents during baseline, we think this problem might be less severe compared to phone surveys when the call is the first point of contact. To minimize this concern further, we assigned the enumerator who visited the respondent at baseline whenever possible and re-introduced our team and the survey in the beginning of the interview.

Our study opens several areas of complementing research. First, a scale-up study without baseline contact would be needed to validate the effectiveness of our study. Fielding the intervention in a larger sample would also offer the opportunity to test for the discussed mechanisms and heterogeneities more clearly. A second important extension would be to include longer-term outcomes such as regular or repeated screening. Beyond the intervention itself, our results showed that substantial misconceptions on who should be screened and when prevail despite including this information in the messages, calling for designing and testing more intensive interventions to address this gap.

With the expansion of mobile phone coverage around the globe, policy makers gain access to a new toolbox of low-cost and light-tough interventions at scale. We show that text messages can induce preventive health behavior and reduce the screening gap for fairly new, yet severe contributors to the health burden of middle-income countries. As universal health coverage expands and is digitized, such text messages can become cost-effective and easily customizable measures to remind a target population of preventive health behavior and stimulate new health care habits.

## 3.2. Essay 4:

### The Effect of Survey-Based Referral Letters for Hypertension on Care and Health Outcomes in South Africa

Joint work with:
Carlos Riumallo Herl PhD

### 3.2.1. Abstract

Like many other LMICs, South Africa suffers from a high burden of hypertension with large shares of the affected populations never receiving blood pressure (BP) screenings or diagnoses. Referral letters issued for high BP measurements taken during survey collection has the potential to increase hypertension screening directly through research itself. We assess the effectiveness of a such referral letters on care and health outcomes as well as to identify whether physical and mental health act as determining factors in the impact of the intervention. We do so, using a regression discontinuity design on pooled NIDS and HAALSI survey data from 2008 to 2019. We find that survey-based referral letters for high blood pressure have little effect on care and health outcomes in this sample, but that differential effects may occur depending on the physical and mental health of the recipients. More specifically, we found worse self-rated health to be associated with better care and BP outcomes, and that these effects are alleviated when individuals with better self-rated health receive the intervention. Additionally, we find that referral letters lead to worse health outcomes in respondents with depressive symptoms.

### 3.2.2. Introduction

Globally, South Africa has one of the highest prevalences of hypertension – a leading risk factor for morbidity and mortality from cardiovascular disease (CVD) ("GBD Compare | IHME Viz Hub" n.d.; Ware et al. 2019). With over 40% of the adult population having high blood pressure (BP), the annual economic costs associated with this condition were estimated to be US$2.79 billion in 2020 – representing approximately 0.76% of South Africa's GDP (Kohli-Lynch et al. 2022). One determinant of the high economic and health burden is suboptimal care: studies show that only about half of all South Africans with hypertension have ever been screened and less than 10% had BP under control (Berry et al. 2017; Geldsetzer et al. 2019).

While several studies propose strategies to scale up hypertension care in South Africa (Basu et al. 2019; Gaziano et al. 2014), one potential additional small-scale channel of increasing hypertension care presents itself through research itself: due to cheap and easy screening technology, many population-based health surveys now include BP measurements in their data collection. This allows for the issuing of referral letters to respondents at risk of having hypertension, urging them to seek formal hypertension screening whenever survey measurements yield high BP readings. Several studies have set out to assess the impact of survey-based referral letters for high BP on care and health outcomes. These studies are often similar in their identification strategy and the outcome variables under inspection, however they vary substantially in the context, sample population, and identified effect sizes. While some attention has been devoted to assessing heterogeneities across sociodemographic characteristics in the effect sizes, evidence on the determinants of successful referral uptake and potential channels underlying varying effect sizes has been sparse. In this study, we complement the existing literature by estimating the effect that referral letters have in a sample of 8,247 South African survey respondents and add to it by exploring physical and mental health as individual-level determinants for the impact of these letters.

We estimate the causal effects of referrals letters using a regression discontinuity design, which exploits the deterministic referral rule based on whether individuals fall above or below established thresholds in their systolic and diastolic blood pressure (SBP and DBP) measurements. We pool survey data from two longitudinal data sources on South African adults aged 40 or older from 2008 to 2019, namely from the "Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa" (HAALSI) project and from

the nationally-representative National Income Dynamics Study (NIDS). We estimate the effect of a referral letter issued at baseline for high SBP and high DBP separately on the outcomes of i) awareness of diagnosis, ii) being currently under treatment, iii) and being hypertensive at follow-up; as well as on the change in iv) SBP and v) DBP between baseline and follow-up. Additionally, we aim to identify whether physical and mental health act as determining factors in the impact of the intervention. We do so by estimating RD specifications using covariate adjustment, which include self-rated health as a proxy for both physical and mental health as well as depressive symptomology as one specific dimension of mental health.

We do not find a significant effect of referral letters on the awareness of diagnosis, treatment, and most blood pressure outcomes after two to four years. Receiving a letter for high SBP significantly and robustly affects the change in DBP between baseline and endline, however the effect is of small magnitude and no impact on hypertension rates at follow-up can be identified. Furthermore, in our analysis of physical and mental health, we find that self-rated health and depressive symptomology are significantly associated with care and BP outcomes. While worse self-rated health is generally associated with better care and BP outcomes, this relationship is attenuated when individuals with better self-rated health receive the treatment. We further provide descriptive evidence suggesting that this may be due to individuals seeking care according to their actual health status and that respondents with better self-rated health update their beliefs when presented with contrasting personalized risk information in the form of the letter. Additionally, we find that referral letters lead to worse health outcomes in respondents with depressive symptoms – potentially reinforcing negative sentiments on self-efficacy and a sense of hopelessness.

The remainder of the paper is structured as follows: we first present an overview of the empirical literature on referral letters as well as of a theoretical model explaining screening uptake. Next, we describe the study methods by presenting the underlying data, how the intervention was conducted, how our outcomes are defined and measured, describe the identification strategy, statistical analysis, and details on the regression analysis incorporating physical and mental health. In the next chapter, we present our results – first describing sample characteristics and the validity of our identification strategy; secondly by describing our main results; and third by displaying the channel analysis. We conclude with a discussion of results, our study limitations, and an outlook for further research.

### 3.2.3. Literature

In related literature, several empirical studies assess the impact of survey-based referral letters for high BP on care and health outcomes using regression discontinuity design. Upper-bound effect sizes of referral letters for high blood pressure were found in a study by Ciancio et al. (2021), who examined adults aged 45 and older with very high blood pressure ranges in rural Malawi.[15] The authors found referral letters significantly decrease average SBP by 13 mmHg and average DBP by 6 mmHg; it increased the likelihood of being hypertensive after 4 years by 20 p.p., and the likelihood of being aware of their hypertension diagnosis by 24 p.p. Chen et al. (2019) examined the effect of referral letters issued by the Chinese Longitudinal Healthy Longevity Survey (CLHLS) from 2011-14 on blood pressure and behavioral risk factors in the follow-up survey in a sample of adults aged 65 and older, who were previously undiagnosed with hypertension. They found a significant decrease in SBP of 6.3 mmHg, but no significant effects on DBP and lifestyle changes after 2 to 3 years. A study on the China Health and Nutrition Survey (CHNS) from 1997 to 2006 found referral letters significantly increase the likelihood of being awareness of one's hypertension diagnosis after 4 years by 2.5 to 4.7 p.p. (Dai et al. 2022). Lastly, Sudharsanan et al. (2020) examine the effect of referral letters in South Africa on adults, aged 30+ and disaggregated by sex, after 2 years using NIDS data. They find no significant effects on the change in SBP between waves for neither men nor women, no significant effects on the change in DBP for men, but a significant decrease in change of DBP over waves of 4.7 mmHg for women.

In our channel analysis, we draw on the work by Picone et al. (2004b) to identify potential channels through which the impact of referral letters may become more or less pronounced. Picone et al. developed a simple two-period model explaining the decision to undergo medical screening leading to early treatment. In this model, an individual derives utility only from their level of health, which depends on the probability of being healthy, the levels of health in the healthy and sick states, the probability of successful treatment in the sick state, the costs of treatment in the sick state, and the costs of screening in both the sick and the healthy state. Based on this, the authors formulate the several predictions. First, higher perceived risk of illness will increase the probability of undergoing screening. Secondly, higher effectiveness of

[15] Respondents were issued a letter, if at least one SBP measurement was above 160 mmHg, or at least one DBP measurement above 110 mmHg (Ciancio et al. 2021).

early detection and treatment will increase the probability of undergoing screening. Factors such as higher costs of treatment or screening decrease screening demand.

Based on these theoretical perspectives and with respect to our setting, referral letters may act through several pathways. First, receiving blood pressure readings and a recommendation to see a health care professional can be seen as a type of personalized risk information intervention that aims at altering perceived risk levels in respondents. Secondly, referral letters may increase the salience of the importance of hypertension screenings and work through an attention and reminder effect for the individual. Additionally, the impact of referral letters is dependent on the perceived benefits of early detection and treatment, as individuals may not follow up on the letters, if they do not expect to receive adequate care for this.

### 3.2.4. Method

*Data*

We pool data from the "Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa" (HAALSI) project and the National Income Dynamics Study (NIDS). HAALSI is an ongoing community-based panel study examining a wide range of biological, social, and economic conditions that shape health in the aging population of South Africa. HAALSI covers a random sample of 5,059 individuals aged 40 years and older from the Agincourt Health and Demographic Surveillance System run by the MRC/Wits Agincourt Research Unit. The average interview time was two hours. Detailed information on the sampling procedure and survey activities can be found in Gómez-Olivé et al. (2018). This study draws on in-person interviews collected at baseline in 2014 and during Wave 2 in 2018-2019, as well as single items taken from a telephone midline survey in 2020.

NIDS is a nationally-representative panel study from 2008-2017 examining the livelihoods of approximately 28,000 individuals from 7,300 households over time. The survey collects information on social, economic, demographic and health indicators, and further includes physical measurements such as blood pressure. On average, an interview lasted approximately half an hour. Detailed information on the sampling procedure and survey activities can be found in Sudharsanan et al. (2020). While in NIDS multiple survey wave pairs are available per

respondent, we define the baseline survey as only the first interview of a respondent.[16] Accordingly, we define the follow-up survey as the interview occurring two years, i.e. one wave, after the baseline interview. We do so as we believe this will lower a potential selection bias, given that respondents may receive referral letters in multiple survey waves and that the receipt of a letter in wave *t* may be conditional on having received a letter in wave *t-1*. Furthermore, this will enhance consistency in pooling data with HAALSI, as respondents in each survey will have received the treatment only once.

*Intervention*

The intervention under examination is a survey-based referral letter issued after blood pressure readings. In NIDS, blood pressure was measured by a trained fieldworker two times using Omron digital blood pressure monitor. If either reading included a DBP reading of 90 mmHg or more or an SBP reading of 140 mmHg or more, the fieldworker issued a referral letter. The letter specified i) height, waist, and weight measures, ii) the blood pressure readings, and iii) a brief description of high blood pressure, its risk for illness, the possibility of controlling it, and an indication of how soon the respondent should seek care for it. The letter can be found in Appendix C.3.1.

In HAALSI, blood pressure was measured three times with 2 minutes between each reading using an Omron automated cuff by a trained fieldworker (Gómez-Olivé et al. 2018). A respondent was issued a referral letter, if either the second or the third reading included a diastolic blood pressure level that was higher than 90 mmHg or a systolic blood pressure level that was higher than 140 mmHg. The referral letter included survey information and a checkbox indicating that the respondent may have a problem with their blood pressure. All respondents additionally received a letter specifying the results of all physical and biomarker measurements. The letters can be found in Appendix C.3.2.

[16] This is in contrast to of Sudharsanan et al. (2020), who utilize all available survey wave pairs per individual in their RD estimations on same data source. This, as well as a focus on effects disaggregated by sex distinguish their analysis from our RD specification using only NIDS data.

*Outcomes*

We examine the effect of referral letters on four main care and blood pressure outcomes measured between two and four years after baseline. Using self-reported data on health services received, we define *Diagnosis* as being aware of ever having been told of high BP by a health professional and *Treatment* as currently being on treatment for high BP. Using physical measurements, we define *Change in average DBP* and *Change in average SBP* as the change in average blood pressure between follow-up and baseline survey – with negative values indicating that blood pressure improved over time. In HAALSI, the average was defined based on the last two out of three BP measures and in NIDS, the average of two out of two BP measures. In both surveys, if one BP measure is missing, we define the average as the non-missing measurement. In an additional analysis, we further analyze having died by follow-up as an outcome and, using HAALSI data only, define the additional outcome *Screening* as being aware of ever having undergone a BP measurement by a health professional. The exact phrasing of each survey question can be found in Appendix C.2.

*Identification*

We employ a sharp regression discontinuity design, which exploits the deterministic referral rule based on whether individuals fall above or below the described thresholds along a continuous BP distribution. In this set-up, observations around the threshold are assumed to be comparable in observable and unobservable characteristics, the only exception being that respondents above the threshold receive a referral letter. This comparability is particularly credible for two reasons: While clinical guidelines specify an exact threshold in the classification of hypertension (WHO 2020a), the pathophysiological relationship between BP and other health indicators does not underlie such a discontinuous jump at the cutoff (Lewington et al. 2002). Additionally, BP readings encompass a degree of randomness stemming from both potential measurement errors and individual-level variations in BP throughout the day (Kallioinen et al. 2017). Therefore, by considering the respondents around the threshold as treatment and control group causal effects can be estimated.

The validity of these effects depends on the assumption that the expected potential outcomes in the absence of the referral letter change smoothly as a function of the forcing variable BP through the threshold (Cunningham n.d.). In this setting, this assumption could be violated, if, for instance, the fieldworker manipulated the blood pressure readings by rounding their

recordings. We test for this scenario by examining the density of the forcing variable around the cutoff following McCrary (2008) and Cattaneo et al. (2018). Furthermore, we run placebo regressions on a range of pre-treatment negative control variables, in order to assess whether discontinuous jumps occur around the cutoff – in which case the main assumption may be violated (Cunningham n.d.). Additionally, the treatment effect could be biased, if fewer or more referral letters were issued than called for by the BP recordings. This could have been the case, if, for instance, the enumerator forgot to hand out the letter to respondents with BP measures above the cutoff. Yet while the enumerators were prompted by the interview recording devices to hand out the referral letter, we are unable to draw from monitoring of whether letters were indeed issued. Therefore, our results must be considered as intention-to-treat estimates, as was done in related literature (Sudharsanan et al. 2020).

*Statistical Analysis*

Main outcomes

Following the literature, we run two separate sets of specifications – either using SBP as the forcing variable, in which case we exclude observations that cross the DBP threshold; or using DBP and excluding observations crossing the SBP threshold (Dai et al. 2022). We define our forcing variables for both DBP and SBP as the maximum of the two readings triggering the referral rule. Furthermore, we center the forcing variable around zero – considering that NIDS refers anybody with BP higher than or equal to140/90 mmHg, while HAALSI refers anybody with a BP higher than 140/90 mmHg.

To assess the impact of referral letters on care and health outcomes, we estimate the following equation:

$$y_i = \alpha_i + \beta_1 Referral_i + \beta_2\, BP_i + \beta_3\, Referral_i * BP_i + \gamma_s + \varepsilon_i$$

where $y_i$ is the respondent's outcome variable (*Screening, Diagnosis, Treatment, Average SBP, Average DBP*); $Referral_i$ is an indicator for receiving a referral letter; $BP_i$ is the forcing variable (SBP or DBP); the interaction term between $Referral_i$ and $BP_i$ is the RD estimand; $\gamma_s$ is a survey fixed effect; and $\varepsilon_i$ are robust standard errors.

We run the specified estimation on respondents falling into bandwidths around the threshold, which are determined using data-driven Mean Squared Error (MSE) optimal bandwidth

selection following related literature. Furthermore, we estimate effect sizes using local linear regression with triangular weights, in order to give greater weight to the observations closer to the cutoff. In sensitivity analyses, we further alter bandwidth size from 60% to 140% of the original MSE bandwidth selection and run the specifications using uniform weights.

Mental and Physical Health

In addition to analyzing the impact of referral letters on care and BP outcomes, we further explore mental and physical health as potential drivers of results by applying covariate adjustments to the RD estimations. We capture the effects of mental and physical health using two indicators: i) self-rated health as a proxy for both physical and mental health, and ii) depressive symptomology, as one specific dimension of mental health. Using these, we run two sets of regression specifications. In the first, we include self-rated health and its interaction term with the treatment in the regression estimation on all described outcomes. In the second, we additionally include depressive symptomology and its interaction term with the treatment.

Self-rated health itself was measured with the question "In general, how would you rate your health today?" using a 5-point Likert scale from "very bad" to "very good" in HAALSI (see Appendix C.2.2). In NIDS, self-rated health was measured with the question "How would you describe your health at present? Would you say it is excellent, very good, good, fair, or poor?" using a 5-point Likert scale as describe in the question (see Appendix C.2.1). We combine these measures into a self-rated health dummy variable, with 1 indicating "good to excellent" health and 0 indicating "very bad to moderate / fair" health.

Depressive symptomology is measured using CESD scales. In HAALSI, depressive symptomology was measured using the CESD-8 scale. We define individuals with a score of 3 or higher as having depressive symptoms (Lewinsohn et al. 1997; Radloff 1977; Jennings, Ralston, and Schatz 2020). In NIDS, depressive symptomology was measured using the CESD-10 scale, in which case we use a score of 10 as the cutoff (Andresen et al. 1994).

Following the theoretical assumptions of care seeking behavior put forward by Picone et al. (2004b), we formulate several hypotheses on the effect of mental and physical health measures:

*H 1.1: Care seeking behavior and thereby downstream BP outcomes differ with respect to self-rated health.*

Self-rated health may capture effects of the perceived risk for presenting with hypertension and thus shape care seeking behavior. Several studies have shown that respondents may not feel the necessity of undergoing hypertension screening if they do not feel ill (Risso-Gill et al. 2015; Gong et al. 2020; M. Marcus et al. 2022). In this case, we would except better self-rated health may be associated with a lower perceived risk for presenting with hypertension, thereby lower care seeking behavior and worse downstream BP outcomes.

Alternatively, self-rated health may capture effects of the perceived benefit of screening, as the amount and type of past experiences with the health system may shape the respondent's perception of their own health. These experiences may shape expectations on how likely it is that one will receive a diagnosis and treatment for hypertension and thus the benefit of seeking care. In this case, the direction of the association between self-rated health and the outcomes is unclear and depends on whether better self-rated health is associated with better or worse experiences with the health system.

*H 1.2: In treated individuals, better self-rated health increases care seeking behavior and thereby downstream BP outcomes.*

Referral letters may alter perceived risk for presenting with hypertension differently depending on self-rated health. When individuals with better self-rated health receive a referral letter that contrasts their positive self-rated health, they may update their beliefs, increasing their perceived risk of presenting with hypertension. In this case, we would expect the treatment to increase care seeking behavior and thereby better downstream BP outcomes in individuals with better self-rated health.

*H 2.1: Depressive symptomology decreases care seeking behavior and thereby downstream BP outcomes.*

Depressive symptomology may relate to the perceived benefits of screening and treatment and thus be associated with care seeking behavior. Studies have shown that individuals with higher depressive symptom burden may not seek health screening due to low self-efficacy, a sense of helplessness and hopelessness, or self-neglect (Mirowsky and Ross 1990; Mancuso et al. 2001; Tillema, Cervone, and Scott 2001; Abrams et al. 2002; Pirraglia et al. 2004). In this case, we would expect depressive symptomology to be associated with a lower perceived benefit of

screening and treatment, thereby lower care seeking behavior and worse downstream BP outcomes.

*H 2.2: Care seeking behavior and thereby downstream BP outcomes differ with respect to the interaction of treatment and depressive symptomology.*

Referral letters may reinforce negative sentiments of hopelessness or low self-efficacy in respondents with depressive symptomology. On the one hand, this could further decrease perceived benefit of screening and treatment, leading to lower care seeking behavior and thereby worse downstream BP outcomes in individuals with depressive symptomology. On the other hand, this could further increase perceived risk of presenting with hypertension, in which case we would expect higher care seeking behavior and thereby better downstream BP outcomes. Therefore, the overall effect of referral letters in respondents with depressive symptomology is unclear.

Descriptive analysis

In order to further disentangle how self-rated health and depressive symptomology affect outcomes, we conduct several descriptive analyses. First, we examine whether self-rated health is associated with confirmed physical health conditions. For this, we make use of biomarker measurements for diabetes, dyslipidemia, and anemia undertaken during HAALSI baseline data collection (for more details on biomarker collection see Gómez-Olivé et al. (2018)). Secondly, we examine the association between self-rated health and the history of diagnosed TB and CVD conditions prior to the survey in both HAALSI and NIDS. We define history of diagnosed TB and CVD as being aware of having received at least one diagnosis for diabetes, dyslipidemia, heart problems, stroke, tuberculosis, or asthma. Third, we examine the association between self-rated health and the share of undiagnosed diabetes in HAALSI, in order to assess whether history of diagnosed CVD is driven by the presence of health conditions or the likelihood of health conditions being detected. We define undiagnosed diabetes by combining information on the biomarker measures of blood glucose, yielding a survey-based diagnosis of diabetes, with self-reported diagnosis of diabetes prior to the survey. Fourth, we examine how depressive symptomology associates with self-rated health in order to assess whether it captures mental health dimensions next to physical health dimensions. Fifth, in order to otherwise proxy connectedness to the health system, we examine the association between self-rated health and distance to the nearest clinic in HAALSI. Lastly, we assess whether self-

rated health is associated with levels of satisfaction and trust with the health system in HAALSI. Satisfaction was measured by asking respondents to rate the satisfaction with the South African healthcare system on a scale from very unsatisfied to very satisfied. Trust was measured using a Likert scale from strongly agree to strongly disagree on the statement "In general, one can trust healthcare providers". In order to assess social desirability bias, we benchmark trust and satisfaction against the question on whether in general, one can trust people.

### 3.2.5. Results

*Sample Characteristics*

The pooled sample contains 8,247 observations, 62% of which are female (see Table 3.2-1). Two thirds of NIDS and 56% of HAALSI sample respondents are female. The mean age is 57 in the pooled sample, with respondents from HAALSI being older on average. In the pooled sample, 34% have no formal education, 37% in NIDS, and 44% in HAALSI – while around 10% have secondary education or more. Mean SBP is 137 to 138 mmHg and mean DBP is 82 to 87 mmHg. About one third of individuals have been diagnosed with hypertension and one fourth are currently under treatment in the pooled sample. In HAALSI, 42% and 29% of respondents have been diagnosed and treated.

Table 3.2-1: Sample Characteristics

| | **Pooled** | | **NIDS** | | **HAALSI** | |
|---|---|---|---|---|---|---|
| | N | Mean | N | Mean | N | Mean |
| Female | 8,247 | 62 | 4,974 | 66 | 3,273 | 56 |
| Age | 8,247 | 57 | 4,974 | 55 | 3,273 | 62 |
| Education | | | | | | |
| None | 8,247 | 34 | 4,974 | 28 | 3,273 | 44 |
| Some primary (1-7 years) | 8,247 | 37 | 4,974 | 37 | 3,273 | 36 |
| Some secondary (8-11 years) | 8,247 | 20 | 4,974 | 25 | 3,273 | 12 |
| Secondary or more (12+ years) | 8,247 | 10 | 4,974 | 10 | 3,273 | 9 |
| Mean SBP | 8,247 | 137 | 4,974 | 137 | 3,273 | 138 |
| Mean DBP | 8,242 | 85 | 4,969 | 87 | 3,273 | 82 |
| Diagnosed | 8,247 | 32 | 4,974 | 26 | 3,273 | 42 |
| Treated | 8,247 | 25 | 4,974 | 22 | 3,273 | 29 |

*Manipulation, Balance, and Power*

In the pooled sample and at the survey level, we find no evidence for manipulation in the distribution of average SBP and DBP around the cutoff at baseline (see Appendix Figure C.1.1 - 1). Further, we find no significant differences in age, sex, education, and awareness diagnosis and treatment rates for high blood pressure in respondents above and below the cutoff, suggesting balance of key observable pre-treatment negative controls in the pooled sample and in the HAALSI sample (see Appendix Table C.1.2 - 1 to Table C.1.2 - 4). In NIDS, we find no significant difference for age, education, and diagnosis rates (see Appendix Table C.1.2 - 5 and Table C.1.2 - 6). We do find a lower likelihood of being female at the 10% level amongst respondents receiving a referral letter in the bias-corrected estimates, but not in the conventional or robust bias-corrected estimates. Power analyses on the pooled sample can be found in Appendix C.1.3. The RD estimations on awareness of diagnosis are powered to detect upper bound effect sizes, but underpowered for detecting lower bound effect sizes found in the literature.[17] The power estimations for the outcome *treatment* yielded in about 80% for 13 percentage points, which is one third of the standard deviation of the outcome in the control group. Benchmark effect sizes from other studies could not be identified for this outcome. Compared to effect sizes in the literature, our RD estimations specifying change in blood pressure over the waves as outcomes are well powered for medium to upper bound effect sizes, but underpowered for lower bound effect sizes.[18]

*Main Results*

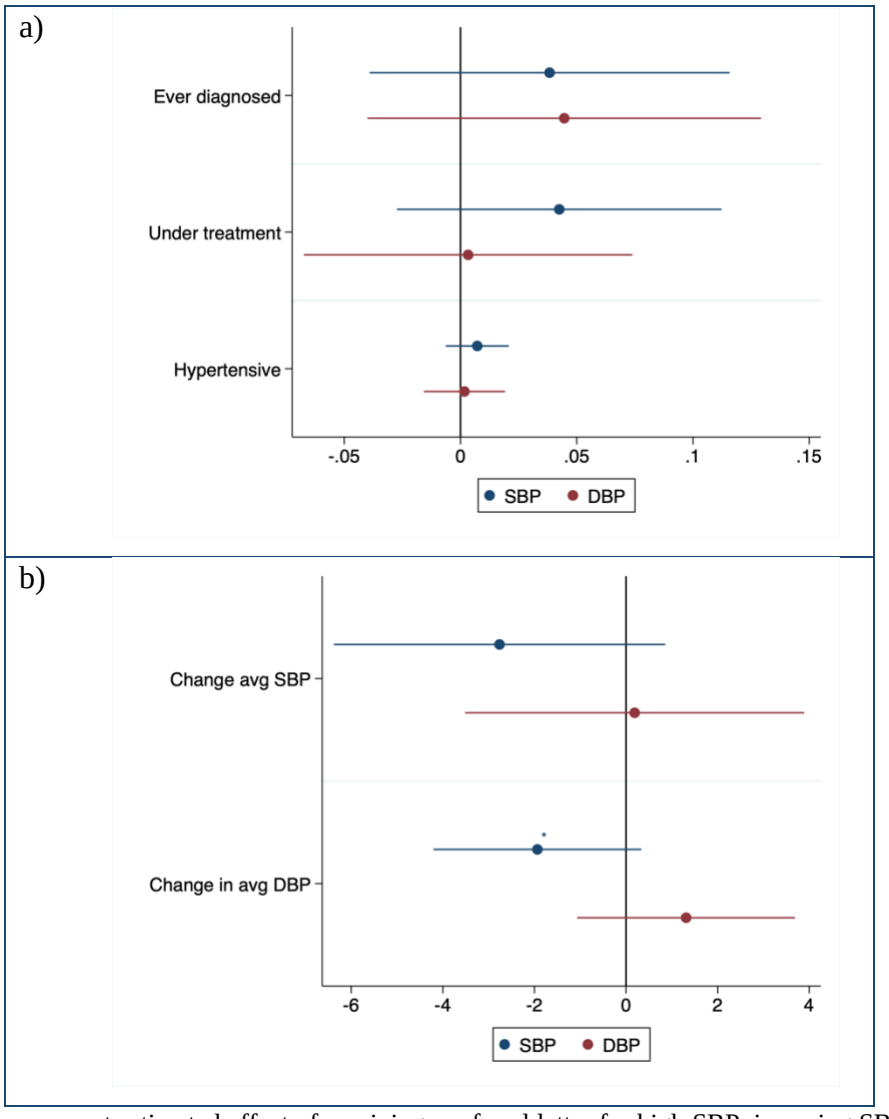
In our main regressions analysis, we find no significant treatment effect of receiving a referral letter for either high SBP or high DBP on having received a diagnosis or treatment for high blood pressure in the pooled sample 4 years later (see Figure 3.2-1, Appendix Table C.1.4 - 1, and Table C.1.4 - 2). Furthermore, while receiving a letter for high SBP does not significantly affect the change in SBP between baseline and follow-up, it was found to reduce the change in DBP by 1.94 mmHg at the 10% significance level. This significance is robust to the bias-

[17] Ciancio et al. (2021) found that in a sample of adults aged 45+ with very high blood pressure (over 160 mmHg SBP) in rural Malawi referral letters significantly increase the probability of being diagnosed after 4 years by 24 p.p. Dai et al. (2022) found that in a sample of adults aged 18+ in China referral letters significantly increased the probability of being aware of being diagnosed with hypertension by 4.7 p.p.

[18] Sudharsanan et al. (2020) find a 4.7 mmHg reduction of SBP change over 2 year time periods in South African women aged 30+ using multiple surveys waves per individual from the NIDS data. Chen et al. (2019) find a 6.3 mmHg reduction in mean SBP about 2 years later in Chinese adults aged 65+. Ciancio et al. (2021) found a 13 mmHg reduction in mean SBP and a 5.5 mmHg reduction in mean DBP 4 years later in rural Malawian adults with very high blood pressure and aged 45+.

corrected and robust bias-corrected RD specification, to using a uniform kernel function, as well as to altering the bandwidth by 20% increments around the original bandwidth size (see Appendix Table C.1.4 - 1 to Table C.1.4 - 5). At the survey level, we find that receiving a referral letter for high SBP or high DBP has no significant effect on the specified outcomes (see Appendix Table C.1.4 - 6 to Table C.1.4 - 9). Furthermore, we find a significant increase (at the 10% significance level) in the likelihood of being aware of ever having undergone a BP measurement by a health professional in the HAALSI sample when using DBP as a forcing variable, but not when using SBP as a forcing variable (see Appendix Table C.1.4 - 10). We find no effect on the likelihood of dying before follow-up (see Appendix Table C.1.4 - 11).

Figure 3.2-1: RD estimates of the effect of a referral letter in the pooled sample




Note: Blue dots represent estimated effect of receiving a referral letter for high SBP, i.e. using SBP as a forcing variable. Red dots represent estimated effect of receiving a referral letter for high DBP, i.e. using DBP as a forcing variable. Horizontal lines display 95% confidence intervals; stars denote significance with *** p<0.01, ** p<0.05, * p<0.1. All estimates are calculated using local linear regression with triangular weights and a survey fixed effect on respondents falling into Mean Squared Error (MSE) optimal bandwidths (see Appendix for table form).

*Physical and Mental Health*

Regression Analysis with Covariate Adjustment for Self-Rated Health

In the regression analysis with covariate adjustment for self-rated health, we find no effect of having received a referral letter for high SBP on care outcomes, i.e. awareness of diagnosis or being under treatment during follow-up, or the change in average SBP between baseline and follow-up (see Table 3.2-2, columns 1 - 5). However, we find that the letter for high SBP significantly decreases the change in DBP by 3.19 mmHg, i.e. resulting in better blood pressure during follow-up rates among treated individuals. Further, we find self-rated health to be significantly associated with care outcomes, but not blood pressure outcomes. Good to excellent self-rated health was found to be associated with a significantly lower likelihood of diagnosis and treatment of 17 p.p. and 14 p.p. respectively (at 1% significance level). The interaction term with treatment showed no significant effect on any outcome.

The regression specifications on the effect of referral letters issued for high SBP explain between less than 1% and 7% of the variability of the response data around the mean. The bandwidth sizes vary between 11.92 mmHg and 20.45 mmHg, yielding a sample with mean age of 59 to 60 years (Table 3.2-2, columns 1 – 5). Furthermore, the described patterns are robust to changing bandwidth from 60% to 140% of their original size (see appendix Table C.1.4 - 12).

When examining the impact of receiving a referral letter for high DBP using covariate adjustment for self-rated health, we again find no effect on care outcomes – i.e. awareness of diagnosis or being under treatment during follow-up, or the change in average SBP between baseline and follow-up (see Table 3.2-2, columns 6 - 9). Further, we find that better self-rated health is significantly and negatively associated with care outcomes in similar magnitude as in columns 1 and 2: good to excellent self-rated health is significantly associated with a lower likelihood of diagnosis and treatment of 15 p.p. and 12 p.p. respectively. The negative association between better self-rated health and diagnosis appears to be alleviated, but not overcompensated by the treatment: when individuals with better self-rated health receive a referral letter for high DBP, they are 9 p.p. more likely to report being aware of a diagnosis for hypertension at a 10% significance level. We see the association between self-rated health and both care outcomes to be robust to changing bandwidth from 60% to 140% of their original

size (see appendix Table C.1.4 - 13). Further, the interaction effect of self-rated health with the treatment on awareness of diagnosis increases in magnitude and significance as bandwidth sizes get smaller.

When examining the effect of a referral letter issued for high DBP on the change of DBP between waves, we find significant coefficients for the main treatment dummy, for self-rated health, and for the interaction between self-rated health and the treatment (Table 3.2-2, column 10). In individuals with poor to moderate self-rated health, the treatment effect of receiving a letter significantly increases the change in DBP by 3.18 mmHg – i.e. resulting in worse blood pressure during follow-up rates among treated individuals. Additionally, good to excellent self-rated health is associated with worse DBP during follow-up, as it associated with a change in DBP between waves of 1.47 mmHg (Table 3.2-2, column 10). Being treated and in good self-rated health significantly decreases the change in DBP between waves in comparison to the treated with poor to moderate self-rated health. The effect of self-rated health both in itself and as an interaction term with treatment are intuitive given that BP during follow-up is expected to be a downstream outcome of the differential pattern in diagnosis and treatment found in columns 6 and 7. Furthermore, the results on the treatment coefficient stays robust to altering bandwidth sizes. Self-rated health displays the same pattern when decreasing bandwidth sizes down to 60% of their original size, but loses significance when increasing bandwidth size. The interaction between self-rated health and the treatment is robust to all but the 60% bandwidth size.

The regression specifications on the effect of referral letters issued for high DBP explain between less than 1% and 4% of the variability of the response data around the mean (see Table 3.2-2, columns 6 - 10). The bandwidth sizes vary between 8.16 mmHg and 12.48 mmHg. The mean age in these analytical samples is 53 years, therefore substantially younger than the sample underlying the estimations for referral letters issued for high SBP. This is likely explained by a differential growth pattern of DBP and SBP over time: both types of BP increase with aging, but DBP often plateaus during older age (Dai et al. 2022). This is also in line with smaller R-squares in specifications using DBP as a forcing variable (columns 6-10) in comparison with those using SBP (columns 1-5).

Table 3.2-2: RD estimates of the effect of a referral letter in the pooled sample with covariate adjustment for self-rated health

| | Referral Letter for high SBP | | | | | Referral Letter for high DBP | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| VARIABLES | (1) W2 High BP ever diagnosed | (2) W2 BP under treatment | (3) Hyper-tensive at W2 | (4) Change in systolic BP | (5) Change in diastolic BP | (6) W2 High BP ever diagnosed | (7) W2 BP under treatment | (8) Hyper-tensive at W2 | (9) Change in systolic BP | (10) Change in diastolic BP |
| RD | 0.04 | 0.04 | 0.00 | -2.96 | -3.19*** | -0.03 | -0.02 | 0.01 | 1.82 | 3.18** |
| | (0.04) | (0.04) | (0.01) | (1.99) | (1.18) | (0.05) | (0.04) | (0.01) | (2.09) | (1.30) |
| Rated Health | -0.17*** | -0.14*** | -0.01 | -0.66 | -0.06 | -0.15*** | -0.12*** | 0.01 | 0.92 | 1.47* |
| | (0.02) | (0.02) | (0.01) | (1.24) | (0.74) | (0.03) | (0.02) | (0.01) | (1.26) | (0.80) |
| RD * Rated Health | 0.01 | 0.00 | 0.01 | 0.33 | 1.75 | 0.09* | 0.03 | -0.01 | -2.10 | -2.57** |
| | (0.04) | (0.03) | (0.01) | (1.90) | (1.13) | (0.05) | (0.04) | (0.01) | (2.02) | (1.24) |
| R-squared | 0.07 | 0.05 | 0.00 | 0.04 | 0.04 | 0.04 | 0.03 | 0.00 | 0.04 | 0.04 |
| Bandwidth | 17.64 | 20.45 | 12.13 | 11.92 | 12.34 | 8.995 | 12.48 | 8.713 | 9.457 | 8.159 |
| Within-bandwiths N | 2667 | 3065 | 1925 | 1768 | 1925 | 1751 | 2576 | 1751 | 1951 | 1751 |
| Mean Age | 59 | 59 | 60 | 60 | 60 | 53 | 53 | 53 | 53 | 53 |

Standard errors in parentheses. Stars denote significance level: *** p<0.01, ** p<0.05, * p<0.1. All estimates are calculated using local linear regression with triangular weights and a survey fixed effect on respondents falling into Mean Squared Error (MSE) optimal bandwidths. Columns 1-4 use SBP as a forcing variable; columns 5-8 use DBP as a forcing variable.

Regression Analysis with Covariate Adjustment for Self-Rated Health and Depressive Symptomology

In the regression analysis with covariate adjustment for self-rated health and depressive symptomology, receiving a referral letter for high SBP mirrors results presented in Table 3.2-2 (see Table 3.2-3, columns 1-5). First, we find a significant decrease in the change in DBP between baseline and follow-up. Secondly, we find that self-rated health is negatively associated with care outcomes. Additionally, we find no significant effect of depressive symptomology or its interaction term on any outcome. These patterns are again robust to changing the bandwidths from 60% to 140% of their original size (see Appendix Table C.1.4 - 14).

When examining the effect of referral letters for high DBP (see Table 3.2-3, columns 6-10), we again find the same patterns of self-rated health as presented in Table 3.2-2. Additionally, we find significant effects of the interaction term of treatment and depressive symptomology on hypertensive status at follow-up and the change in BP. Being treated and experiencing depressive symptomology increased the likelihood of being hypertensive at follow-up by 2 p.p. Furthermore, it significantly increased the change in SBP between baseline in endline by 4.78 mmHg and the change in DBP by 2.53 mmHg – worsening BP outcomes over time. At the same time, the significant treatment effect for receiving a letter as found in Table 3.2-2 disappears when including the depressive symptomology covariates. Again, these patterns are again mostly robust to changing the bandwidths from 60% to 140% of their original size (see Appendix Table C.1.4 - 15). Only the association between self-rated health and the change of DBP loses significance in the smallest and largest bandwidth sizes and its interaction term with treatment is robust only to increasing the bandwidth size.

Table 3.2-3: RD estimates of the effect of a referral letter in the pooled sample with covariate adjustment for self-rated health and depressive symptom

| | Referral Letter for high SBP | | | | | Referral Letter for high DBP | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| VARIABLES | (1) W2 High BP ever diagnosed | (2) W2 BP under treatment | (3) Hyper-tensive at W2 | (4) Change in systolic BP | (5) Change in diastolic BP | (6) W2 High BP ever diagnosed | (7) W2 BP under treatment | (8) Hyper-tensive at W2 | (9) Change in systolic BP | (10) Change in diastolic BP |
| RD | 0.03 | 0.02 | -0.00 | -3.32 | -3.64*** | -0.05 | -0.04 | -0.00 | -0.46 | 2.00 |
| | (0.04) | (0.04) | (0.01) | (2.16) | (1.29) | (0.05) | (0.04) | (0.01) | (2.29) | (1.41) |
| Rated Health | -0.16*** | -0.14*** | -0.01 | -0.63 | -0.12 | -0.14*** | -0.12*** | 0.01 | 0.79 | 1.42* |
| | (0.02) | (0.02) | (0.01) | (1.25) | (0.74) | (0.03) | (0.02) | (0.01) | (1.27) | (0.81) |
| RD * Rated Health | 0.01 | 0.01 | 0.01 | 0.47 | 1.88 | 0.09** | 0.03 | -0.01 | -1.48 | -2.25* |
| | (0.04) | (0.03) | (0.01) | (1.92) | (1.14) | (0.05) | (0.04) | (0.01) | (2.04) | (1.24) |
| Depressive Symptom | 0.02 | 0.01 | -0.00 | 0.26 | -0.52 | 0.02 | -0.00 | -0.01 | -0.66 | -0.38 |
| | (0.02) | (0.02) | (0.01) | (1.21) | (0.72) | (0.03) | (0.02) | (0.01) | (1.17) | (0.74) |
| RD * Depressive Symptom | 0.01 | 0.05 | 0.01 | 0.88 | 0.99 | 0.04 | 0.04 | 0.02** | 4.78** | 2.53** |
| | (0.04) | (0.03) | (0.01) | (1.87) | (1.12) | (0.04) | (0.03) | (0.01) | (1.89) | (1.16) |
| R-squared | 0.07 | 0.05 | 0.00 | 0.05 | 0.04 | 0.04 | 0.03 | 0.00 | 0.04 | 0.04 |
| Bandwidth | 17.69 | 21.11 | 12.04 | 11.98 | 12.33 | 8.795 | 12.17 | 8.721 | 9.612 | 8.147 |
| Within-bandwiths N | 2667 | 3217 | 1925 | 1768 | 1925 | 1751 | 2576 | 1751 | 1951 | 1751 |
| Mean Age | 59 | 59 | 60 | 60 | 60 | 53 | 53 | 53 | 53 | 53 |

Standard errors in parentheses. Stars denote significance level: *** p<0.01, ** p<0.05, * p<0.1. All estimates are calculated using local linear regression with triangular weights and a survey fixed effect on respondents falling into Mean Squared Error (MSE) optimal bandwidths. Columns 1-4 use SBP as a forcing variable; columns 5-8 use DBP as a forcing variable.

Descriptive Analysis on Self-Rated Health

We find that individuals with bad to moderate self-rated health are significantly more likely to present with at least one of three health conditions (diabetes, anemia, or dyslipidemia) than individuals with good to excellent self-rated health – suggesting that health perception is a valid proxy for physical health status (see Appendix Table C.1.5 - 1). Furthermore, individuals with worse self-rated health are significantly more likely to report being aware of at least one diagnosis of TB or a CVD health condition. At the same time, we do not find a significant difference in the share of undiagnosed diabetes cases by self-rated health status. This suggests that self-rated health speaks to the level of care received, which in turn seems to be driven by actual health status rather than a differential likelihood of being diagnosed. Moreover, the mean share of respondents with depressive symptomology is also significantly higher in those with worse self-rated health – suggesting self-rated health also captures mental health dimensions. However, we also find that individuals with better self-rated health are living significantly farther away from a health clinic. While this will likely be associated with socioeconomic gradients in health, it could additionally explain the results of Table 3.2-2 and Table 3.2-3, in that respondents with better self-rated health potentially seek less care due to higher transaction costs of reaching a clinic. Lastly, we find overall high levels of trust and satisfaction with the health system, which do not differ by self-rated health status (see Appendix Figure C.1.5 - 1): about 86% of all respondents agree that in general one can trust healthcare providers and 86% of all respondents are satisfied with the South African health care system. In contrast, only 47% of respondents agree that in general one can trust people.

### 3.2.6. Discussion and Conclusion

Like many other LMICs, South Africa suffers from a high burden of hypertension with large shares of the affected populations never receiving blood pressure screenings or diagnoses (Geldsetzer et al. 2019; Berry et al. 2017). Due to the high hypertension prevalences and cheap screening technology, many population-based health surveys now include blood pressure measurements in their data collection – allowing for referral letters to be issued to respondents at risk of having hypertension. However, while several studies have assessed the impact that these survey-based referral letters have on care and health outcomes, effect sizes have varied substantially across settings and determining factors are largely left unexplained. In this study, we set out to estimate the effect that the referral letters have in a sample of 8,247 South Africans survey respondents and to identify whether physical and mental health are individual-level determining forces for the impact of these letters.

Using a regression discontinuity design on pooled NIDS and HAALSI survey data from 2008 to 2019, we find that referral letters had no significant effect on the awareness of diagnosis, treatment, and most blood pressure outcomes after two to four years. While receiving a letter for high SBP significantly and robustly affects the change in DBP between baseline and endline, the effect is too small to be clinically meaningful, leaving hypertension rates at follow-up unaffected.

In our channel analysis, we find that physical and mental health are significantly associated with care and BP outcomes. As was proposed in hypothesis *H1.1*, we found that better self-rated health is generally associated with lower awareness of diagnosis and treatment, and to some extent to higher average DBP during follow-up. Our descriptive analysis suggests that differential patterns in the perceived risk of hypertension and cost-benefit structures may be potential reasons for this. In regard to the former, we show that self-rated health appears to be a reflection of actual health, but does not underlie differential patterns of likelihood of diagnosis or trust and satisfaction in the health system. This suggests that individual with lower self-rated health may seek more care due to true knowledge of their own health status and thereby higher perceived risk of having hypertension, rather than due to more positive attitudes towards the health system. Analogue to this, higher self-rated health may reflect lower perceived risk for presenting with hypertension and therefore lower care seeking behavior, as was found in previous literature (Risso-Gill et al. 2015; Gong et al. 2020; M. Marcus et al. 2022). Speaking

to the cost-benefit structure of screening and treatment, we found that individuals with better self-rated health live significantly further away from the nearest health clinic – offering a second potential reason for their worse care outcomes.

Furthermore, we find some indication that receiving a referral letter can alleviate these differential patterns in care outcomes by self-rated health status. This is in line with hypothesis H 1.2. and suggest that referral letters may lead to updated beliefs among individuals with better self-rated health, leading to an increased perceived risk of presenting with hypertension. This is in line with previous literature that has shown individuals may adapt their health behavior when presented with personalized risk information (Pascaline Dupas 2011a; Albada et al. 2009).

Moreover, we do not find any associations between depressive symptomology and any specified outcomes. However, we find some indication that receiving the referral letter in combination with depressive symptomology may lead to worse BP outcomes and an increase in the likelihood of being hypertensive at follow-up, partially confirming hypothesis H 2.2. Further, the directionality of effects suggest that referral letters may reinforce negative sentiments of hopelessness or low self-efficacy and thereby lower the perceived benefit of screening and treatment. However, given that we are unable to identify effects on care outcomes, this interpretation should be considered with caution. The negative association is in line with existing evidence, which shows that depressive symptomology is linked to lower cancer screening rates (Pirraglia et al. 2004; Vigod et al. 2011).

Lastly, we find that effects vary depending on whether a referral letter was issued for high SBP or for high DBP. One potential explanation for this may be that age substantially affects the sample on which the regression discontinuity analysis is based. As older adults more frequently present with high SBP but normal DBP, and younger to middle-aged adults more commonly have high DBP but normal SBP (Sanchez et al. 2009; Fang et al. 1995; Kanegae et al. 2017; Nürnberger et al. 2003), any analysis using SBP as a forcing variable may yield older samples than those using DBP as a forcing variable. As the RD design can be considered a local average treatment estimator (Cunningham n.d.), effect sizes may vary depending on the underlying sample. This interpretation would also be supported by the effect sizes presented in related literature: studies examining the effect of referral letters in older sample populations (Chen et

al. 2019; Ciancio et al. 2021) are larger than those that include also younger adults in their analyses (Dai et al. 2022; Sudharsanan et al. 2020).

Our study underlies several limitations. First, we are lacking monitoring data on whether referral letters were in fact issued as instructed. Because of this our estimates must be considered as intention-to-treat effects, as we explained in the method section. Second, a range of outcomes is self-reported and may therefore underlie several measurement biases. Respondents may feel pressure to report socially desired outcomes, which could lead those that received a referral letter to falsely claim having undergone screening, having received a diagnosis, or being currently under treatment during follow-up. We believe several factors may alleviate this concern: i) receiving a referral letter is a relatively light-tough intervention that may not be remembered after two to four years; ii) interviews between waves will have been conducted by different field workers; and iii) effects on BP as a non-self-reported, downstream outcome to the self-reported outcomes are in line with the results on care outcomes. Next to a social desirability bias, the self-reported survey items may underlie a recall bias. Because respondents may have forgotten or not understood a diagnosis for hypertension, our study can only speak to the awareness of having received a diagnosis. While different to an actual diagnosis, we argue that awareness of diagnosis is an equally important concept to measure, as it is an important precondition to behavior change that respondents retain the information provided to them by health care practitioners. The recall bias could, however, bias our results, if the referral letter led to a better memory of received care. For this, we call again on arguments iii) above. In addition to the outcome variables, also the CESD scale for depressive symptomology may underlie measurement bias, as respondents may feel hesitant to report truthfully given the sensitive nature of the questions. While we cannot assess this directly, we draw on validation studies conducted in this setting and elsewhere (Adams et al. 2020; E. C. Baron, Davies, and Lund 2017). Further, the descriptive analysis relies mainly on HAALSI data. As HAALSI participants are on average older and more likely to be diagnosed than NIDS respondents, insights may not necessarily translate onto other populations. Additionally, we can draw causal conclusions on only on the interaction terms of self-rated health and depressive symptomology with the referral letter, but not on their own. Therefore, we can only provide observational evidence on hypotheses H 1.1 and H 2.1. Lastly, we are unable to directly measure underlying pathways of change, such as perceived risk of having hypertension or perceived benefit of screening and diagnosis. Therefore, we are unable to causally attribute the described findings to these pathways.

In conclusion, cheaper and more readily available technology makes it increasingly feasible to conduct physical and biomarker measurements on survey participants. We find that referral letters based on these measurements have little effect on care and health outcomes two to four years later in South African adults overall. However, the pooled analysis masks important individual-level determinants in the impact of the intervention: referral letters may have differential effects depending on the physical and mental health of the recipients. More research should be devoted to identifying how surveys can maximize the benefit of delivering collected personalized risk information to their participants in an impactful, responsible, and sustainable manner.

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# 5. Declarations

## 5.1. Versicherung für die Zulassung zur Promotionsprüfung

Ich versichere,

1. dass ich die eingereichte Dissertation „Access to Care for Cardiometabolic Diseases in Low- and Middle-Income Countries“ selbstständig angefertigt habe und nicht die Hilfe Dritter in einer dem Prüfungsrecht und wissenschaftlicher Redlichkeit widersprechenden Weise in Anspruch genommen habe,
2. dass ich das Prüfungsrecht einschließlich der wissenschaftlichen Redlichkeit – hierzu gehört die strikte Beachtung des Zitiergebots, so dass die Übernahme fremden Gedankenguts in der Dissertation deutlich gekennzeichnet ist – beachtet habe,
3. dass beim vorliegenden Promotionsverfahren kein Vermittler gegen Entgelt eingeschaltet worden ist sowie im Zusammenhang mit dem Promotionsverfahren und seiner Vorbereitung
   - kein Entgelt gezahlt oder entgeltgleiche Leistungen erbracht worden sind
   - keine Dienste unentgeltlich in Anspruch genommen wurden, die dem Sinn und Zweck eines Prüfungsverfahrens widersprechen
4. dass ich eine entsprechende Promotion nicht anderweitig beantragt und hierbei die eingereichte Dissertation oder Teile daraus vorgelegt habe.

Mir ist bekannt, dass Unwahrheiten hinsichtlich der vorstehenden Versicherung die Zulassung zur Promotionsprüfung ausschließen und im Falle eines späteren Bekanntwerdens die Promotionsprüfung für ungültig erklärt werden oder der Doktorgrad aberkannt werden kann.

23.08.2022

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Datum, Unterschrift

## 5.2. Author Contributions

All research papers that are included in this dissertation are co-authored as indicated on the respective title pages and the contributions are as follows.

**Essay 1**

*Joint work with Cara Ebert (CE), Pascal Geldsetzer (PG), Michaela Theilmann (MT), Brice Wilfried Bicaba (BWB), Glennis Andall-Brereton (GAB), Pascal Bovet (PB), Farshad Farzadfar (FF), Mongal Singh Gurung (MSG), Corine Houehanou (CH), Mohammad-Reza Malekpour (MRM), Joao S. Martins (JSM), Sahar Saeedi Moghaddam (SSM), Esmaeil Mohammadi (EM), Bolormaa Norov (BN), Sarah Quesnel-Crooks (SQC), Roy Wong-McClure (RWM), Justine I. Davies (JID), Mark A. Hlatky (MAH), Rifat Atun (RA), Till W. Bärnighausen (TWB), Lindsay M. Jaacks (LMJ), Jennifer Manne-Goehler (JMG), and Sebastian Vollmer (SV)*

PG, JID, MAH, RA, TWB, LMJ, JMG, SV and I contributed to conceptualization of the paper, with JMG, SV, and I leading the investigation. BWB, GAB, PB, FF, MSG, CH, MRM, JSM, SSM, EM, BN, SQC, and RWM led the primary data collection. JMG, MT, RA, SV, TWB, JID, PG, SV, DF, and I led the data collation. I conducted the formal analysis and wrote the first draft. Validation was carried out by CE, MT, JMG, SV, and I. All authors provided comments and edits on multiple iterations of the manuscript. All authors had access to the data and had the final responsibility to submit for publication.

**Essay 2**

*Joint work with Jennifer Manne-Goehler (JMG), Michaela Theilmann (MT), Farshad Farzadfar (FF), Sahar Saeedi Moghaddam (SSM), Mohammad Keykhaei (MK), Amirali Hajebi (AH), Scott Tschida (ST), Julia M. Lemp (JML), Krishna K. Aryal (KKA), Matthew Dunn (MD), Corrine Houehanou (CH), Bahendeka Silver (BS), Peter Rohloff (PR), Rifat Atun (RA), Till W. Bärnighausen (TWB), Pascal Geldsetzer (PG), Manuel Ramirez-Zea (MRZ), Vineet Chopra (VC), Michele Heisler (MH), Justine I. Davies (JID), Mark D. Huffman (MDH), Sebastian Vollmer (SV), and David Flood (DF)*

JMG, SV, DF, and I conceived the idea for this study. FF, SSM, MK, AH, KKA, CH, and SB led the primary data collection. JMG, MT, RA, SV, TWB, JID, PG, SV, DF, and I led the data collation. DF and I verified the underlying data and did the statistical analysis with assistance from MT and SV. DF and I drafted the first version of the manuscript with substantial revisions also received from JM-G, PR, MH, and SV. All authors provided crucial input on multiple iterations of the manuscript. All authors had access to the data and had the final responsibility to submit for publication.

**Essay 3**

*Joint work with Anna Reuter (AR), Lisa Rogge (LR), and Sebastian Vollmer (SV)*
AR, LR, and I jointly developed the idea. AR, LR, SV and I conceptualized the study. AR, LR and I prepared and monitored the data collection in the field, conducted the analysis and wrote

the draft. SV contributed to the interpretation of results and writing. All authors read and approved the final manuscript.

**Essay 4**

*Joint work with Carlos Riumallo Herl (CRH)*

CRH and I jointly developed the idea and conceptualized the study. CRH and I led the data curation. I conducted the formal analysis and wrote the first draft. Validation was carried out by CRH and I. CRH provided crucial input, comments, and edits on the manuscript.

# A. Appendix for Essays 1 and 2

## A.1 Search Methods

We obtained datasets through a systematic online search and request approach with the HPACC research consortium (Manne-Goehler et al. 2022). The search and request approach is routinely updated to include newly conducted datasets: For Essay 1, we searched for all countries on the World Bank list of economies from June 2020. On April 2021, the search was updated for Essay 2.

1. STEPS Surveys: STEPS repository and STEPS website

We first identified all countries in which a World Health Organization (WHO) Stepwise Approach to Surveillance (STEPS) survey had been conducted during a year in which the country fell into an eligible World Bank country income category of low-income or middle-income. Prior to the STEPS surveys being made available in the WHO STEPS survey Central Data Catalog in 2019, we systematically requested each eligible STEPS survey from a list of these surveys that the WHO maintains on their website. The research team contacted the responsible party for each survey, based on the information provided on this website. If the contact information was out dated or unavailable, the authors relied on publications utilizing STEPS data and electronic searches of the survey or contact name. For the Caribbean region, country involvement was facilitated by the Caribbean Public Health Agency (CARPHA).
Beginning in 2019, additional eligible surveys were downloaded from the Central Data Catalog. The search words used in the WHO Central Data Catalog were: (1) STEPS collection, (2) surveys conducted ≥2008, (3) low-and middle-income countries.

2. Survey Programs and Pooled Data Sources

Whenever the search above yielded no eligible survey, we went on to search the Demographic and Health Surveys (DHS), the WHO Study on Global Ageing and Adult Health (SAGE), the Gateway to Global Aging studies, the NCD Risk Factor Collaboration (NCD RisC), the Global Health Data Exchange (GHDx), and the International Diabetes Federation (IDF) Diabetes Atlas. Potentially eligible surveys were confirmed to be the most recent data available via a google search and subsequently requested.

3. Google Search

Whenever the search above yielded no eligible survey, we conducted a Google search based on the following:

Search engine: Google

Search terms: "[country name]" AND ("population-based" OR household) AND ("blood glucose" OR "plasma glucose" OR "blood sugar" OR hemoglobin OR haemoglobin OR A1c OR HbA1c OR A1C OR Hb1c OR Hba1c OR HGBA1C OR "blood pressure" OR hypertension OR hypertensive OR cholesterol OR LDL OR HDL OR lipoprotein OR triglycerides OR triglyceride OR lipid OR lipids)

Number of hits reviewed: Hits reviewed until eligible survey identified, or, in the case of no eligible survey identified, first 50 hits (10 hits per page/5 pages reviewed)

Search date: April 8, 2020

Essay 1 survey inclusion criteria:
The survey was conducted during or after 2008; in cases where two surveys were available for a particular country, the most recent was used;
The survey data were made available at the individual level;
The survey contained a biomarker for hypercholesterolemia (total or LDL cholesterol);
The survey was conducted in an upper-middle, lower-middle or low-income country according to the World Bank at the time the survey was conducted;
The survey was nationally representative with a response rate of over 50%;
The survey included a suite of questions that assessed access to a core and comparable group of health services for diagnosis, preventive counselling, and treatment of hypercholesterolemia.

Essay 2 survey inclusion criteria:
The survey was conducted during or after 2013; in cases where two surveys were available for a particular country, the most recent survey was used;
The survey contained a biomarker for diabetes (either a glucose measurement or HbA1c);
The survey data were made available at the individual level;
The survey was nationally representative;
The survey was conducted in an upper-middle, lower-middle or low-income country according to the World Bank in the year the survey was conducted;

Overall, the search process yielded 35 datasets included in Essay 1 and 41 datasets in Essay 2.

## A.2 Data Access Statement

Data included in these studies are publicly available for 25 included country surveys of Essay 1 and 38 included country surveys of Essay 2. Microdata can be downloaded at the following links:

Bangladesh STEPS 2018:
https://dhsprogram.com/data/dataset/Bangladesh_ Standard-DHS_2011.cfm?flag=0

Chile NHS 2009/10:
https:// www.minsal.cl/estudios_encuestas_salud/

Mexico National Survey on Health and Nutrition (ENSANUT):
https://ensanut.insp.mx/encuestas/ensanut2018/descargas.php

STEPS Microdata repository:
https://extranet.who.int/ncdsmicrodata/index.php/catalog/STEPS)

For countries without publicly available microdata, please contact the HPACC Consortium at hpacc@uni-heidelberg.de for further information on requesting data.

## A.3 Country Specific Methods

### A.3.1 Sampling Methods

Note: In order to ensure accuracy in reporting, sampling methods are pasted verbatim from specified sources.

**Afghanistan: STEPS 2018**
In the sampling methodology districts are used as primary sampling units (PSUs), villages/blocks are the SSUs, and households within districts serves as TSUs. Based on the

guidelines of the WHO, the total number of the PSUs within a sampling frame should be greater than 100 among which 50-100 PSUs should be randomly selected. The total number of districts in 34 provinces of Afghanistan is 417. From 417 districts 55districts were selected based on the available resources using Stepwise-Approach XLs form.

The total sample size was distributed proportionate to the size of the districts, then the sample size of the districts was divided by 15 (maximum number of the household to interviewed within an EA) and number of EAs within each district was calculated. Using the EPI sampling frame EAs were selected within each district. Within each EA the total number of the households were calculated and it was divided to calculate the sampling interval. The household with each randomly selected, within each household interview with a randomly selected male or female members was conducted.
Age range of participants included: 18-69 years

*Source: Afghanistan STEPS 2018 Report. Available at:*
*https://extranet.who.int/ncdsmicrodata/index.php/catalog/782*

**Algeria: STEPS 2016-2017**
"A multi-stage cluster sample of households. One individual within the age range of the survey was selected per household. Analysis weights were calculated by taking the inverse of the probability of selection of each participant. These weights were adjusted for differences in the age-sex composition of the sample population as compared to the target population. Different weight variables are available per Step:
wStep1 - for interview data
wStep2 - for physical measures
wStep3 - for biochemical measures

This allows for differences in the weight calculation for each Step of the survey as the age-sex composition of the respondents to each Step can differ slightly due to refusal or drop out. Additionally, some countries perform subsampling for Step 2 and/or Step 3. When no subsampling is done and response rates do not differ across Steps of the survey, the 3 weight variables will be the same."
Age range of participants included: 18-69 years

*Source: no report or fact sheet available. Sampling information obtained from: https://extranet.who.int/ncdsmicrodata/index.php/catalog/91/study-description*

**Armenia: STEPS 2016**
The STEPS survey of non-communicable disease (NCD) risk factors in Republic of Armenia was carried out from September 2016to December 2016. The Republic of Armenia carried out Step 1, Step 2, and Step3. Socio demographic and behavioral information was collected in Step 1. Physical measurements such as height, weight and blood pressure were collected in Step 2. Biochemical measurements were collected to assess blood glucose and cholesterol levels and urine analyze to assess salt intake levels in Step 3. The survey was a population-based survey of adults aged 18-69A cluster sample design was used to produce representative data for that age range in Armenia. A total of2349adults participated in the survey. The overall response rate was 42%.
Age range of participants included: 18-69 years

*Source: Armenia STEPS Fact Sheet. Available at:*
*https://extranet.who.int/ncdsmicrodata/index.php/catalog/102*

**Azerbaijan: STEPS 2017**

"A multi-stage cluster sample of households. One individual within the age range of the survey was selected per household. Analysis weights were calculated by taking the inverse of the probability of selection of each participant. These weights were adjusted for differences in the age-sex composition of the sample population as compared to the target population.
Different weight variables are available per Step:
wStep1 - for interview data
wStep2 - for physical measures
wStep3 - for biochemical measures
This allows for differences in the weight calculation for each Step of the survey as the age-sex composition of the respondents to each Step can differ slightly due to refusal or drop out.
Additionally, some countries perform subsampling for Step 2 and/or Step 3. When no subsampling is done and response rates do not differ across Steps of the survey, the 3 weight variables will be the same."
Age range of participants included: 18-69 years

*Source: no report or fact sheet available. Sampling information obtained from: https://extranet.who.int/ncdsmicrodata/index.php/catalog/127/studydescription#page=overview&tab=study-desc*

**Bangladesh: STEPS 2018**

"Sampling design: Samples were collected by multistage, geographically stratified probability based sampling on the basis of Primary Sampling Unit (PSU) developed by Bangladesh Bureau of Statistics (BBS) for census 2011. To ensure generalization and reliability of the survey results to the entire target population in Bangladesh, the sample size calculator as recommended by WHO (sample size calculator STEPS) was used to derive a sample size. The sample size was calculated that is sufficient to produce reliable estimates for all the indicators for men and women and for 4 age-groups (18-24, 25-39, 40-54, 55-69).
[…]

Sampling Frame and primary sampling unit: The sampling frame for the survey was the complete list of Primary Sampling Unit (PSU) i.e. Enumeration Areas (EAs) (about 293,533) covering the whole country prepared by the BBS for the 2011 Population and Housing Census of the People's Republic of Bangladesh. A PSU is a geographic area covering 100 to 220 households with an average of 113 households. The sampling frame contained information about the PSU location, type of residence (urban or rural), and the estimated number of residential households. A sketch map that delineates the PSU geographic boundaries was available for each PSU. The population coverage rate of this Census 2011 was around 95.85% of the total population. **(Annexure A)**
A special zonal operation was carried out by BBS before 2011 census in 2010 whereby both the urban and rural areas were subdivided with updating of *mauzas (rural)* and *mahallas(urban)* maps with demarcation of PSU boundaries comprising of 100 to 120 (average) houses. Thus based on 2011 census, the sampling frame for the survey was about 293,533 PSUs for both rural and urban areas. The urban stratum included urban and city corporation areas. In Bangladesh, 23.3% of the households are in urban areas; 8.2% are in city corporations, and 15.1% are in other than city corporations.
A new division has been added in 2014 after conclusion of census 2011. So, all the PSUs in the 2011 census were mapped out as per the latest divisions. Thus the sampling frame for STEPS survey 2018 in Bangladesh comprised of 293,533 PSUs: 65,193 urban and 228,340 rural PSUs. Table 2 describes the complete sampling frame by division and by urban and rural areas.
Households in this survey was defined according to BBS as "A dwelling in which persons either related or unrelated living together and taking food from the same kitchen".

Sampling strategy: This survey used the same 496 PSUs which were sampled and used during a recently concluded GATS-II survey. In GATS Bangladesh 2017 these PSUs were equally allocated to each division (62 each), and within each division, were equally allocated to urban and rural stratum (248 PSUs each to both urban and rural strata). The rural and urban PSUs were arranged by population size in terms of household numbers for both urban and rural stratum in each division. In each stratum (rural and urban), 31 PSUs were selected independently in each division by probability proportional to size (PPS) sampling
A household listing operation was carried out in all the selected PSUs by BBS during GATS-II survey in July 2017 was used and no new household listing was carried out for this survey. As the survey used the same PSUs as used during GATS-II survey, HHs lists prepared by BBS during GATS-II survey in July 2017 served as sampling frame for the selection of households in the second stage.
A fixed number of 20 households were systematically selected from each sampled PSU with an equal probability using a fractional interval technique. Selected households in all the selected PSUs were randomly assigned as "male" or "female" in a ratio that produced equal numbers of male and female households. The 20 selected HHs in a PSU were divided into two groups as 1) male HHs for interview of a male member and 2) female HHs for interview of a female member. All the sampled HHs from each PSU were listed sequentially, and alternate house was assigned as female or male household, with the first household in the list assigned as female household.
Finally, one individual was sampled randomly from all the eligible adults in a participating household using the survey app in android tablets. No replacements and no changes of the pre-selected households were allowed at the implementing stage to prevent bias."
Age range of participants included: 18-69 years

*Source: National STEPS Survey for Non-communicable Diseases Risk Factors in Bangladesh 2018. Available at: https://apps.who.int/iris/handle/10665/332886*

**Belarus: STEPS 2015**
"The sampling frame is a collection of data and materials from which are selected for the survey. The optimal sampling frame should be complete, accurate and current. Best of all, the above criteria are met by the results of the population census, which became the basis for constructing the sample for the STEPS study. Census population represents a representative territorial sampling frame in the form a hierarchical set of parcels grouped in a certain way. Plots censuses are, on average, about the same size. For each site there is a schematic map that provides a clear, non-overlapping demarcation of geographic districts, as well as information on the population and the number of households.

The largest in size is the census area, which includes several instructor sites. The smallest unit in the hierarchical structure of parcels by censuses - enumeration areas. A positive aspect of using enumeration areas as primary sampling units (PSUs) is that they have a small and approximately the same size (each includes about 100 HHs on average). Consequently this, the PSU is a territory within which it is possible to effectively organize field work. To conduct a population census, the territory of the Republic of Belarus was divided into almost 32 thousand enumeration areas. Due to the fact that the last population census in the Republic of Belarus was carried out in 2009, to update the sample, the current data of polyclinics were used, medical outpatient clinics, FAPs and rural Soviet accounting in rural areas."
Age range of participants included: 18-69 years

*Source: Translated directly from the Belarus STEPS 2016 report. Available at: https://extranet.who.int/ncdsmicrodata/index.php/catalog/100/related_materials*

**Benin: STEPS 2008**
"The STEPS survey in Benin was a population-based survey of adults aged 25-64. A cluster sample design was used to produce representative data for that age range. A total of 6,904 adults participated

in the Benin STEPS survey. Recruitment was based on a random five-stage sampling frame. Sixty of 546 districts were randomly selected according to the sizes of their populations. In each district retained, a list of neighborhoods or villages was drawn up and half were selected. In each neighborhood retained, dwellings, households, and then subjects were randomly selected. An investigator went to the center of each neighborhood or village and randomly chose a direction to go before entering one out of every two dwellings. In the dwellings retained, he listed the households and randomly selected one out of two. Within each household, the participant was identified using the Kish method. This procedure was followed until the predetermined sample was obtained for the neighborhood or village concerned. The response rate for the survey was 99%. With respect to the biological data collected in STEP 3, this module was] systematically proposed to six subjects out of ten."
Age range of participants included: 25-64 years
*Source: Houehanou YC, Lacroix P, Mizehoun GC, Preux PM, Marin B, Houinato DS. Magnitude of cardiovascular risk factors in rural and urban areas in Benin: findings from a nationwide steps survey. PLoS One 2015; 10(5): e0126441.*

**Bhutan: STEPS 2014**
"To achieve a nationally representative sample, a multistage sampling method was used to select enumeration areas, households and eligible participants at each of the selected households in three stages. The 2005 National Census was chosen as the basis for the sampling frame, with "Geogs" (blocks) in rural areas and towns in urban areas forming the primary sampling units (PSUs). Since the population distribution for urbanicity is 70:30 (rural:urban), 63 PSUs in rural and 14 PSUs in urban areas were chosen. PSUs were selected through the probability proportionate to size (PPS) sampling using the number of households in each PSU. Two secondary sampling units (SSUs) for every rural PSU and 4 SSUs for every urban PSU were selected. This led to the selection of 126 SSUs from rural and 56 SSUs from urban areas. This was also carried out by PPS sampling, using the number of households in each SSU. A total of 16 households from each SSU (both rural and urban) were selected using systematic random sampling. The sampling frame for this was the list of households with a unique identification number (ID) developed by the enumerators for the survey. At the household level, the Kish sampling method was used to randomly select one eligible member (aged 18–69 years) of the household for the survey. The Kish method ranks eligible household members in order of decreasing age, starting with males and then females, and randomly selects a respondent using the automated program for Kish selection in the handheld personal digital assistant (PDA)."
Age range of participants included: 18-69 years

*Source: National survey for noncommunicable disease risk factors and mental health using approach WHO Steps Approach in Bhutan – 2014. Available at: http://www.who.int/chp/steps/bhutan/en/. Additional reference: World Health Organization Regional Office for South-East Asia. National survey for noncommunicable disease risk factors and mental health using WHO STEPS approach in Bhutan—2014. Geneva: World Health Organization; 2014.*

**Botswana: STEPS 2014**
"Botswana has a population of over 2 million with 27 districts and 4,845 enumeration areas and sample size of 300 enumeration areas with a target population of 6,400 people was systematically drawn from a pool of the whole enumeration areas. Against the identified enumeration areas numbers of households were listed and proportion of participants was calculated from the total sample size required for the country. Finally a computer generated random number was drawn to go into specific households in that specific enumeration area and at the end eligible participants residing in the household were listed into the electronic hand held data assistant (PDA) and at the end a name was picked automatically to participate in the survey."
Age range of participants included: 15-69 years

*Source: Botswana STEPS report. Available at: https://extranet.who.int/ncdsmicrodata/index.php/catalog/318*

**Burkina Faso: STEPS 2013**

"Sampling methodology: The study was conducted on a sample obtained from a three-stage cluster stratified as recommended by the WHO for STEPS screening surveys. risk factors for noncommunicable diseases. The sampling frame used was that derived from the general census of the population and habitat 2006 (RGPH 2006) and updated in 2010 during the survey Demographic and Health Survey of Burkina Faso (EDS-BF, 2010). This update concerned the enumeration areas (EAs) that correspond to the cluster as part of this study.
Selection of clusters: The choice of clusters was made according to a systematic random selection proportional to their size (in number of households) within strata (regions). To do this clusters were organized by stratum and place of residence (urban / rural). A total of 240 clusters of which 185 were in rural areas and 55 in urban areas were selected for the investigation.
Selection of households: Households were randomly drawn after an enumeration exhaustive list of all households in the cluster. A draw tool designed on Excel by the team. The technique was used in the field for selecting households to investigate. In total, 20 households in clusters were selected to participate in the study.
Selection of individuals: The choice of individuals was made randomly using Kish's method. In total, an individual aged 25 to 64 living in a selected household was fired for participate in the survey."
Age range of participants included: 25-64 years

*Source, translated from: Rapport de l'enquete national sur la prevalence des principaux facteurs de risques communs aux maladies non transmissibles au Burkina Faso Enquete STEPS 2013. Available at: http://www.who.int/chp/steps/burkina_faso/en/.*

**Chile: NHS 2009-10**
"The sampling frame was constituted from the Population and Housing Census 2002. The design of the study was transversal, with a random sample of complex type households (stratified and multi-stage by clusters) with national, regional and area representation rural / urban. The target population was adults older than or equal to 15 years. The survey had a response rate in the eligible population of 85%. The refusal rate was of 12%. 5,434 people were interviewed. A nurse performed clinical and examinations to 5,043 participants and 4,956 accepted laboratory tests (blood and urine). The total sample loss of the oversized sample was 28% (this including rejection, non-contact and other causes of random loss). The raw sample was designed with overrepresentation of some population groups (older adults, regions other than the Metropolitan Region and rural areas) to increase sample efficiency and homogenize the accuracy of the estimators. The expansion of the sample data is because it grants each participant the weight that corresponds to it according to the design sample and at the same time corrects the distortion of the raw sample, making it coincide with the census population projection for January 2010 for Chilean adults over 15 years of age."
Age range of participants included: 15 years or older

*Source, translated from: Resumen Ejecutivo: Encuesta Nacional de Salud ENS Chile 2009-10. Available at: http://epi.minsal.cl/encuesta-ens-anteriores/.*

**Costa Rica: STEPS 2010**
"The Costa Rican NCRFSS survey was a cross-sectional survey based on a probabilistic cluster sampling design. The NCRFSS survey was conducted during 2010 under the supervision of the Caja Costarricense de Seguro Social, a government public healthcare provider, and covers the overall adult population aged ≥20 years. Multistage cluster sampling was performed stratified by geographical areas, age groups (20–39, 40–64, and ≥65 years) and gender. The first sample stage was the randomized selection of the country's geographical areas as primary sample units followed by the random selection of sectors in selected areas as secondary sample units. The random selection of areas and sectors was performed with probability proportional to size; the area or sector size was determined by the population >20 years during 2009, as estimated by the Costa Rican Census and Statistics National Institute (INEC). Households were chosen through a random number generator using dwelling lists obtained from the health technician assistant in every community until all age group and gender strata sample sizes were achieved. A family dwelling was defined as a group of people who

share the same table to eat. Survey participants were selected by the Kish method, which samples participants within a household with equal probability of selection, as recommended by the WHO STEPwise methodology. To be eligible for inclusion in the study, subjects had to be ≥20 years of age, permanently residing in the selected homes, and to have provided written consent. Pregnant or lactating mothers and those who were within 6 months postpartum were excluded from the study. Each participant selected for the study was informed of the study objectives and details before agreeing to participate in the investigation. In all, 3653 noninstitutionalized adults were surveyed, with an 87.8% response rate of the eligible population."
Age range of participants included: 20 years or older

*Source: Wong-McClure R, Gregg EW, Barcelo A, Sanabria-Lopez L, Lee K, Abarca-Gomez L, Cervantes-Loaiza M, Luman ET. Prevalence of diabetes and impaired fasting glucose in Costa Rica: Costa Rican National Cardiovascular Risk Factors Survey, 2010. J Diabetes. 2016 Sep;8(5):686-92.*

**Ecuador: STEPS 2018**
"The STEPS sample design used probabilistic sampling techniques in order to guarantee the geographic representativeness and the study domains of the survey, and to calculate the expansion factors and the errors associated with the sampling.
The target population or universe of study included the total of adults between 18 and 69 years old, disaggregated by men and women, residing in the territory of Ecuador, except Galapagos. According to the INEC population projection, it included 10,249,369 people. The observation unit and elementary unit of analysis were the people between 18 and 69 years of the Ecuadorian territory, except for Galapagos.
[…]
Type and design stages of the sample. The STEPS sample was selected following a probabilistic element sampling scheme with the following three selection stages: i) first stage: selection of Primary Sampling Units (PSU) by stratum; ii) second stage: selection of 12 occupied dwellings within each UPM selected in the first stage; and, iii) third stage: selection of 1 person between 18 and 69 years old per household."
Age range of participants included: 18 to 69 years

*Source, translated from: Encuesta STEPS Ecuador 2018. Available at: https://extranet.who.int/ncdsmicrodata/index.php/catalog/774*

**Eswatini: STEPS 2014**
"A Multi-stage cluster sampling design was applied. The survey covered all the four regions of the country. The size of the country and the distances between the regions and communities made it possible for the survey to sample a population representing all the 4 regions. The Multi-stage sampling procedure was implemented in the following procedural steps:

Stage 1: All four regions were included as a sampling frame of our Primary Sampling Unit (PSU).The number of the PSUs at this stage ensured precision in the survey estimates and as a result 216 PSUs were selected using probability proportional to size sampling.

Stage 2: The second stage of cluster sampling procedure entailed listing, sorting and random systematic sampling of the Secondary Sampling Units (Households) within the PSUs selected in stage1 where 20 households were selected from each PSU. Based on census data, only households with eligible participants were systematically sampled through random systematic sampling.

Stage 3: At this level, all the eligible participants within a household were sequentially listed into the PDAs and only one participant per household was randomly sampled using KISH method built into the PDAs. The KISH method is a widely used technique that uses a pre-assigned table of random numbers to identify the person to be interviewed."
Age range of participants included: 15 to 69 years

*Source: WHO STEPS: Noncommunicable Disease Risk Factor Surveillance Report Swaziland 2014. Available at: http://www.who.int/chp/steps/swaziland/en/.*

**Ethiopia STEPS 2015:**

According to the WHO step-wise approach to the surveillance of NCD risk factors, a community-based cross sectional study was carried out.

The target population for this survey included all men and women age15-69 years old who have been living at their place of residence for at least six months. This target population included all people who consider Ethiopia to be their primary place of residence. This definition included those individuals residing in Ethiopia regardless of their citizenship status. . People with the following characteristics were not included: those who were not a permanent resident of Ethiopia, and those who were institutionalized including people residing in hospitals, prisons, nursing homes, and other similar institutions or residents whose primary residences are military camps or dormitories. Furthermore, critically ill, mentally disabled and those with some type of physical disability that is not suitable for physical measurement were excluded from this study. In general, the target population of the study included individuals 15-69 years old and residing in all geographic areas of the country.

Age range of participants included: 15 to 69 years

*Source: Ethiopia STEPS 2015 Report. Available at: https://extranet.who.int/ncdsmicrodata/index.php/catalog/794*

**Georgia: STEPS 2016**

"The STEPS survey of noncommunicable disease (NCD) risk factors in Georgia was carried out from June 2016 to September 2016. Georgia carried out Step 1, Step 2 and Step 3. Socio demographic and behavioural information was collected in Step 1. Physical measurements such as height, weight and blood pressure were collected in Step 2. Biochemical measurements were collected to assess blood glucose and cholesterol levels in Step 3. The survey was a population-based survey of adults aged 18-69. A Multi-stage cluster sampling design was used to produce representative data for that age range in Georgia. A total of 5554 adults participated in the survey. The overall response rate was 75.7%."

Age range of participants included: 18 to 69 years

*Source: Georgia STEPS Survey 2016 Fact Sheet. Available at: http://www.who.int/chp/steps/georgia/en/.*

**Guyana: STEPS 2016**

"A response rate of 66.68% will be selected based on the experience and response rates of other surveys over the years such as the recent Demographic Health Survey 2009. [...] STEPS 3 involve taking blood samples from a proportion of the sample, in this case 50% of the sample, in order to measure raised blood glucose levels and abnormal blood lipids. [...] The STEPS sample will be prepared by the Bureau of Statistics Guyana following the recommended STEPS sample methodology. A multi-stage cluster sampling design will be used. Guyana is divided into 10 administrative regions and within the administrative regions there are seven towns and each region is further divided into enumeration districts. For the STEPS survey 288 enumeration districts will be selected using the population probability sampling method and from each enumeration district 12 households will be selected giving a total sample size of 3456. Further at the household level each participant will be randomly selected by the electronic tablet. For STEP 3 50% of the sample will be randomly selected to participate. A re-listing of some households may also be necessary, such as those interior region locations, in which case in addition to household listings, enumeration districts maps will also be provided so that a re-listing can be done where required."

Age range of participants included: 18 to 69 years

*Source: STEPwise Approach to Chronic Disease risk factor surveillance (STEPS): Guyana's Implementation Plan. June 20, 2016. Ministry of Public Health, Guyana.*

**Iran: STEPS 2016**

"The sampling part, which includes determining the sample size and the cluster head, belongs to the pre-study phase and was planned in the form of a specific protocol for sample size and statistical sampling. All experts in the quality control team supervised the finding of samples and cluster heads.

In order to estimate the prevalence rate of the risk factors for non-communicable diseases in the country in 1395, a sampling method proportionate to the population was used, which is a common approach in survey studies. Therefore, the selected sample size was proportionated to the population of that province. On the other hand, for estimating the prevalence of the risk factors in the province, in order to be on the safe side, the smallest sample size for achieving the predicted rates was calculated at 95%. This rate was equal to 384 samples, which was selected as the smallest sample size in the least populated province, Ilam. The required sample size for other provinces was therefore calculated according to the population of that province proportionate to the population of the reference province, Ilam. Besides, to control the non-response error, 10% was added to the calculated sample size in each province.

In order to decrease costs and increase efficiency, for provinces with 800 samples or more, weights were given to their samples. Weight-giving is an effective method used in surveys in order to decrease the sample size. This was achieved in the selected provinces by considering the calculated sample size as half and the sampling weight as double. The total sample size was calculated to be 30150 and to achieve this sample size, sampling from 3015 clusters was required."

Age range of participants included: 18 and older

*Source: Iran STEPS 2016 report.*
*Available at: https://www.who.int/ncds/surveillance/steps/STEPS_2016_Atlas_EN.pdf?ua=1*

**Iraq: STEPS 2015**

"The sample frame consisted of the population of Iraq of (18+) years for both sexes residing in the urban and rural area. It was based on the results of listing and numbering operation for the year 2009 that covered all governorates. Due to the unstable conditions at the time of the survey three governorates (Naynawa, Salahaddin and Al-Anbar) were excluded. A major challenge confronted was the late demographic change due to population movement, displacement and migration. All permanent residents of (18+) years of age, who were resident in Iraq within one month at the time of implementation of the survey were considered eligible.

A cross-sectional community based survey covering 15 governorates in Iraq. A Multi-stage cluster sampling technique was depended to select the minimum representative sample size to estimate the prevalence of the risk factors of noncommunicable disease through direct interview, physical examination and laboratory examination of blood samples of study participants. A total of 412 clusters were randomly selected each contain ten households. One subject from each household was randomly selected using KISH table to participate in the survey with a total sample size of 4120. The Sample was designed to provide estimates on a number of indicators on the situation of Noncommunicable diseases risk factors in Iraq at the national level. A national based rather than a governorate based sample is selected. A multi stage cluster sampling was used with stratification to urban and rural areas. Primary sampling units (PSUs) were the blocks, which consisted of 70 households or more before selection."

Age range of participants included: 18 years and older

*Source: Iraq STEPS 2015 report.*
*Available at: https://www.who.int/ncds/surveillance/steps/Iraq_2015_STEPS_Report.pdf*

**Jordan STEPS 2019**

A national cross-sectional survey was conducted adopting a two-stage stratified-cluster sampling design. The margin error was (5%) and the confidence level was set at 95%. The Jordan Population and Housing Census 2015 was used as a sampling frame for Jordanians. A sample of 3000 households was randomly drawn to represent the Jordanian population. It was designed in a probability proportional to size (PPS) way to provide valid and reliable survey estimates across the entire Kingdom of Jordan - rural and urban areas, the twelve governorates and the smaller communities within. The sample also ensured reliable estimates in terms of geographical distribution, where Jordan was divided into three regions; north, centre, and south, also at governorate level. The north of Jordan covered Ajloun, Irbid, Jerash, and Mafraq, the centre region covered Amman, Balqa, Madaba, and Zarqa, and the south region covered Aqaba, Karak, Ma'an, and Tafieleh. Furthermore, each governorate was subdivided into area units called census blocks, which were the Primary Sampling Units (PSU-Blocks) for this survey (on average a PSU comprises 50-70 households). The PSU-Blocks were then regrouped to form clusters. From each PSU, eight households were randomly drawn with an equal probability systematic selection. A household was defined as a group of people living in the same dwelling space who eat meals together, acknowledging the authority of a man or a woman as the head of the household. After the household selection and obtaining the permission of household residents to participate in the survey, all the eligible household members were entered into the STEPS program, which ran a random selection to choose one member household.
Age range of participants included: 18 to 69 years

*Source: Jordan STEPS 2019 Report. Available at: https://extranet.who.int/ncdsmicrodata/index.php/catalog/853*

**Kenya: STEPS 2015**

"The 2015 Kenya STEPs survey was a national cross-sectional household survey designed to provide estimates for indicators on risk factors for non-communicable diseases for persons age 18 – 69 years. The sample was designed with a sample size of 6,000 individuals to allow national estimates by sex (male and female) and residence (urban and rural areas). The survey used the fifth National Sample Surveys and Evaluation Programme (NASSEP V) master sample frame that was developed and maintained by KNBS. The frame was developed using the Enumeration Areas (EAs) generated from the 2009 Kenya Population and Housing Census to form 5,360 clusters split into four equal sub-samples. A three-stage cluster sample design was adopted for the survey involving selection of clusters, households and eligible individuals. In the first stage, 200 clusters (100 urban and 100 rural) were selected from one sub-sample of NASSEP V frame. A uniform sample of 30 households from the listed households in each cluster was selected in the second stage of sampling. The last stage of sampling was done using Personal Digital Assistants (PDAs) at the time of survey, where one individual was randomly selected from all eligible listed household members using a programmed KISH method of sampling."

Age range of participants included: 18 to 69 years

*Source: WHO: Kenya STEPwise Survey for Non Communicable Diseases Risk Factors 2015 Report. Available at: http://www.who.int/chp/steps/Kenya_2015_STEPS_Report.pdf?ua=1.*

**Kiribati: STEPS 2015**

"The second Kiribati STEPS Survey was a population-based survey of 18-69 year olds. The decision was to use three age groups: 18-29, 30-44, 45-69 years for men and women using the following corrections:
• Design Effect of 1.0 (clustering at village and household level)
• 95% confidence interval; p value .05
• 0.7% response rate
• Baseline prevalence percentage indicator: 0.5
• FPC – not applicable
• 6 age-sex groups (18-29 years, 30-44 years, 45-69 years)
As STEPS is intended to be nationally representative, a multi-stage cluster sampling method was used. The STEPS sampling spreadsheet was completed using the most recent census information (2012). The sample was selected in two stages assuming no replacement. At the first stage, a sample of Enumeration Areas (Islands and villages) from each stratum using probability proportional to size (PPS) sampling was selected. In the second stage, a fixed number of households from each selected Enumeration Area using systematic sampling was selected. The third stage of sampling selection was done at the household level using the KISH method.
The sampling identified that data collection would be needed on the following islands: Makin, Butaritari, Marakei, Abaiang, North Tarawa, South Tarawa,Betio, Maiana, Abemama, Kuria, Aranuka, Nonouti, Tabiteuea North, Tabiteuea South, Arorae, Tabuaeran and Kiritimati. Further details in Annex 3."
Age range of participants included: 18 to 69 years

*Source: Kiribati STEPS 2015 report. Available at: https://extranet.who.int/ncdsmicrodata/index.php/catalog/724*

**Kyrgyzstan: STEPS 2013**
"A multi-stage cluster sample of households. One individual within the age range of the survey was selected per household.
Analysis weights were calculated by taking the inverse of the probability of selection of each participant. These weights were adjusted for differences in the age-sex composition of the sample population as compared to the target population.

Different weight variables are available per Step:
wStep1 - for interview data
wStep2 - for physical measures
wStep3 - for biochemical measures
This allows for differences in the weight calculation for each Step of the survey as the age-sex composition of the respondents to each Step can differ slightly due to refusal or drop out."
Age range of participants included: 25 to 64 years

*Source: no report or fact sheet available. Sampling information obtained from: https://extranet.who.int/ncdsmicrodata/index.php/catalog/271/study-description#page=overview&tab=study-desc*

**Lebanon: STEPS 2017**
"A national cross-sectional survey adopting a two-stage cluster sampling design was conducted for Steps 1, 2 and 3. The sampling frames references used were the population distribution in Lebanon 2014, retrieved from the Central Administration for Statistics (CAS) and the Syrian population distribution data 2015, retrieved from UNHCR. 144 clusters were selected for the Lebanese sample and 144 clusters for the Syrian sample. The Primary Sampling Units (PSUs) were cadastral areas (cadasters) and the Secondary Sampling Units (SSUs) were the

households. Twenty participants were recruited from each cluster. The latest available population estimates (cadastral data) were used, to randomly recruit PSUs by Probability Proportionate to Size (PPS). To account for the issue of the variability in the cadasters' sizes, very small cadasters (<200 individuals) were combined with neighboring PSUs before selecting the sample, to enhance the likelihood of finding 20 target participants. On the other hand, cadasters with a large population size that were guaranteed to be sampled at least twice were handled as strata and each stratum were assigned a fixed number of random starting points based on how often it was selected with certainty. This was done using satellite images divided into grids, previously obtained from the Centers for Disease Control and Prevention (CDC) for all Lebanese cadasters.

For the Lebanese sample, the research team relied on the standard Expanded Program for Immunization (EPI) method for a systematic random selection of the households. Accordingly, within each selected PSU, households were identified using a systematic random approach following the WHO-UNICEF-EPI cluster method. The fieldworkers started with the highest floor on the right side of a building. If the household hosted an eligible participant, they proceeded with data collection, if not, they visited a second household which is selected by skipping 5 households. If during sampling, non-Lebanese households were selected, the fieldworker skipped them in a straight line until a Lebanese household was identified. This method has been previously used for national surveys in Lebanon. One participant was randomly selected within each household, using the eSTEPS application. Households were chosen until the target of 20 participants was reached.

The PSUs for the Syrian refugees' sample were identified, using the most recent available refugee estimates to randomly recruit PSUs by PPS. The same measures aforementioned were done to account for the variation in the cadasters' sizes. The WHO-UNICEF- EPI cluster method was employed to select households. The fieldworkers targeted Syrian households; accordingly, when during sampling, non-Syrian households were selected, the fieldworker skipped them in a straight line until a Syrian household was identified. One participant was randomly selected within each household, using the eSTEPS application.

For both samples, following STEPS' team recommendations, sampling of participants was done without replacement, i.e. once a person was selected that person was not replaced with another one. Efforts were made to include all selected households. If the house was unoccupied at the time of the visit or if an adult was not available for an interview at the time of the visit, that house was revisited up to 4 times, with different visiting times. The number of refusals and non-responses was recorded."
Age range of participants included: 18 to 69 years

*Source: Lebanon STEPS 2016-2017 report. Available at: https://www.who.int/ncds/surveillance/steps/Lebanon_STEPS_report_2016-2017.pdf?ua=1*

**Marshall Islands: HYBRID 2017**
"Stage 1: Households were identified at random according to geographical stratification in Majuro and Ebeye. The country was stratified into two major groups, Urban (Majuro and Ebeye) and Rural (all outer islands). In Majuro and Ebeye, household cluster sampling was used to randomly select households in these areas.
Stage 2: In Majuro and Ebeye, one individual was selected at random from each household using the KISH table method. All adults in Kili, Arno, Wotje, and Jabwor, Jaluit atolls were included in the sample because the adult populations are about 200 each on these atolls."
Age of participants included: ≥18

*Source: Republic of the Marshall Islands Hybrid Survey Final Report 2018. Available at: https://extranet.who.int/ncdsmicrodata/index.php/catalog/742*

**Mexico: ENSANUT 2018**
The ENSANUT 2018-19 is a national, urban and rural probabilistic survey. The units of analysis defined for the survey are the following: - Household is the set of people related by some kinship or not who usually sleep in a dwelling under the same roof, benefiting from a common income contributed by one or more of the household members. - Population aged 0 to 4 years (preschoolers)- Population aged 5 to 9 years (schoolchildren)- Population aged 10 to 19 years (adolescents)- Population aged 20 years and older (adults)- Utilizers

Once the PSUs and strata were constructed, the PSUs for the 2018-19 ENSANUT were selected in two stages: first, INEGI selected a master sample of PSUs with probability proportional to their number of dwellings in the year 2012, then, for the 2018-19 ENSANUT, a subsample of PSUs with equal probability was selected within each stratum. Finally, in each PSU, dwellings were selected with equal probability; on average, five dwellings were selected in each PSU of the high urban stratum and 20 dwellings were selected in the PSUs of the rural and urban complement strata.

Whenever possible, one adult, one adolescent, one schoolchild and one preschooler were selected from each household with equal probability. Also, whenever possible, up to two users of medical services during the last 15 days were selected in 40% of the dwellings, and in the remaining 60% of the dwellings, up to one user was selected.
Age range of participants included: All ages

*Source: ENSANUT Report. Available at: https://ensanut.insp.mx/encuestas/ensanut2018/informes.php [Translated]*

**Moldova: STEPS 2013**
"A total of 4807 randomly selected respondents participated in the survey. They were all aged 18–69 years, and the group comprised both sexes, as well as residents of all districts and the territorial administrative unit "Gagauz-Yeri", along with Chişinău and Balti municipalities. The survey did not cover the districts from the left bank of the Nistru River and the municipality of Bender. A two-stage cluster sampling procedure was carried out to select randomly participants from among the target population. Cluster sectors from the 2004 Moldova Population Census were used as a basic unit. Given the differences in lifestyle and disease status between populations in urban and rural areas, the target population was stratified into urban and rural areas of residence for the STEPS survey. At the first stage, within each stratum, primary sampling units (PSUs) (enumeration areas (EAs)) were selected systematically with probability proportional to the 2004 Population Census EAs (measure of size equal to the number of population in the EAs, provided by the census). Before selection, the census sectors were sorted geographically from north to south within each stratum, in order to ensure additional implicit stratification according to geographical criteria. A total of 400 clusters representing 400 EAs were selected from the 10 991 census EAs. These probabilistically selected clusters were used also in Moldova's DHS conducted in 2005, and the Multiple Indicator Cluster Surveys (MICS) conducted in 2012. Cartographic materials from the Population Census conducted in Moldova in 2004 were not available, thus it was not possible to use them for the STEPS survey. Therefore, for the first stage the probabilistic samples from the abovementioned surveys were used.
Out of the 400 selected clusters, 167 were rural and 233 were urban. The distribution of the sample of 400 PSUs (EAs) for the DHS/MICS surveys was inversely proportional to the

number of population within each stratum, taking into account that the response rate is lower in urban areas than rural owing to the smaller average size of the households in urban areas compared with rural areas. Thus, disproportional allocation with oversampling for urban areas was applied in the STEPS survey. A final weighting adjustment procedure was carried out to enable estimates at national and urban/rural levels.

At the second stage, 15 households (secondary sampling units (SSUs)) were selected within each of the 400 PSUs. From the updated list of households used for the MICS 2012 survey, 15 households were selected randomly per cluster, using the Microsoft Excel random sample tool. A total of 6000 individuals were selected from among the 400 clusters. The Kish method *(17)* was applied for the random selection of one individual aged 18–69 years from each household."
Age of participants included: 18-69 years

*Source: Republic of Moldova STEPS 2013 report. Available at: https://www.who.int/ncds/surveillance/steps/Moldova_2013_STEPS_Report.pdf*

**Mongolia: STEPS 2013**
"A nationwide, cross-sectional survey was conducted covering 8 districts of Ulaanbaatar city and 21 aimags of Mongolia. A total of 6013 individuals aged 15-64 years old, representing the Mongolian adult population, were involved in the survey.
Sampling: The survey was designed to cover all geographical areas of Mongolia, and a multi stage stratified sampling process was carried out to randomly select participants from the target population. Given the urban vs. rural differences in lifestyle and disease status, the target population was stratified into urban and rural areas and the sample was drawn proportionally based on the target population in each area. Ulaanbaatar, Darkhan and Erdenet cities represented urban areas, while the remaining aimags and soums represented rural areas.
Primary units for Ulaanbaatar, Darkhan and Erdenet cities were khoroos, whereas soums served as primary units for rural areas. The same principle used in the previous STEPS surveys in 2005 and 2009 was applied for sampling unit selections for each stage. From each selected household at the tertiary units of multi-stage cluster sampling in both urban and rural areas, only one individual aged 15-64 years old was randomly selected.
The survey covered a total of 65 cluster sampling units. These units included randomly selected individuals from 32 soums in 21 rural aimags and 33 khoroos in Ulaanbaatar, Darkhan and Erdenet cities. The below Table-1 presents selected clusters, cluster sampling units and the numbers and proportion of participants out of the total population. In order to be able to compare the survey results and findings by urban and rural areas, we conducted sampling based on the principles to select approximately similar numbers of participants from both urban and rural areas."
Age of participants included: 15-64 years

*Source: Mongolia STEPS 2013 reports. Available at: https://extranet.who.int/ncdsmicrodata/index.php/catalog/615/related_materials*

**Mongolia: STEPS 2019**
A multistage stratified sampling design was used to produce representative data for that age range in Mongolia. A total of 6654 adults participated in the survey. Analysis weights were calculated by taking the inverse of the probability of selection of each participant. These weights were adjusted for differences in the age-sex composition of the sample population as compared to the target population. Different weight variables are available per Step:
wStep1 - for interview data
wStep2 - for physical measures

wStep3 - for biochemical measures
This allows for differences in the weight calculation for each Step of the survey as the age-sex composition of the respondents to each Step can differ slightly due to refusal or drop out. Additionally, some countries perform subsampling for Step 2 and/or Step 3. When no subsampling is done and response rates do not differ across Steps of the survey, the 3 weight variables will be the same.

*Source: No report available. Sampling information obtained from https://extranet.who.int/ncdsmicrodata/index.php/catalog/836/study-description#page=sampling&tab=study-desc*

**Morocco: STEPS 2017**
"One of the essential elements for establishing a probability sampling plan is the constitution an adequate sampling frame. For the purpose of the STEPS survey, the sampling frame used to meet the sampling need was the 2014 master sample, developed by the HCP based on data from the 2014 population and housing census. It has the advantage extrapolate the sample results to the target population and estimate the accuracy desired. The stratification of observation units belonging to any sampling frame makes it possible to design sampling plans ensuring optimal sample size; a significant reduction in costs and a substantial improvement in the accuracy of expected estimators. However, the choice of criteria allowing the population to be divided into homogeneous groups (strata) and having recent and reliable data on these criteria is a task that requires generally considerable efforts (updating the sampling frame) both in terms of methodological than that of data collection.

In Morocco, the particularity of cities containing several social categories for which, synthesizing the vector of heterogeneous demographic and socioeconomic behavior into a representative characteristic makes stratification a difficult task. The stratification adopted was geographical for the two environments according to the weight in terms of households, each of which has a specific stratification: For urban units, the criteria used were the administrative division into regions, provinces / prefectures and the dominant habitat type. As for the rural environment, the primary units were stratified according to the geographical criterion, and the type of relief dominant at the municipal level. "
Age range of participants included: 18 years and older

*Source: Morocco STEPS report [translated online]: https://extranet.who.int/ncdsmicrodata/index.php/catalog/544/study-description*

**Myanmar: STEPS 2014**
"To achieve a nationally representative sample, a multi-stage sampling method was used to select townships, wards and villages, households and eligible participants at each of the selected households.
*Stage 1: Selection of primary sampling units (PSUs)*
Administratively, Myanmar is divided into 330 townships. A township is subdivided into wards for urban settings and village tracts and then villages for rural settings. The list of townships has been used as the sampling frame at the first stage of sampling. Townships form the Primary Sampling Units (PSUs). Out of the total 330 PSUs, 52 PSUs were selected using Probability Proportionate to Size of population in each PSU (PPS).
*Stage 2: Selection of Secondary Sampling Units (SSUs)*
From each selected PSU (township), 6 SSUs (wards and villages) were chosen using probability proportionate to population size, totaling 312 SSUs for the whole country.
*Stage 3: Selection of eligible participants at household level*
From each selected SSU (ward/village), 30 households were selected using systematic random sampling. The sampling frame for this sampling is the list of households with unique

identification number (ID) developed from a recent listing of households available from the Basic Health Staff.
*Stage 4: Selection of eligible participants at household level*
One eligible participant (aged between 25 and 64 years) in the selected
households was recruited for the survey. The Kish sampling method was used to randomly select one eligible member of the household. Using the Kish Method, eligible participants (adults aged 25 to 64 years) in each household were ranked in order of 8 decreasing age, starting with males then females, then randomly selected using the automated program for Kish selection in the handheld PDA. Each PSU (township) was estimated to contribute 180 participants, totaling 9,360 participants for 52 selected townships for the whole country. In actual study, the total sample size was 8757 participants."
Age range of participants included: 18 years and older

*Source: STEPwise approach to chronic disease risk factor surveillance report 2014. Available at: https://www.who.int/ncds/surveillance/steps/myanmar/en/*

**Nauru STEPS 2015**
As STEPS is intended to be nationally representative, a simple random sample of individuals was identified, based on the most recent census survey. As STEPS is intended to be nationally representative, a simple random sample of individuals was identified, based on the most recent census survey.

*Source: No report available. Sampling information obtained from https://extranet.who.int/ncdsmicrodata/index.php/catalog/836/study-description#page=sampling&tab=study-desc*

**Nepal: STEPS 2019**
STEPS-2019 is national cross-sectional population-based household survey that used multi-stage cluster sampling design to sample households and eligible adult men and women (15-69 years of age) for questionnaire interview and physical examination (anthropometry, blood pressure measurement, blood glucose and cholesterol and urine sample for salt).

Survey population included men and women aged 15-69 years who have been the usual residents of the household for at least six months and have stayed in the household the night before the survey. People with the follow characteristics were not included: Those whose primary place of residence was in military base or group quarters, Those residing in hospitals, prisons, nursing homes and other institutions, Those too frail and mentally unfit to participate in the study, Those with any physical disability, Those unable or unwilling to give informed consent.

Sampling of Primary units (clusters):
This national representative sample was selected through multistage cluster sampling. Sampling frame consisting of the distribution of oldwards as in census 2011 was obtained from Central Bureau of Statistics (CBS). Then, in each of the province, the oldwards were compared with current classification of metropolitan, sub metropolitan, municipality, and rural municipalities and recorded as per new classification which has been recently updated by the government of Nepal. The location of the new classifications were matched with the oldwards and, finally, used as the sampling frame for selecting Primary Sampling Units (PSUs) for 2019 STEPS survey.

As a trade-off between survey costs and reducing the standard error, it was decided to sample 25 survey participants from each cluster, requiring sampling of 36.12 ~37 clusters in each of 7 provinces i.e. 259 clusters at national level.

Within each Province, the numbers of clusters were assigned to the three sub-strata in metropolitan, sub-metropolitan, municipality and rural municipality in proportion to the share of population in each of these 3 substrata in the total Province population.

Sampling of households and individuals from clusters:
A total of 25 households were sampled from each of the cluster. A sampling frame of the all households in the sampled PSUs was obtained through a complete household listing and mapping carried out in the sampled PSUs in September 6 to December 6 2018.

Sampling frame for selection of households from each PSU was prepared by conducting household listing and mapping. The team of enumerators visited the sampling PSUs and carried out a complete mapping of all the households in the PSU. If the sampled cluster were large, (if the population exceeds 300), cluster was segmented. In that case, field team started from northeast corner of each PSU and prepared an enumeration area of 300 household's with at least one person aged 15 years or more. Household listing questionnaire was used to list all of the household's members in selected PSUs. The listing was carried out electronically using Android ODK software. Mapping was done along with household listing. Drawing a location map of the cluster as well a detailed sketch map of all structures residing in the cluster was done These materials guided the interviewers to return to the pre-selected households for interview.

This lists of the households so prepared from all sampled PSUs served as the sampling frame for the selection of households in the next stage. From the prepare list, 25 households per PSU were sampled using equal systematic random sampling after determining the sampling interval by dividing the number of listed household by 25 and by randomly selecting the starting number between 0 and the sampling interval. From each of the selected, one adult member was sampled randomly for participation in the survey using the android tablet.
Age range of participants included: 15 to 69 years

*Source: Nepal STEPS 2019 Report. Available at: https://extranet.who.int/ncdsmicrodata/index.php/catalog/771*

**Seychelles: National Survey of Noncommunicable Diseases 2013**
"The survey was performed in a sex and age stratified random sample of all adults aged 25-64 years of Seychelles between October and December 2013 on Mahé and during 2 weeks in February 2014 in the islands of Praslin and La Digue. These three islands account for >98% of the total population of Seychelles. The eligible sample was extracted from the population registry. The survey was attended by 1240 adults, with a participation rate of 73%. Participants were invited to attend the survey on selected days in study centers located in Mahé, Praslin, and La Digue. All the eligible participants who did not attend were actively traced using (telephone, local administration, announcements on radio, etc) and invited to attend the survey. Since participants were randomly selected from the general adult population, findings of the survey can be inferred to the general adult population of Seychelles."

Source: *National Survey of Noncommunicable Diseases in Seychelles 2013-2014 (Seychelles Heart Study IV): methods and main findings. Available at: http://www.who.int/chp/steps/seychelles/en/.*

**Solomon Islands: STEPS 2015**
"A multi-stage cluster sample design was used to produce representative data. Analysis weights were calculated by taking the inverse of the probability of selection of each participant. These weights were adjusted for differences in the age-sex composition of the sample population as compared to the target population.

Different weight variables are available per Step:
wStep1 - for interview data
wStep2 - for physical measures
wStep3 - for biochemical measures
This allows for differences in the weight calculation for each Step of the survey as the age-sex composition of the respondents to each Step can differ slightly due to refusal or drop out."

Age range of participants included: 18 to 69 years

*Source: no report or fact sheet available. Sampling information obtained from: https://extranet.who.int/ncdsmicrodata/index.php/catalog/710/study-description#page=overview&tab=study-desc*

**Sri Lanka: STEPS 2014/15**

"A national cross-sectional survey was conducted using the WHO STEPwise survey protocol to obtain nationally representative estimates from the adult population, aged 18 to 69 years, in Sri Lanka.

2.2 Study population

The target population of the study was adults aged 18 to 69 years old residing in Sri Lanka.

2.3 Inclusion criteria

All individuals aged 18 to 69 years of age, and residing in the particular address for more than 6 months were included.

2.4 Exclusion criteria

Individuals who fall into following categories were excluded from the survey. • Who were living in the particular address for less than 6 months

• Who were foreigners and living in the country on a temporary basis • Who were mentally unfit

• Who were physically too frail to be included in the study

2.6 Sampling method

A multi stage cluster sampling method was used to select a nationally representative sample from the total population. Department of Census and Statistics of Sri Lanka performed the selection of the study sample. Population of each divisional secretariat (DS) divisions as per the preliminary results of the Census done in 2012 was used for sampling.

Sri Lanka is administratively divided in to 9 provinces and 25 districts. Each district is divided to Divisional Secretariat (DS) areas. Each DS area is divided to many Census Blocks, and each Census Block consists of many households.

Primary sampling unit (PSU)

The primary sampling unit (PSU) was a Divisional Secretariat (DS) area. Out of 331 DS areas available, 80 DS divisions were selected using proportionate to the size (PPS) sampling.

Secondary sampling unit (SSU)

A census block was considered as a SSU. From each DS division (PSU), six secondary sampling units (SSU) were selected using the proportionate to the size (PPS) sampling technique. Therefore, a total of 480 SSUs or census blocks were selected from 80 PSUs.

Tertiary sampling unit (TSU)

Number of houses in each census block depends on the area density and the population density in each DS division. Tertiary sampling unit (TSU) was the household and 15 households from each CB by random systematic sampling by the Department Census and Statistics. Therefore, a sample of 7200 (80x6x15) households were selected. In some instances, there were more than one household living in one house. People who are cooking and eating together were considered as one household. Whenever there were more than one household in a house, one household was selected randomly to be included in the study.

Selection of participants

Only one participant from each household was included in the survey. All the eligible members in the selected family were listed in descending order according to the age. Once this was done, these data was fed to the personal digital assistants (PDAs). The PDAs then automatically selected the eligible participant using the Kish method. "

*Source: Non Communicable Disease Risk Factor Survey Sri Lanka 2015 Report. Available at: https://www.who.int/ncds/surveillance/steps/sri_lanka/en/*

**St. Vincent & the Grenadines: STEPS 2013**
"The survey covered the entire island St. Vincent and the Grenadines, and was conducted using the following zoning categories:
1) Mainland (St. Vincent)
2) Northern Grenadines (Bequia and Mustique)
3) Southern Grenadines (Canouan and Union Island)

The sample size was proportionately divided between the three main reporting strata (St.Vincent/Northern Grenadines/Southern Grenadines). The country's most recent age breakdown based on the 2001 national census by St. Vincent was used to approximate the adult population 18-69 years by Island grouping. The survey was stratified by sex, age groups 18-29, 30-44 and 45-69 years and by geographical location – St. Vincent, Northern Grenadines and Southern Grenadines.

A three-stage cluster sampling approach was used. Enumeration districts were randomly selected using Probability Proportional to Size (PPS) from the sampling frame. A total of 199 enumeration districts were selected. The sampling frame was developed using the number of households per enumeration district taken from the 2012 preliminary census report; enumeration districts had been subsequently revised (2010-2011) so that no enumeration district containing more than 150 Households would be randomly selected from the selected enumeration districts. The number of households per enumeration district to be selected was 26. Where an enumeration district had been split into 2 or more new enumeration districts the number of households in the previously defined enumeration district was divided equally between the newly revised enumeration districts. The household list for each selected enumeration district was updated prior to selection of households during a re-listing exercise. This was necessary as the existing household listing for each enumeration district was outdated.

Eligible persons at the household level were randomly selected using the Kish method. If no one was present in the selected household, a notification of visit card was left and the interviewer revisited. There was a total of three visits to the household before it was listed as non-response (one initial recruitment visit and two call backs). The interviewer then moved on to the next house on the list in the original order. Although the person selected for interview were to be at least 18 years and not older than 69 years on the last birthday, there were a few instances where some participants were turning 18 or 70 years; those cases were addressed during data cleaning.

Biological samples, testing and Nutrition intake (24 hour recall):
Fifty percent (50%) of the survey participants were asked to provide a biological specimen (finger prick) for Glucose and cholesterol testing using Glucose and Lipid Sampling Kits and respond to the nutrition intake (24 hour recall). The biological sample was only collected with participants' explicit consent; the samples were not stored or used for additional undetermined or undisclosed future testing to which respondents did not agree at the time of participation."
Age range of participants included: 18 to 69 years

*Source: WHO STEPS: Noncommunicable Disease Risk Factor Surveillance. Report for St. Vincent & the Grenadines 2015. Available at: http://www.who.int/ncds/surveillance/steps/stvincent/en/*

**Sudan: STEPS 2016**
„A four-stage cluster sampling design was implemented. The four sampling stages were; 1) selection of states from the six regions 2) selection of clusters (a cluster was a Popular Administrative unit), 3) selection of households and 4) selection of eligible individuals. First Stage (State): Administratively Sudan is divided into 18 states which are grouped in six regions, (North, East, Khartoum, Central, Kordofan and Darfur region (Table 1). States were randomly

selected from each region. No geographical areas or populations were excluded from the sampling frame. Thus 11 states were selected, probability proportional to the size, to represent the six regions. A list of the selected states is shown in Table 2.1. Second Stage (Cluster PAU): The Popular Administrative Units (PAU) is the smallest geographically border unit. These were defined as the 'cluster' in the region. Clusters were randomly sampled from all PAUs, from both urban and rural strata, according to probability proportional to size in each state, and urban/rural distribution. The PAUs inaccessible due to security conditions were not excluded from the sampling frame, because within certain areas the security status was continuously changing. However, it was planned that if a PAU was found to be inaccessible at survey time, it should be replaced. However, no replacement was required during this survey. Third Stage (Household): Within the selected PAUs, all households (HH) were included in the sampling frame. Accordingly (HH) were selected using systematic random methods.
Fourth Stage (Individual): The members of the household were first listed in the mobile application (customized software). The inclusion criteria for the listed members were: all individuals aged between 18 to 69 years, from both sexes, irrespective of his health status and living in the selected household for a minimum of 6 weeks. The application was then run and it randomly selected the individual who will be selected to participate in the study."
Age of participants included: 18-69 years.

*Source: Sudan STEPS 2016 report. Available at: https://www.who.int/ncds/surveillance/steps/Sudan_STEPwise_SURVEY_final_2016.pdf?ua=1*

**Tajikistan STEPS 2016**
"A multi-stage cluster sample of households. One individual within the age range of the survey was selected per household.
Analysis weights were calculated by taking the inverse of the probability of selection of each participant. These weights were adjusted for differences in the age-sex composition of the sample population as compared to the target population.

Different weight variables are available per Step:
wStep1 - for interview data
wStep2 - for physical measures
wStep3 - for biochemical measures
This allows for differences in the weight calculation for each Step of the survey as the age-sex composition of the respondents to each Step can differ slightly due to refusal or drop out."
Age range of participants included: 18-69 years
*Source: report not available. Sampling information obtained from: https://extranet.who.int/ncdsmicrodata/index.php/catalog/270/study-description#page=sampling&tab=study-desc*

**Timor-Leste: STEPS 2014**
"Note: Data from Census 2010 were used for all sampling considerations. Even though pl[4,22]anning and mapping for 2015 Census is ongoing, data from the Census will only be available after July 2015.
STEP 1: Selection of Enumeration Area
(1) List of EA with number of HH by district for Census 2010 was obtained from the Directorate of Statistics. There are 1826 EAs in Timor-Leste. Out of these, 150 EAs were selected.
(2) The number of EAs to be selected from each district was based on their proportion in the country's population as per Census 2010.
(3) The numbers of Households (HH) per EAs varied from 0 to more than 300. Therefore, probability proportion to size (PPS) was used.
(4) For each district, the EAs were arranged in ascending order of HH size.

(5) Sampling interval was obtained by dividing the total number of HH in the district by the number of EA to be selected from that district.
(6) A random number was generated between one and the sampling interval for that district, using tools available at random.org.
(7) The EA where that random number fell was the first EA to be selected.
(8) Subsequently, the sampling interval was added to the random number and the EA where this new number fell was selected. For the next number, the sampling interval was added to the number and so on, till the population of HH was exhausted or target number of EA achieved.
(9) This was done separately for each district.
(10) The final list was compiled and had 150 EAs. These are spread over about 125 sucos.
STEP 2. Selection of Households in an Enumeration Area
Listing the house numbers to be visited
(1) It was decided to use the 2010 HH size of each EA. Based on past experience, it was expected that the increase would be on an average about 4–5%.
(2) The list of households to be selected by enumerators was decided centrally.
(3) Sampling interval was calculated by dividing the total number of households in the EA by 18.
(4) The first HH number was selected randomly by reading the last two digits of a currency note. If the number represented by the two digits was more than 18, the last digit was taken into consideration. For each EA, a different currency note was used. This could also be done it by using the tool at random.org. or by draw of lots.
(5) The subsequent HH are identified by adding the sampling interval as was done for selection of EA."
Age range of participants included: 18 to 69 years

*Source: Timor-Leste STEPS Survey Report, [online] at http://www.who.int/entity/chp/steps/Timor-Leste_2014_STEPS_Report.pdf?ua=1*

**Tokelau: STEPS 2014**
"The 2005 Tokelau STEPS survey was design as a whole population-based cross-sectional study of 15-64 year olds in the three atolls. There was no sampling involved in this survey as all eligible individuals were targeted for participation."
Age range of participants included: 15 to 64 years

*Source: Tokelau NCD Risk Factors STEPS Report. Available at: https://www.who.int/ncds/surveillance/steps/STEPS_Report_Tokelau.pdf*

**Tonga: STEPS 2017**
"An initial sample of 4,500 individuals (respondents) between the ages of 18 to 69 years old was targeted to undertake the STEPS survey for 2017 in Tonga.
Because it is important to compare the results by island divisions (national level), it is required with importance to produce the estimates in the divisional level (National Level). Therefore the sampling fractions will be adjusted from its proportional to the size (number of households) to have higher sampling fraction (coverage) for the smaller size island division as shown in the following table:

| Pop | Census | STEPS | sample |
|---|---|---|---|
| Island | Total HH | ideal sample size | coverage | Number of Selected Blocks |
| 1 | Tongatapu | 12,953 | 3240 | 25.0% | 270 |
| 2 | Vava'u | 2,715 | 684 | 25.2% | 57 |
| 3 | Ha'apai | 1,179 | 288 | 24.4% | 24 |
| 4 | Eua | 885 | 228 | 25.8% | 19 |
| 5 | Niua | 273 | 60 | 22.0% | 5 |
| Total | | 18,005 | 4,500 | 25.0% | 375 |

The final sample numbers presented in the table above were rounded such that they were divisible by 12 (an enumerators workload) to accommodate field logistics. As such the sample size is recorded to 4,500. The sample was selected independently within each of the 5 target areas.
The sampling in each area was then undertaken using a three-stage process. The first stage involved the selection of census blocks using Probability Proportional to Size (PPS) sampling, where the size measure was the expected number of households in that block. For the second stage, a fixed number (twelve) of households were selected from each selected census block using systematic sampling. The household lists for all selected blocks were updated just prior to the second stage of selection. Once the selected 12 households are found, then the list of household members age 15 to 64 by gender will be recorded. The final stage will be to use the Random Sample Generator (Android Application) to randomly select one person from the household to be enumerated so that it captures the required composition of the sample with specific age-group distribution and gender."
Age range of participants included: 18 to 69 years

*Source: Tonga STEPS Survey 2017 Sampling Design. Available at: https://pacificdata.org/data/dataset/spc_ton_2017_steps_v02_m/resource/261f0a3c-4979-4a42-a560-1b103c617a42?inner_span=True*

**Turkmenistan: STEPS 2018**
Sample
The main purpose of the sample design for STEPS research in Turkmenistan - nationwide coverage and reflection of the situation in the country as a whole for measurable indicators.
The survey was conducted among adults in Turkmenistan aged 18-69 years. (target population), who gave written informed consent, for exceptions: persons in the ranks of the National Armed Forces; population WHO STEPS Non-communicable disease risk assessment 26 www.who.int/chp/steps permanently residing (staying) in specialized institutions social and rehabilitation assistance, hospitals and other institutions health care, correctional facilities.

Method of sampling and stratification
The STEPS study was used to generate a sample set two-stage probability sampling method using stratification procedures and selection at each of the sampling stages. Geographical coverage - all regions of Turkmenistan: Akhal, Balkan, Dashoguz, Lebap and Mary provinces and the city of Ashgabat (the capital), which corresponds national administrative-territorial division. To ensure the uniformity of the distribution of the sample set across the country was
stratification. Taking into account the division of each province into urban and rural
The total population was determined by 11 streets (the city of Ashgabat - only the city street, in velayatakh - 10 strat). The total sample size was distributed in proportion to the number households on the streets.
Age range of participants included: 18 to 69 years

*Source: Translated from 2018 STEPS Survey Report. Available at: https://www.who.int/ncds/surveillance/steps/turkmenistan/en/*

**Tuvalu: STEPS 2015**
"The Tuvalu STEPS Survey was a population based cross-sectional survey of 18-69 year olds. Analysis weights were calculated by taking the inverse of the probability of selection of each participant. These weights were adjusted for differences in the age-sex composition of the sample population as compared to the target population.

Different weight variables are available per Step:
wStep1 - for interview data
wStep2 - for physical measures
wStep3 - for biochemical measures

This allows for differences in the weight calculation for each Step of the survey as the age-sex composition of the respondents to each Step can differ slightly due to refusal or drop out. Additionally, some countries perform subsampling for Step 2 and/or Step 3. When no subsampling is done and response rates do not differ across Steps of the survey, the 3 weight variables will be the same."
Age range of participants included: 18 to 69 years

*Source: no report or fact sheet available. Sampling information obtained from: https://extranet.who.int/ncdsmicrodata/index.php/catalog/639/study-description#page=overview&tab=study-desc*

**Uganda: STEPS 2014**

Sample Design

The study methodology followed the World Health Organization's (WHO) STEP wise approach to surveillance (STEPS) which provides a standardized method for analyzing and disseminating data on risk factors for non-communicable diseases (NCDs). The sample for the Uganda NCDs was designed to provide Cardiovascular Diseases (CVD) prevalence's, smoking and tobacco use and alcohol consumption estimates for the country as a whole and for urban and rural areas separately. A two stage sampling design was used to draw the sample. At the first stage, Enumeration Areas (EAs) were drawn with Probability Proportional to Size (PPS), and at the second stage, households which were the ultimate sampling units were drawn using Simple Random Sampling (SRS). A total of 350EAs were selected from 2014 Uganda Population and Housing Census Mapping Frame. At the EA level, the target was 14 households.

Sample frame

The 2014 Uganda NCD survey used a sampling frame of the 2014 Population Census Mapping listing provided by the Uganda Bureau of Statistics (UBOS). The UBOS has an electronic file consisting of 78,950 Enumeration Areas (EAs) created for the 2014 Population and Housing Census. An EA is a geographic area consisting of a convenient number of dwelling units that serve as counting units for the census. Tables A.1 provides information on the distribution of EAs and households in the sampling frame by region and residence. The table shows that among the 78,950 EAs, 13,087 (22%) are in urban areas and 65,863 (78%) are in rural areas. The average size of an EA, measured in number of households, is 95 in an urban EA and 77 in a rural EA, with an overall average of 79.

Age range of participants included: 18 to 69 years

*Source: Ministry of Health. Non-Communicable Disease Risk Factor Baseline Survey: Uganda 2014 Report. Available at: https://www.who.int/ncds/surveillance/steps/Uganda_2014_STEPS_Report.pdf*

**Vietnam: STEPS 2015**

"At the same time of STEP survey, MOH also conduct the Global Adult Tobacco Survey (GATS) at the same scale, location, and study subjects (>15 years for GATS and 18-69 for STEPS). The sampling of STEPS was done in as part of the sampling for the (GATS) conducted in combination manner to save time and resources for these two surveys. Applied the multi-stages complex sampling process, the sampling process done by GSO was as follow: • Sampling of clusters (EA) In the first stage of sampling, the primary sampling unit (PSU) was an enumeration area (EA). There are about 170,000 EAs in the whole Viet Nam and the average number of households in each EA is different between urban and rural areas. An average number of households in an urban EA and a rural EA is 133 households and 120 households, respectively. Sample of EAs were selected from the master sample frame. The master sample frame was a cluster frame made by the GSO based on the frame of

Population and Housing Census 2009 and updated with data of 2014. Based on the Population and Housing Census data 2009, GSO prepared a 15% of master sample to serve as a national survey sampling frame. The master sample frame contains 25,500 enumeration areas (EAs) from 706/708 districts of Viet Nam (2 island districts were excluded from the GSO master sample frame). The master sample frame of GSO was divided by two stratification variables: urbanization (1 = urban; 2 = rural) and district group (1 = district/town/city of province; 2 = plain and coastal district; 3 = mountainous, island district). It means that the master sample frame was divided into 6 sample frames or 6 strata. The probability proportional to size (PPS) sampling method was used to select sample of EAs from 6 strata of master sample frame. The final sample of GATS included 315 EAs in the urban and 342 EAs for the rural. From these 657 EAs, 315 EAs were systematically selected for STEPS. Sampling of households At the second stage of sampling, 10% households in each EA were selected. Thus, 15 households from the selected urban EA and 14 households from the selected rural EA were chosen using simple systematic random sampling. The total households for STEPS 2015 were 4,651 households.
Sampling of individuals: One eligible person is then randomly selected from each selected household for the STEPS 1 interview. The selection of individual is automatically done by the PDA program after eligible household members are entered into the PDA. The selection probability of an eligible individual was calculated as a product of selection probability for each stage. The sampling base weight for an eligible individual was the inverse of the selection probability shown above."
Age range of participants included: 18 to 69 years

*Source: National Survey on the Risk Factors of Non-communicable diseases (STEPS) Viet Nam Report 2015. Available at: https://www.who.int/ncds/surveillance/steps/viet_nam/en/*

**Zambia: STEPS 2017**
"To ensure that the sample reflected the entire country of Zambia, a multi-stage cluster sampling technique was used to select a nationally representative sample of adults in Zambia aged 18 to 69 years. It was decided to utilize the household listing from the Zambia PopulationBased HIV Impact Assessment (ZAMPHIA) - a household-based national survey that was conducted between March and August 2016 in order to measure the status of Zambia's national HIV response. ZAMPHIA offered the most pragmatic up to date and accessible national household listing to be used as the sampling frame for this survey. The ZAMPHIA survey included 60,581 households drawn from 1,103 clusters referred to in this report as standard enumeration area (SEA) (Table 2.4.1). Thus the sample drawn for the STEPS survey was a subsample of the households selected for the ZAMPHIA survey. In the first stage of sampling, SEAs were selected from each province using probability proportional to size (PPS). In the second stage, 15 households in rural SEAs and 20 households in urban SEAs were selected systematically using appropriate sampling interval based on the number of households in that SEA. These households constituted the final list of households for the STEPS survey prepared for the field investigators (FI). In the third stage, while the FI approached the household and sought consent, all eligible members in the household were entered into the Android-based devise used for the survey. The device then selected one member from the eligible members using a simple random sampling technique. The selected member was then interviewed having gone through the ethical process of consent after being provided with information on the survey. If the selected member was not available, a scheduled visit was made. If the selected member could not be reached after two scheduled visits he or she was considered as non-response. There was no replacement strategy so as to maintain the integrity and representativeness of the sample."
Age range of participants included: 18 to 69 years

*Source: STEPS 2017 Report. Available at: https://extranet.who.int/ncdsmicrodata/index.php/catalog/620*

### A.3.2 Lipid Measurement Methods

In seven countries biomarkers were measured via blood samples sent to a laboratory; in 22 countries biomarkers were measured with a point-of-care device; in six countries, the biomarker measurement method could not be identified.

| Measurement | Country |
|---|---|
| Accutrend GC | Tokelau |
| Accutrend Plus | Tuvalu |
| CardioCheck PA | Afghanistan, Belarus, Benin, Bhutan, Burkina Faso, Ecuador, Eswatini, Ethiopia, Jordan, Kenya, Kiribati, Moldova, Morocco, Nauru, Nepal, Solomon Islands, Sri Lanka, St. Vincent & the Grenadines, Sudan, Sri Lanka, Timor-Leste, Tokelau, Tonga, Turkmenistan, Uganda, Vietnam, Zambia |
| Konelab 30i | Seychelles |
| Laboratory | Bangladesh, Belize, Chile, Costa Rica, Guyana, Iran, Iraq, Lebanon, Mexico |
| Prima Home Test | Mongolia |
| SD LipidoCare Analyzer | Myanmar |
| Unknown | Algeria, Azerbaijan, Botswana, Ecuador, Georgia, Kyrgyzstan, Marshall Islands, Tajikistan |

In the following, please note: In order to ensure accuracy in reporting, lipid measurement methods are pasted verbatim from specified sources.

**Algeria: STEPS 2016**
No further information available

**Azerbaijan: STEPS 2017**
No further information available

**Bangladesh: STEPS 2018**
"An appointment/clinic card was also given to every participant for biochemical measurement containing fasting instructions. This card contained the appointment date, time and place for blood glucose and lipid measurement. On the given date and time, the enumerators made biochemical assessment (Fasting blood glucose and lipid) using cardio-check.
Participants were instructed to fast overnight for 12 hours and diabetic patients on medication were requested to bring their medicine/insulin with them and take their medicine after providing the blood sample. To ensure high response rate for STEP3, the enumerators called the respondents on the day of testing if he/she failed to come as per the appointment.
[…]
Blood glucose and lipids: After STEP 1 and STEP 2 of data collection at sampled households, biochemical assessments were performed the next day at a designated place for each PSU for blood glucose and total cholesterol, measured in venous blood samples. Concentrations of glucose, total cholesterol and HDL cholesterol were measured in plasma samples. Fasting samples were taken to measure raised blood glucose.
Participants were instructed to fast overnight for 12 hours at the time of household visit for Step I and II. During the appointment, participant was asked to sit in comfortable position with exposing forearm in a table or if patient could not sit in that case at supine position. If the technician was not able to collect blood despite two attempts, he/she didn't try to attempt the

3rd prick, and just recorded the reason for non-collection of sample in laboratory and interview tracking sheet. Each participant was given 50 taka and made him / her rest and then allowed to go).
The ante-cubital fossa was cleaned with disinfectant (70% alcohol) and identified the ante-cubital vein. Then 5ml of blood will be collected by disposable syringe. 2 ml of this blood was transferred to Fluoride-oxalate vacutainer (brown top) for serum glucose testing and 3 ml of the blood was kept in a normal tube and allowed to stand for separation of plasma (for lipid profile) with proper labeling. The sample for blood glucose was left in upright position in vacutainer rack and then centrifuged and separated serum was keep in the cold box (2–8$^0$C) surrounded by ice packs and sent to the NIPSOM Lab within 24 hours.
Each sample tube was labeled with the participant identification number using autogenerated ID tablet, as automatically generated during the questionnaire administration. The medical technologist labeled the laboratory ID (Based on PSU and HH number) against the corresponding participant ID on the appointment card following their lists.
Disposable sterile gloves in multiple sizes: The medical technologist and lab staffs used sterile gloves during blood collection from the participant. Each time the medical technologist washed his/her hands including gloves with Chlorhexidine Gluconate (0.5%) and Isopropyl alcohol (70%) (Hexisol) and collect blood sample with sterile syringes and needles. A single-use disposable needles, and syringes or lancing devices were in sufficient numbers to ensure that each patient has a sterile needle and collection device or equivalent for each blood sampling. All the used syringes and all other used materials were collected in a supplied biohazard bag. The needles were stored in hard plastic container/box. All the medical wastes created for sample collections were sent within biohazard bag to NIPSOM. Finally all the medical wastes were disposed centrally scientifically by PRISM[14], the specific agency concerned with management of biomedical wastes. NIPSOM had an agreement with PRISM for management of all laboratory and biomedical wastes. Sufficient laboratory sample tubes were supplied to prevent reuse and manual washing.
Immediately after reaching to the NIPSOM laboratory, the samples were properly registered with lab ID and sent for measuring blood glucose, lipid profile with biochemistry auto analyzer (Selectrao Pro M) for blood glucose, Human, Germany; for HDL with control, Elitech; TG, Elitech; with control, Humatrol/ serodos; cholesterol, Elitech with control Humatrol, Germany."

*Source: National STEPS Survey for Non-communicable Diseases Risk Factors in Bangladesh 2018. Available at: https://apps.who.int/iris/handle/10665/332886*

**Belarus: STEPS 2016**
"Biochemical studies were performed to determine the level of blood glucose, total cholesterol and high density lipoprotein (HDL). The concentration of glucose, total cholesterol and HDL was measured in fasting capillary blood of all respondents who signed an informed consent using the CardioCheck PA analyzer. Based on the results of laboratory studies, the respondents were divided into groups, taking into account the assumptions indicated in Table 3.7."

*Source (translated via google translate from):*
*Prevalence of Risk Factors of Non-Communicable Diseases in the Republic of Belarus, STEPS 2016. Available at:*
*https://extranet.who.int/ncdsmicrodata/index.php/catalog/100/related_materials*

**Benin: STEPS 2015**
"Equipment:

Electronic device for the determination of capillary glycemia and total cholesterol + Triglycerides brand CardioChek P.A with MEMO chips and suitable strips
[…] The actual survey took place from October 19 to December 30, 2015.
During data collection, the first day was devoted to administering the questionnaire and taking physical measurements. An appointment was then made for the next morning at the respondent's home or sometimes in the nearest care unit or another appropriate place for fasting blood sugar and cholesterol tests.
[…] The morning of the second day was first devoted to fasting blood sugar and cholesterol tests by the team's qualified health worker (Laboratory Technician or Nurse) who pricked the participants' fingers with a single use, sterile needle, and then took a small drop of blood to do the tests in front of the participant and give the results on the spot. The rest of this day and the third are devoted to revisits, then the cycle begins again."

*Source: Benin Ministry of Health, Programme National de Lutte contre les Maladies Non Transmissibles (2016). Rapport final de l'enquête pour la surveillance des facteurs de risque des maladies non transmissibles par l'approche ''STEPSwise'' de l'OMS ENQUETE ''STEPS 2015'' au Bénin. Available at:*
*https://www.who.int/ncds/surveillance/steps/benin/en/*

**Bhutan: STEPS 2014**
"Immediately after the training, survey teams were allocated to the chiwog/enumeration areas where they would go to conduct the survey. Each team administered the STEP 1 (Questionnaire) and STEP 2 (Physical measurements) on the first visit to a household. The participants were then asked to fast overnight i.e. not consume any food or drinks (except water) after 10 p.m. the previous night until the blood sample was collected in the morning. A container was provided to collect urine samples prior to the beginning of the fast. Participants were asked to go to the testing centre set up by the survey team (located in the vicinity) the next morning. Here the blood samples were taken and the urine samples delivered to the survey team. Urine samples were sent by the survey team to the Jigme Dorji Wangchuk National Referral Hospital Laboratory (JDWNRH) in Thimphu for analysis of sodium and creatinine to determine mean population salt intake."

*Source: National survey for noncommunicable disease risk factors and mental health using approach WHO Steps Approach in Bhutan – 2014 Available at:*
*https://www.who.int/ncds/surveillance/steps/Bhutan_2014_STEPS_Report.pdf*

**Botswana: STEPS 2014**
No further information available

**Burkina Faso: STEPS 2013**
"Step 3: the third step consisted of measuring blood glucose and blood cholesterol in capillary blood.
[...] Collection Equipment:
- Cardiocheck

[...] Operating difficulties were also encountered with blood sampling equipment, in this case cardiochecks, due to the ambient temperature which is often very high in places. The collection period coincided with a relatively warm climate and this often delayed data collection while waiting to find a spare cardiocheck."

*Source, translated from: Report of the national survey for the prevalence of the main risk factors of noncommunicable disease in Burkina Faso 2013. Available at: https://www.who.int/ncds/surveillance/steps/burkina_faso/en/*

**Chile: NHS 2009-10**

"The centralization of processing the samples reduced the variability of the laboratory analysis and allowed for a better monitoring of the quality of the processes. For this reason, it has been decided that all samples should be analysed by the Central Laboratory of the PUC, despite complex logistics and an increase in costs.

The Central Laboratory of the PUC has its own internal and external quality controls and it is sufficiently accredited. (Chilean norm 2.547: ISO 15.189). The preparation of the samples was undertaken in regional laboratories of the national health system SNSS which was monitored via interviews on the phone, field visits and a defined set of control indicators (e.g. number and type of alicuotes stored, average duration of centrifugation and monitoring of the temperature in freezers).

[...] The samples were divided into three aliquotes of 300ul in the regional laboratories. The aliquotes were stored at -20°C until being sent to the ISP (Chilean Public Health Institute) in where they were frozen at -80°C.

[...] This questionnaire was administered by a nurse in the household of the participant during a second visit. Here, the nurse collected the blood and urine sample, measured blood pressure, weight, hip, waist, and throat circumference and conducted a haemoglobin test.

[...] Total cholesterol: Enzymatic CHOD-PAP method
HDL colorimetric cholesterol (homogenous HDL)
LDL calculated with the Friedewald formula
Encymatic triglycerides with white glycerol
Encymatic glicemia (Hexokinase glucose)

[...] Number of samples:
Total cholesterol 2804
HDL cholesterol 2802
LDL cholesterol 2794
Triglyderides 2804
VLDL cholesterol 2794

[...] Lipds were measured for 55% of the study population."

*Source, translated from: Resumen Ejecutivo: Encuesta Nacional de Salud ENS Chile 2009-10. Available at: http://epi.minsal.cl/encuesta-ens-anteriores/.*

**Costa Rica: STEPS 2010**

No further information available

**Ecuador: STEPS 2018**

"Each STEP 3 team included a health professional, liaison, and driver with their respective vehicle.
[…]

The activities of the health personnel were to implement STEP 3, that is, to determine the level of glucose and total cholesterol in capillary venous blood, using the portable glucose and cholesterol measurement equipment.
The STEPS 1 and 2 team applied the questionnaire on day 1, and the STEP 3 team took the biological samples on day 2, based on appointments made by the field team."

*Source, translated from: Encuesta STEPS Ecuador 2018. Available at: https://extranet.who.int/ncdsmicrodata/index.php/catalog/774*

"Cardiochek devices were used for the blood measures in Step 3."

*Source: NCD Microdata repository: Ecuador – STEPS 2018. Available at: https://extranet.who.int/ncdsmicrodata/index.php/catalog/774/study-description#page=data_collection&tab=study-desc*

**Eswatini: STEPS 2014**
"Fasting blood glucose and total cholesterol comprised the targeted biochemical measures of health risks for NCDs. On the first day of the survey after completion of STEP 1 and STEP 2, participants were asked to fast overnight of that day. i.e. people were asked not to consume any food except for clear water after taking dinner on that night until the survey team came in the morning of the following day (day 2). People in the selected EA were seen in their various homesteads where a finger prick was done using a CardioChek PA test system and a drop of blood was tested for glucose and total cholesterol. Those that complied with advice (fasting overnight) were eligible for testing."

*Source: WHO STEPS: Noncommunicable Disease Risk Factor Surveillance Report Swaziland 2014. Available at: https://www.who.int/ncds/surveillance/steps/Swaziland_2014_STEPS_Report.pdf*

**Guyana: STEPS 2016**
"[...] Guyana [...] drew venous blood and did the blood analysis at the laboratory.
Guyana's Laboratory at which the blood testing was done is the Central Medical Laboratory, Georgetown, Guyana."

*Source: Email contact with country team from the Caribbean Public Health Agency (CARPHA). Country Report forthcoming*

**Iran: STEPS 2016**
"Laboratory measurement and Bio–banking
We aimed to store the biological samples that will be randomly collected from all provinces (city/village) of Iran. Using the auto analyzer (Cobas C311 Hitachi High–Technologies Corporation. Tokyo Made in Japan) approved by Health Reference Laboratory, the levels of Total Cholesterol, Glucose, HDL–C, ALT, and Triglyceride were assessed from the plasma.
[…]
Temperature and transport requirements
Maintaining the optimal conditions for the transfer of biological samples using the updated standards for promotion of quality of biological samples and biomolecules maintenance, we developed the comprehensive participatory protocol and related instructions.
Blood and urine sample collection and transport were performed obtained from tube containing lithium heparin (3 cc) and urine (6 cc), the gathered biological samples were transferred to the central processing/archiving laboratory of study in NCDRC. Through a

detailed time-binding action plan, the processes from collection to the central processing/archiving lab were managed in the shortest time (less than 18 hours).
All samples were transported in vaccine transport boxes. During transportation, in each cold box, a digital thermometer recorded the temperature of environment of the biological sample. These enable us to keep biological samples from freezing/ thawing.
[…] The first and second steps of study have been run for all selected samples and the third step was considered for those who were 25≤years of age."

*Source: Djalalinia S, Modirian M, Sheidaei A, Yoosefi M, Zokaiee H, Damirchilu B, Mahmoudi Z, Mahmoudi N, Hajipour MJ, Peykari N, Rezaei N, Haghshenas R, Mohammadi MH, Delavari A, Gouya MM, Naderimagham S, Kousha A, Moghisi A, Mahdavihezaveh AR, Abachizadeh K, Majdzadeh R, Sayyari AA, Malekzadeh R, Larijani B, Farzadfar F. Protocol design for large–scale cross–sectional studies of surveillance of risk factors of non–communicable diseases in Iran: STEPs 2016. Arch Iran Med. 2017; 608 – 616.*

**Iraq: STEPS 2015**
"Laboratory requirements were procured by the Public Health central lab and distributed to the labs under quality control where biochemical analysis was carried out."

*Source: Noncommunicable Diseases Risk Factor STEPS Survey Iraq 2015. Available at: https://www.who.int/ncds/surveillance/steps/iraq/en/*

**Kiribati: STEPS 2015/16**
"In general, the survey personnel obtained informed consent from survey participants, gave fasting instructions to those participating in STEP 3, and made appointment times for those who consented to participate in the survey. Survey personnel conducted STEP 1 (questionnaire) at home if the participant was willing; if not, it will follow STEPS 2 and 3, which was done at a central location in each village on the second (or third) morning.
[…] The survey included taking blood and urine samples. To measure fasting blood glucose and total cholesterol, participants fasted from 10:00pm the previous night until 7:00am the following morning. Capillary blood samples were drawn using the finger prick method; and the Cardiochek used to measure total cholesterol, HDL and glucose in samples."

*Source: Kiribati NCD Risk Factors STEPS Report 2015-2016.*
*Available at: https://www.who.int/ncds/surveillance/steps/kiribati/en/*

**Kyrgyzstan: STEPS 2013**
No further information available

**Lebanon: STEPS 2017**
"After completing Steps 1 and 2, the participants were referred, on specific dates, to the pre-assigned PHC for blood withdrawal. The centrifuged blood and urine samples were collected from the different centers and sent to the central laboratory for biochemical measurements. The laboratory procedures are found in the implementation plan (Annex 1)."

*Source: Who Stepwise Approach For Non-Communicable Diseases Risk Factor Surveillance. Lebanon 2016-2017. Available at:*
*https://extranet.who.int/ncdsmicrodata/index.php/catalog/410/related_materials*

**Marshall Islands: HYBRID 2017**
No further information available

**Moldova: STEPS 2013**

"Laboratory tests were performed for blood glucose, total cholesterol and HDL cholesterol. Concentrations of glucose, total cholesterol and HDL cholesterol were measured in capillary blood the next day after STEPS 1 and 2 of the data collection. Capillary blood tests were performed for all survey respondents using a CardioCheck PA Analyzer, after fasting."

*Source: Prevalence of Noncommunicable Disease Risk Factors in the Republic Of Moldova STEPS 2013. Available at: https://www.who.int/ncds/surveillance/steps/moldova/en/*

**Mongolia: STEPS 2013**

"Laboratory Analysis – blood glucose, total cholesterol and triglycerides were measured in peripheral (capillary) blood at the data collection site using dry chemical methods, biochemical analysis and automated analyzer. Serum samples were collected to analyze LDL and HDL cholesterol and spot urine was collected to determine sodium and creatinine levels in urine.

[…] Randomly selected individuals aged 15-64 years old who were eligible to participate and agreed upon, and signed a consent form, were involved in the step-3, laboratory testing. A researcher who performed anthropometric measurements, and signed the survey card, checked if the participant was eligible, and selected for the step-3 laboratory analysis. For the STEP-3 laboratory analysis, one-third of the selected participants aged 25-64 years were recruited. Laboratory analysis included testing for blood glucose, cholesterol, triglycerides, high density lipoprotein (HDL), and low density lipoprotein (LDL). Laboratory tests for LDL and HDL in blood, as well as sodium and creatinine content in urine were performed and analyzed in "Gyals" LLC's laboratory using biochemical automated analyzer.

**Dry chemical method:** Concentrations of glucose, cholesterol and triglycerides as the intermediate, secondary risk factors of NCDs, were measured in peripheral (capillary) blood at the data collection sites with dry chemical methods using multi-functional "Prima home test" diagnostic device. Prima Home Test Multicare-In Meter for Glucose/ Cholestrol/ Triglycerides Diagnostic device is equipped with 2 technologies: Amperometric with glucose electrodes strips and Reflectometric with cholesterol and triglycerides strips. This diagnostic kit is easy-to-use, very clean and hygienic because it has the strip ejector switch to avoid contact with the used strips. It has a memory capacity of 500 measurements with date and time and analyzes results within 30 seconds. Thus, the participants were informed about the test results directly, at the study sites.

The research team members of the STEP III or laboratory step were involved in researchers' training on how to use the "Prima home test" diagnostic kit, methodology to collect peripheral (capillary) blood at the data collection sites and safety measures.

**Measuring procedures:** After the "Prima home test" portable diagnostic device is regulated properly, a small size of blood sample is collected from a finger tip of a survey participant, and applied to the "yellow area" of a test strip. Blood glucose, cholesterol and triglycerides levels can be determined directly from this test. After each test, a laboratory staff member accurately entered the test results into a hand held computer, prior to starting the next participant's test.

The "Prima home test" portable diagnostic device has the capacity to measure within the following range:

- Glucose: 0.6-33.3 mmol/L
- Cholesterol: 3.3-10.2 mmol/L
- Triglycerides: 0.56 - 5.6 mmol/L

  When the measurement result was lower than the measuring range of the device, the result was evaluated as "very low", and if the result was higher than the measuring range of the device, then the result was evaluated as "very high". For instance, the measuring capacity for the lowest level of glucose is 0.6 mmol/L, therefore, the measurement

results lower than this level was evaluated as “very low”. Similarly, if the glucose level was higher than 33.3 mmol/L, the highest level of the device’s measuring range, the result was evaluated as “very high”. The “very low” and “very high” measurement results were entered into computer programmes.

[…] High density lipoprotein (HDL) and Low density lipoprotein (LDL) content was measured in serum with an automatic analyzer using a direct or two-point linear method in 2,070 blood samples. Urine creatinine was determined using the Mindrayfafle method. A one-time (spot) test for sodium in the urine was determined using the electrolyte method in 2,058 urine samples, by “Gyals” LLC’s Laboratory.

The following requirements were complied with in blood and urine sample collection and transportation:

- Blood sample size to be not less than 2-3 ml
- Urine sample size to be not less than 8-10 ml
- Store samples in a special container in order to prevent hemolyzed specimens and clotted samples
- Samples to be stored at the temperature range of 2-8 0C
- Deliver blood and urine samples to the laboratory within one day in Ulaanbaatar, and within three days in rural areas, complying with the required conditions for storage and transportation
- Referral sheet for laboratory test samples must contain the survey participant’s age, sex, the date when a sample was collected, and the date when a sample was delivered to the laboratory.

The following reagents and diagnostic kits were used for the laboratory tests:

1. For determining High density lipoprotein (HDL) content: HDL – Cholesterol - Kit manufactured by “Mindray” firm (Lot #142112023, Expiry date: May 2014)
2. For determining Low density lipoprotein (LDL) content: LDL – Cholesterol - Kit (Lot #142012017, Expiry date: May 2014)

[…] External and internal monitoring and evaluation were conducted on a regular basis in order to ensure the accuracy of, and compliance with, the standard requirements of the laboratory test results of the biochemical analysis. Regular internal quality control was conducted on a daily basis utilizing control serums “Multi control sera N” and “Multi control sera P” manufactured by the “Mindray” factory. In addition, the external independent quality control was conducted by the “Sysmex” corporation, where accuracy of the laboratory tests was monitored using “MEQAS for biochemistry” control samples prior to and during the biochemical analysis.

Gyals laboratory conducted the biochemical analysis during the period between May 14, 2013 and June 17, 2013 and handed over the test results coded by each survey participant to the PHI’s research team.“

*Source: Third national STEPS Survey on the Prevalence of Noncommunicable Disease and Injury Risk Factors-2013. Available at:*
*https://www.who.int/ncds/surveillance/steps/mongolia/en/*

**Morocco: STEPS 2017**

“During the second visit of the teams, Step3 was carried out by capillary blood test. The material used was Cardiochek PA with a Chip MeMo, blood glucose Strips and blood lipids. The results were immediately given to the participants in results sheets. Each participant's barcodes were used to enter data on the tablets using the same code, allowing us to aggregate the data from the two runs. The recovered spots were packaged in the necessary conditions and sent daily to the reference laboratory by a specific transport company.”

*Source, translated from: National Noncommunicable Disease Risk Factor Survey Report 2017-20178. Available at: https://www.who.int/ncds/surveillance/steps/morocco/en/*

**Myanmar: STEPS 2014**

"Fasting blood glucose, 2 hour blood glucose, total blood cholesterol, triglycerides, HDL and LDL cholesterol were determined using SD LipidoCare Analyzer.

There were 18 data collection teams. In each data collection team, there were 6 members i.e. 1 team leader (medical doctor) for overall management and glucose loading and testing samples for blood glucose and lipids, 2 team members for face-face interview, 2 team members for measuring height and weight and 1 helper for registering and arranging participants.

A 5-day training workshop for the survey data collection teams was conducted at University of Medicine (2),Yangon on 11-15 August 2014

[…] The training workshop included sessions on the overview of STEPwise approach to NCD risk factor surveillance, the plan of the National Survey on Diabetes Mellitus and Risk Factors for Non-communicable Diseases in Myanmar, how to approach selected households and individuals including use of Kish method, PDA-based data collection, interview skills, informed consent, detailed discussion on the survey instrument and how to use show cards, mock interviews, demonstration and practice on physical measurements, use of SD LipiddoCare Analyzer for blood glucose and lipids, emergency management and referral of critically high blood glucose level for medical doctors in the data collection teams and quality control of all field processes.

Each team were provided with a field kit containing: […] devices and test strips for STEP 3 (plus lancets, swabs and sharp containers, gloves, pipettes) and glucose packs for oral glucose tolerance tests.

[…] On the day of the survey when STEP 1 and STEP 2 have been finished, participants were asked to fast overnight i.e. people were be asked not to consume any food or drinks after 10 p.m. at night, except water, until the morning of the following day.

Participants were asked to go to the designated testing centre the next morning where capillary blood was be taken by finger prick for rapid test. Those participants that complied with the fasting advice were eligible for blood sample collection. Blood glucose, cholesterol, triglycerides, HDL and LDL were measured using SD LipidoCare Analyzer onsite, which requires a finger-prick blood draw to measure glucose and blood lipids."

*Source: Report on National Survey of Diabetes Mellitus and Risk Factors of Non-communicable Diseases in Myanmar (2014). Available at: https://www.who.int/ncds/surveillance/steps/myanmar/en/*

**Seychelles: National Survey of Noncommunicable Diseases 2013**

"The following blood tests were performed within 2-3 hours of blood collection at the clinical laboratory of the Seychelles Hospital: total cholesterol, HDL-cholesterol, triglyceride, glucose, creatinine, uric acid, calcium, CRP (all these tests from 1 tube 84 with 1.5 ml serum), glucose (from yellow tube with sodium fluoride and potassium oxalate), A1c (violet EDTA tube). Insulin was analyzed 3 months later from one 1.5 ml microtube of serum.

• All analyses, except insulin and A1c, were done using a fully automatic analyzer Konelab 30i (Finland) with reagents from Thermo Fischer Scientific (USA).

• All tests performed using Konelab 30i were checked with controls on a daily basis.

[…] Cholesterol was measured after enzymatic hydrolysis by cholesterol esterase to cholesterol and free fatty acids, and free cholesterol oxidized by PEG cholesterol oxydase in peroxide, and then submitted to peroxidase to form a chromophore. Imprecision is <3.5% total CV, e.g.

repeatability (within run) of 0.9% CV + within device (total) 1.4% CV at concentration of cholesterol of 5.2 mmol/l.
HDL-cholesterol was measured with an enzymatic colorimetric test after precipitation of non HDL lipoproteins. The cholesterol concentration of HDL-C is determined enzymatically similary as cholesterol (above). Imprecision is <4% of total CV, e.g. 0.5% CV within run + 1.1% CV between run + 1.6% CV between day; total % CV 2.0 at HDL concentration of 1.26 mmol/l.
Triglycerides were measured by hydrolysis by lipase (LPL) to glycerol and fatty acids, glycerol is phosphorylated to glycerol-3- phosphate (by GK), then oxidized to hydrogen peroxide (GPO and POD) to form a quinoneime dye. Imprecision is <4% of total CV, e.g. 0.7% CV repeatability (within run) and CV 2.0% within device (total) at a concentration of triglyceride of 2.07 mmol/l."

*Source: National Survey of Noncommunicable Diseases in Seychelles 2013-2014 (Seychelles Heart Study IV): methods and main findings. Available at: https://www.who.int/ncds/surveillance/steps/Seychelles_2013_STEPS_Report.pdf*

**Solomon Islands: STEPS 2015**
**"**Cardiochek was used for blood glucose and cholesterol measurements."

*Source: NCD Microdata Repository: Solomon Islands – STEPS 2015. Available at: https://extranet.who.int/ncdsmicrodata/index.php/catalog/710/study-description#page=data_collection&tab=study-desc*

**Sri Lanka: STEPS 2014/15**
**"**Cardiochek devices used for glucose and cholesterol measurements."

*Source: NCD Microdata Repository: Sri Lanka – STEPS 2014. Available at: https://extranet.who.int/ncdsmicrodata/index.php/catalog/614/study-description#page=data_collection&tab=study-desc*

**St. Vincent & the Grenadines: STEPS 2013**
"Fifty percent (50%) of the survey participants were asked to provide a biological specimen (finger prick) for Glucose and cholesterol testing using Glucose and Lipid Sampling Kits and respond to the nutrition intake (24 hour recall). The biological sample was only collected with participants' explicit consent; the samples were not stored or used for additional undetermined or undisclosed future testing to which respondents did not agree at the time of participation."

*Source: Ministry of Health, Wellness & the Environment (2015). National Health & Nutrition Survey – Non-Communicable Disease Risk Factor Surveillance Report. Kingstown, Saint Vincent and the Grenadines. Available at: https://www.who.int/ncds/surveillance/steps/StVincent_STEPS_Report_2013-14.pdf?ua=1*

**Sudan: STEPS 2015**
"Blood samples were collected from those who complied with fasting advice and had given their informed consent. Blood glucose and cholesterol were measured using cardio-check examination equipment (Cardio check P.A. In vitro diagnostic medical devices for use with PTS panels test strips. Manufacturer: Polymer Technology Systems, INC, Indianapolis, IN USA CE 0197)."

*Source: Sudan STEPwise Survey for Non-communicable Diseases Risk Factors 2016 Report. Available at: https://www.who.int/ncds/surveillance/steps/sudan/en/*

**Tajikistan: STEPS 2016**
No further information available

**Timor-Leste: STEPS 2014**
"STEP 3 included biochemical measurements including fasting blood glucose and cholesterol were done by dry chemistry method using CardioCheck devices (Figure 2.5). All the measurements were taken at the house of the participant. […]
Day 1 – Survey of the suco for verification of the number of households, calculation of sampling interval, approaching households, taking consent from the selected individuals, interviewing for the STEP 1 and STEP 2, informing the respondents to fast for next day. Day 2 and 3 – Morning fasting samples to be taken from the respondents (by trained enumerators only) whose interviews were completed the previous day. The remaining respondents were interviewed and asked to be fasting for the next day to collect blood samples. The data collection effectively took 45 days "

*Source: Timor-Leste STEPS Survey Report, [online]*
*Available at http://www.who.int/entity/chp/steps/Timor-Leste_2014_STEPS_Report.pdf?ua=1*

**Tonga: STEPS 2017**
"Cardiochek PA devices were used for the blood measures in Step 3."

*Source: NCD Microdata repository: Tonga – STEPS 2017. Available at: https://extranet.who.int/ncdsmicrodata/index.php/catalog/713/study-description#page=data_collection&tab=study-desc*

**Tokelau: STEPS 2014**
"Targeted biochemical measures of health risks for NCDs were measured including fasting blood glucose and total cholesterol. Selected core survey personnel were trained in conducting these measurements through the use of specific protocols with monitored quality control.
Each participant was provided with an appointment sheet and fasting instructions and also informed that there was refreshment prepared for them at the survey site so that they can have something to eat after measurement of their fasting blood glucose and total cholesterol.
As indicated in the diagram for the set-up of the venue, biochemical measurements were conducted in Station 2 after they had registered. Participants were instructed to fast from 10:00pm the previous night and scheduled for 07:00am the following morning for biochemical measurements with refreshment ready by the time the completed this station so that participants had something to eat before continuing on to the next STEPS of the survey. The survey team as well had an early morning each day of the survey, at about 6:00am to ensure that all stations were ready before the first participant registered.
Fasting blood glucose was measured using the Advantage glucose meter with test strips and capillary blood samples using finger pricks. The blood sampling and measure of fasting blood glucose followed specific control testing protocols, using the Accutrend Glucose control solution at the beginning of the day and after testing of about 20-25 patients or when there was an unusual participant result.
With each finger prick, two blood samples were obtained, one for the fasting blood glucose, and one for the blood cholesterol measurement. Total cholesterol was measured using the Accutrend GC meter and approporiate cholesterol test strips. The total cholesterol was measured once in mmol/Litre. Also, the meter was calibrated for accuracy at the beginning of the day, after about 20-25 participants, or when there was an unusual participant result. Accutrend Cholesterol control solution was used in this calibration.

After completion of these biochemical measurements, participants were directed towards the refreshment station, however, a few preferred to continue on to the blood pressure station before refreshment."

*Source: Tokelau NCD Risk Factors STEPS Report. Available at: https://www.who.int/ncds/surveillance/steps/STEPS_Report_Tokelau.pdf*

**Tuvalu: STEPS 2015**

"Accutrend Plus meter and Accu-chek Performa were used for cholesterol and glucose measurements."

Source: *NCD Microdata repository:Tuvalu – STEPS 2015. Available at: https://extranet.who.int/ncdsmicrodata/index.php/catalog/639/study-description#page=data_collection&tab=study-desc*

**Vietnam: STEPS 2015**

"Devices for testing blood glucose and cholesterol (Cardio Check).
[…] STEPS 2 and 3: conducted by provincial preventive medicine centers under the supervision from National and Regional Epidemiology/Pasteur Institutes at selected Commune Health Station (CHS).
[…] - Finger blood test was used to measure blood glucose, total cholesterol and HDL
[…] Each province had one data collection team including 5 GATS interviewers who were in charge of interviewing at households and 3 local staff who were in charge of conducting STEPS 2 and 3 at the CHS. In each EA, the data collection was carried out in 2 days.

- The first day: Interview at household
  5 GATS interviewers visited households in the provided list. A the households interviewer do the following:
  […]
  - Instruct subject for overnight fasting and visiting the CHS in the next morning for physical measurement and blood test.
  - In case the STEPS 2-3 cannot be done the next day, then the team in charge will inform respondents of a suitable nearest date and then visited the households the day before to pass on the tube for urine sample collection and provided instruction for the respondents to fast and come to the CHS the day after for STEPS 2-3 data collection.
  - The STEPS1 Coordinator then provided the interviewee list to STEPS 2-3 team coordinator for follow up and for STEPS 2-3 data collection.
- The second day: Physical measurement and blood tests at commune health station

In the morning when STEPS 2-3 data collection took place, village health collaborators went to households to invite subjects to bring urine tube to the CHS and participate in physical measurements and blood tests. The data collection was conducted in the early morning to ensure the fasting of subjects.
At the CHS, there was 3 staff to collect data:

- 01 technician to perform blood test using handheld devices and collects urine tube to store in the cold vacuum.
- 01 staff to perform blood pressure measurement following standard procedures.
- 01 staff to measure height, weight, waist circumference, and make conclusion."

*Source: Vietnam Ministry of Health, General Department of Preventive Medicine (2016): National Survey on the Risk Factors of Non-communicable Diseases (STEPS) Vietnam, 2015. Hanoi. Available at:*
*https://www.who.int/ncds/surveillance/steps/viet_nam/en/*

**Zambia: STEPS 2017**
"STEP 3 included blood chemistry rapid diagnostic tests to assess fasting blood glucose and total cholesterol. This was done by the use of Cardio-Check spot testing equipment.
[…] STEP 3 was done in the morning of the following day in most cases. However in some places modifications were made so that participants were prepared beforehand through local leaders and community health workers, who were contact before the research teams arrived. Eligible members from sampled families were asked to come to a central location on a named day and time. Participants were told not to eat until they were seen by the research team. Once on site, the research team explained the purpose of the study to sampled families. Prior to entering the names of those eligible, selection was done and urine was collected immediately after validating that it wasn't the first time to pass urine that morning. For those who had fasted, glucose measurements were taken the same day while those who had not fasted, glucose measurements were done the following morning."

*Source: Republic of Zambia Ministry of Health: Zambia Steps for Noncommunicable Diseases Risk Factors. Available at: https://www.who.int/ncds/surveillance/steps/zambia/en*

### A.3.3 Blood Glucose Measurement Methods

| Diabetes Biomarker | Country | Post Hoc Adjustment* |
|---|---|---|
| **Point-of-care fasting capillary glucose** | | |
| Accu-check | Tuvalu | None |
| Accutrend® Plus (Roche, Basel, Switzerland) | Guyana | Multiplied by 1.11 |
| CardioCheck® PA (pts Diagnostics, Indianapolis, Indiana, USA) | Afghanistan, Belarus, Benin, Bhutan, Burkina Faso, Eswatini, Kenya, Kiribati, Moldova, Morocco, Nauru, Nepal, Solomon Islands, St. Vincent & The Grenadines, Sudan, Sri Lanka, Timor-Leste, Tokelau, Turkmenistan, Uganda, Vietnam, Zambia | None |
| MultiCare-in© (Biochemical Systems International, Arezzo, Italy) | Georgia | None |
| SD LipidoCare Analyzer (automatic plasma equivalent) | Myanmar | None |
| Prima home test | Mongolia | None |

| | | |
|---|---|---|
| Unknown | Algeria, Azerbaijan, Botswana, Ecuador, Kyrgyzstan, Tajikistan | None |
| **Laboratory-based Assessment of Fasting Plasma Glucose** | | |
| Central laboratory was used for processing | Bangladesh, Lebanon, Mexico | N/A |
| Cobas 6000 and C311 analyzer (Roche Diagnostics, Indianapolis, Indiana, USA) | Iran | N/A |
| Enzymatic assay (glucose oxidase) | Iraq | N/A |
| CardioCheck PA Analyser | Ethiopia, Jordan | N/A |
| **Hemoglobin A1c (HbA1c)** | | |
| Dried blood spots using the Hemocue system | Indonesia | N/A |
| Plasma sample by Cobas C311 auto-analyzer (Roche kits) | Iran | N/A |
| Central laboratory | Mexico | N/A |
| Unknown | Guyana | N/A |
| Unknown | Armenia | N/A |

Note: N/A=Not available.

### A.3.4 Blood Pressure Measurement Methods

| Country | Measurement device | Number of measurements | Interval between measurements |
|---|---|---|---|
| Afghanistan | Calibrated sphygmomanometer | 3 | 3 minutes |
| Algeria | No report available | No report available | No report available |
| Armenia | No report available | No report available | No report available |
| Azerbaijan | Riester Ri-Champion Automatic Digital Monitor-1715 | 3 | 10 minutes |
| Bangladesh | Life Source UA-767 Plus Digital Monitor | 3 | 10 minutes |
| Belarus | Boso-Medicus Uno | 3 | 3 minutes |
| Benin | Boso Medicus Uno | 3 | 3 minutes |
| Bhutan | Omron digital upper arm | 3 | 5 minutes |

| Country | Measurement device | Number of measurements | Interval between measurements |
|---|---|---|---|
| | meter (model not specified) | | |
| Botswana | Not specified | Not specified | Not specified |
| Burkina Faso | Omron Digital Monitor HEM-705CP | 3 | 10 minutes |
| Ecuador | Not specified | Not specified | Not specified |
| Eswatini | Boso Medicus PC (model not specified) | 3 | 3-5 minutes |
| Ethiopia | Boso-Medicus Uno | 3 | 3 minutes |
| Georgia | Boso Medicus Uno | 3 | 3 minutes |
| Guyana | Omron digital upper arm meter (model not specified) | 3 | 3 minutes |
| Iran | Beurer BM 20 | 3 | 5 |
| Iraq | Not specified | Not specified | Not specified |
| Jordan | Omron M3 | Not specified | Not specified |
| Kenya | Omron M2 Digital Monitor | 3 | 3-5 minutes |
| Kiribati | OMRON M4 Digital Automatic Blood Pressure Monitor | 3 | 2-3 minutes |
| Kyrgyzstan | No report available | No report available | No report available |
| Lebanon | Manual mercury sphygmomanometer | 2 | 5 minutes |
| Mexico | Omron HEM-907 XL | “AHA protocol” | “AHA protocol” |
| Moldova | Boso-Medicus Uno | 3 | 3 minutes |
| Mongolia | Not specified | Not specified | Not specified |
| Morocco | Spengler® ES 60 | 3 | “a few minutes” |
| Myanmar | Boso-Medicus automatic digital blood pressure monitor (model not specified) | 3 | 3 minutes |
| Nauru | No report available | No report available | No report available |
| Nepal | Omron digital upper arm meter (model not specified) | 3 | 3 minutes |
| Solomon Islands | No report available | No report available | No report available |
| Sri Lanka | Not specified | Not specified | Not specified |
| St. Vincent & the Grenadines | Omron Digital Monitor M4 - I | 3 | 3 minutes |
| Sudan | Boso-Medicus Uno | 3 | 3 minutes |
| Tajikistan | No report available | No report available | No report available |
| Timor-Leste | Omron digital upper arm meter (model not specified) | 3 | 2 minutes |
| Tokelau | No report available | No report available | No report available |

| Country | Measurement device | Number of measurements | Interval between measurements |
|---|---|---|---|
| Turkmenistan | OMRON device | No report available | No report available |
| Tuvalu | No report available | No report available | No report available |
| Uganda | Boso Medicus Uno | 3 | 3-5 minutes |
| Vietnam | BOSO Device | Not specified | Not Specified |
| Zambia | Not specified | 3 | 3-5 minutes |

Note: N/A=Not available.

### A.3.5 Country Classification

We grouped countries by geographic region as defined by the World Health Organization (WHO n.d.) and income group as defined by the World Bank in the year the survey was conducted (World Bank 2020). We classified Nauru (World Bank n.d.) and Tokelau (Government of Tokelau n.d.) as upper-middle-income countries based on our review of per-capita income, as World Bank classifications were not available in the year the survey was conducted.

### A.3.6 Sampling Weights

The STEPS datasets include three survey weights for each part of the survey instrument, including the interview (Step 1), physical measurements (Step 2), and biochemical measurements (Step 3), as different samples of participants are included in the three survey parts. STEPS weights are adjusted for the probability of selection, non-response, and differences between the sample population and the target population. Because the analyses in this study rely on lipid measurements as part of the STEPS instrument Step 3, Step 3 weights, referred to as WStep3, were applied in the analyses of STEPS data.

Although most of the datasets included in the study are STEPS surveys (32 STEPS surveys were included), for Chile the 2009/10 National Health Survey, for Seychelles the 2013 National Survey of Noncommunicable Diseases, and for the Marshall Islands the 2017 HYBRID Survey were used. In these surveys also specific weights for biochemical measurements were used where available.

The table below lists the weight variables used for the respective dataset:

| STEPS Survey: | Weight Variable |
|---|---|
| Algeria | wstep3 |
| Azerbaijan | wstep3 |
| Bangladesh | wstep3 |
| Belarus | wstep3 |
| Benin | wstep3 |
| Bhutan | wstep3 |
| Botswana | wstep3 |
| Burkina Faso | wstep3 |
| Costa Rica | wstep3 |
| Ecuador | wstep3 |
| Eswatini | wstep3 |

| | |
|---|---|
| Guyana | wstep3 |
| Iran | wstep3 |
| Iraq | wstep3 |
| Kiribati | wstep3 |
| Kyrgystan | wstep3 |
| Lebanon | wstep3 |
| Moldova | wstep3 |
| Mongolia | wstep3 |
| Morocco | wstep3 |
| Myanmar | wstep3 |
| Solomon Islands | wstep3 |
| Sri Lanka | wstep3 |
| St. Vincent and the Grenadines | wstep3 |
| Sudan | wstep3 |
| Tajikistan | wstep3 |
| Timor-Leste | 1* |
| Tokelau | wstep3 |
| Tonga | wstep3 |
| Tuvalu | wstep3 |
| Vietnam | wstep3 |
| Zambia | wstep3 |
| | |
| **Non-STEPS surveys** | |
| Chile - 2009/10 National Health Survey | fexp_fac and fexp_ex |
| Seychelles - 2013 National Survey of Noncommunicable Diseases | wpop |
| Marshall Islands - 2017 HYBRID Survey | 1[+] |

*Notes*: *As a STEPS survey country, the Timor-Leste data included wstep3. However, the weighted sample characteristics were not consistent with what would be expected from the population of Timor-Leste (or any population) and it was decided that unweighted data were used as the more conservative option.
[+]For Marshall Islands no sample weights were provided as the sampling was said to be representative of the population.

When weights were missing, the average weight was assigned to observations with missing weight values. Further, when observations had to be dropped from the sample because of missing values, for example, in covariates, the survey weights were adjusted proportionally.

In the main analysis of cascades, each country contributes equally to the estimations. To achieve this, the relevant weights of all datasets were rescaled so that the sum of weights in one dataset referring to one country equals 1. In analyses in which surveys should contribute to estimations by their respective country's population size, weights were rescaled so that the sum of weights in one dataset equals the country's population size.

## A.4 Data Cleaning

We used total cholesterol directly as reported. We calculated LDL cholesterol (LDL-C) from total cholesterol (TC), triglycerides, and HDL cholesterol. Whenever LDL-C values were already calculated, we recalculated them to ensure consistency across countries. Hence, in the following we specify cleaning not only for TC and LDL-C, but also for HDL cholesterol and triglycerides.

### A.4.1 Plausible ranges

Lower cut-off

Values below 3 mg/dL for total cholesterol (N=0), triglycerides (N=0), and HDL cholesterol (N=44) to missing. This is the most conservative exclusion of data, given the possible measurement ranges of the various point-of-care measurement devices used in the countries (see S3 Text) (pts Diagnostics n.d.).

Upper cut-off

While it is difficult to define upper ranges for total cholesterol, as physiologically very large values can occur, we decided to apply an upper cut-off, primarily because point-of-care devices are not always well-equipped to reliably measure these (pts Diagnostics n.d.; Panz et al. 2005). We oriented ourselves on the upper cut-offs that can be reliably measured by point-of-care-devices as well as ranges indicated to us by in-country lab partners and decided on the following: values above 300 mg/dL for TC (N=170), 600 mg/dL for triglycerides (N=72), and 100 mg/dL for HDL cholesterol (N=48) were set to missing. For LDL-C, values were set to missing if triglycerides were higher than 400 mg/dL (N=131). We include a sensitivity cascade analysis (Fig E in S1 Fig), in which we do not impose an upper cut-off for TC. As can be seen this does not substantially alter the results.

LDL-C negative values:

After dropping values below 3 mg/dL for TC, triglycerides, and HDL cholesterol, 12 observations had negative calculated LDL-C values. Of these, all corresponding TC, triglycerides, and most HDL cholesterol values were individually biological plausible. Each of these observations was flagged and then their LDL-C value was set to missing.

### A.4.2 Definitions

LDL cholesterol

All LDL-C values were derived by our team according to the Friedewald equation (Friedewald, Levy, and Fredrickson 1972):

$$\text{LDL-C (mg/dL)} = \text{TC (mg/dL)} - \text{HDL (mg/dL)} - \text{TG (mg/dL)} / 5$$

Triglycerides and HDL cholesterol were only utilized to derive LDL-C. While both triglycerides and HDL cholesterol have been established as independent risk factors for coronary heart disease, their relevance and efficacy as targets of therapy is still unclear (National Cholesterol Education Program 2001).

High total cholesterol

An individual was classified as having high TC if their level was above 6.21 mmol/L (according to ATP III guidelines) or if they reported taking medication for high cholesterol (National Cholesterol Education Program 2001). If individuals had only a self-reported medication status and no TC measurement, they were excluded from the analysis. A sensitivity analysis that includes 1209 additional individuals with no biomarker measurement, for whom high TC is

defined purely based on the respondent's self-reported medication status can be found in Fig D S1 Fig.

High LDL cholesterol

An individual was classified as having high levels of LDL-C if their level was above 4.14 mmol/L (according to ATP III guidelines) or if they reported taking medication for high cholesterol. If individuals had only a self-reported medication status and no LDL-C measurement, they were excluded from the analysis.

### A.4.3 Skip Patterns

Biomarkers were taken of all respondents, except for pregnant women.
The self-reported variables follow the specified skip pattern:

| Country | Ever tested | Ever told | Taking meds |
|---|---|---|---|
| Algeria, Azerbaijan, Bangladesh, Belarus, Benin, Bhutan, Botswana, Burkina Faso, Ecuador, Eswatini, Guyana, Iran, Iraq, Kiribati, Kyrgyzstan, Lebanon, Marshall Islands, Moldova, Mongolia, Morocco, Myanmar, Solomon Islands, Sri Lanka, Saint Vincent & the Grenadines, Tajikistan, Timor-Leste, Tokelau, Tonga, Tuvalu, Vietnam, Zambia | asked | skip | skip |
| Chile, Costa Rica | asked | asked | skip |
| Sudan | ? | ? | ? |
| Seychelles | asked | asked | asked |

The cascades analysis was based on the natural STEPS skip pattern of "ever tested – asked", "ever told – skip", "taking meds – skip". This skip pattern is followed by the majority of countries. This means that if respondents replied to the question about whether they have ever had their lipids measured with "0: No", then the subsequent questions on whether they have been ever told their hypercholesterolemia diagnosis or are taking medication were not asked, leaving their values for these respondents missing. Instead they were simply assumed to all be equal to "0: No", since somebody who has never been tested could not be diagnosed.
For the countries following the skip pattern, we made this assumption tangible by setting the missings due to skip pattern to "0: No". Answers that were coded as "don't know" were also recoded as "0: No".
For the countries that did not follow the skip pattern, we still imposed it artificially for matter of consistency with the STEPS countries. That is, whenever respondents answered the lead question with "0: No", the following (skip) questions were set to "0: No". There were very few instances in which this actually changed the coding. In case of the diagnosis stage, 2 observations switched from yes to no in Seychelles; 16 observations switched from yes to no in Chile; 11 observations switched from yes to no in Belize; and 81 observations switched from yes to no in Costa Rica. For the medication question, 1 observation switched from yes to no in Seychelles; 11 observations switched from yes to no in Chile; 2 observations switched from yes to no in Belize; and 72 observations switched from yes to no in Costa Rica.

| Country | Lifestyle Advice |
|---|---|
| Algeria, Belarus, Benin, Bhutan, Botswana, Burkina Faso, Costa Rica, Eswatini, Guyana, Iran, Iraq, Kiribati, Kyrgyzstan, Lebanon, Moldova, Mongolia, Morocco, Myanmar, Seychelles, Solomon Islands, Sri Lanka, Saint Vincent & the Grenadines, Sudan, Tajikistan, Timor-Leste, Tokelau, Tonga, Tuvalu, Vietnam | asked |
| Azerbaijan, Bangladesh, Ecuador, Zambia | skipped |

In four countries, also the lifestyle advice questions followed a skip pattern. This skip pattern was introduced by the question of whether the respondent has visited a doctor or health professional in the time frame as specified in the lifestyle advice questions (see below for exact phrasing). If respondents said no, they would not be asked the lifestyle advice questions either. In order to be consistent with the procedure above, we recoded lifestyle advice in these cases to be "0: No".

### A.4.4 Consistency of Phrasing Across Surveys

***Essay 1 Survey Questions***

Measurement

| | |
|---|---|
| Algeria, Azerbaijan, Bangladesh, Belarus, Benin, Bhutan, Botswana, Burkina Faso*, Ecuador, Eswatini, Guyana, Iran, Kiribati, Kyrgyzstan, Lebanon, Moldova, Morocco, Solomon Islands, Sri Lanka, Saint Vincent & the Grenadines, Tajikistan, Timor-Leste, Tokelau, Tonga, Tuvalu, Vietnam, Zambia | Have you ever had your cholesterol (fat levels in your blood) measured by a doctor or other health worker? |
| Chile | When was the last time you had your cholesterol measured |
| Costa Rica | In the last 12 months, has there been any lipid analysis (cholesterol, triglycerides, or fats) in the blood) |
| Marshall Islands | Blood cholesterol is a fatty substance found in the blood. Have you ever had your blood cholesterol checked by a doctor, nurse, or other health worker? |
| Mongolia, Myanmar | Have you ever had your cholesterol measured by a doctor or other health worker? |
| Seychelles | Have you ever had your blood cholesterol checked? |

Diagnosis

| | |
|---|---|
| Algeria, Azerbaijan, Belarus, Benin, Bhutan, Botswana, Burkina Faso*, Ecuador, Eswatini, Guyana, Iran, Kiribati, Kyrgyzstan, Lebanon, Moldova, Mongolia, Morocco, Myanmar, Solomon Islands, Sri Lanka, Saint Vincent & the Grenadines, Tajikistan, Timor-Leste, Tokelau, Tonga, Tuvalu, Vietnam, Zambia | Have you ever been told by a doctor or other health worker that you have raised cholesterol? |
| Chile | Has a doctor, nurse or other health professional ever told you that you have had or have high cholesterol? |
| Costa Rica | Have you been diagnosed with an alteration of lipids (cholesterol, triglycerides, or fats) by a doctor or other health professional |
| Marshall Islands | Have you ever been told by a doctor, nurse, or other health professional that your blood cholesterol is high? |
| Seychelles | Has a doctor, nurse or any other healthcare worker ever told you that you have high blood cholesterol |

Medication

| | |
|---|---|
| Belarus | In the past two weeks, have you taken any high cholesterol drugs (medication) prescribed by a doctor or other healthcare professional? |
| Algeria, Azerbaijan, Bangladesh, Benin, Bhutan, Botswana, Burkina Faso*, Ecuador, Eswatini, Guyana, Iran, Kiribati, Kyrgyzstan, Lebanon, Moldova, Mongolia, Morocco, Myanmar, Solomon Islands, Sri Lanka, Saint Vincent & the Grenadines, Tajikistan, Timor-Leste, Tokelau, Tonga, Tuvalu, Vietnam, Zambia | In the past two weeks, have you taken any oral treatment (medication) for raised total cholesterol prescribed by a doctor or other health worker? |
| Chile | Are you currently taking or doing some program, treatment or change in lifestyle to keep your cholesterol controlled? What kind of treatment are you taking? |
| Costa Rica | Do you currently receive any of the treatments or the advice indicated below, prescribed by a doctor or other health professional, for having alterations of the lipids (cholesterol, triglycerides, or fats)? Medication taken during the last two weeks |
| Marshall Islands | Are you currently receiving drugs medicine prescribed by a doctor or other health worker for your high cholesterol that you have taken in the past two weeks? |
| Seychelles | Do you currently take any medication to reduce your blood cholesterol (statin)? |

Advice

| | |
|---|---|
| Azerbaijan, Bangladesh, Ecuador | During any of your visits to a doctor or other health worker in the past 12 months, were you advised to do any of the following? Start or do more physical activity; maintain a healthy body weight or lose weight; reduce fat in your diet; quit using tobacco or don't start; eat at least five servings of fruit and/or vegetables each day |
| Algeria, Belarus, Benin, Bhutan, Botswana, Burkina Faso*, Eswatini, Guyana, Iran, Kiribati, Kyrgyzstan, Lebanon, Moldova, Morocco, Myanmar, Solomon Islands, Sri Lanka, Saint Vincent & the Grenadines, Tajikistan, Timor-Leste, Tokelau, Tuvalu, Vietnam, Zambia | During the past three years, has a doctor or other health worker advised you to do any of the following? Start or do more physical activity; maintain a healthy body weight or lose weight; reduce fat in your diet; quit using tobacco or don't start; eat at least five servings of fruit and/or vegetables each day |
| Chile, Marshall Islands | NA |
| Costa Rica | Do you currently receive any of the treatments or the advice indicated below, prescribed by a doctor or other health professional, for having alterations of the lipids (cholesterol, triglycerides, or fats)? Special diet by medical prescription; Advice or treatment to lose weight |
| Mongolia | During the past three years, has a doctor or other health worker advised you to do any of the following? Do at least 30 minutes of physical activity on at least 5 days per week; maintain a healthy body weight or lose weight; reduce fat in your diet; quit using tobacco or don't start; eat at least five servings of fruit and/or vegetables each day |
| Seychelles | During the past 12 months, did a health officer advise you about smoking; your diet; in relation to weight control; about the need to have more regular physical activity, perhaps in relation to a medical condition that you may have? |
| Tonga | During the past three years, has a doctor or other health worker advised you to do any of the following? Start or do more physical activity; maintain a healthy body weight or lose weight; quit using tobacco or don't start |

* No survey instrument was available for Burkina Faso. However, from the survey report as well as the question labeling of the data, it appears that these questions were taken directly from the generic WHO STEPS questionnaire (unlike others relating to food hygiene and fruit and vegetable intake that were adapted to the local context).

As can be seen above, there are no substantive differences in the ever measured questions across countries, except for small deviations in the case of Costa Rica – which refers to past 12 months only – and Chile. This has to be taken into account when interpreting the cascades results of Costa Rica as we might be underestimating the met need for care at the measurement stage, if many diagnoses occurred earlier than one year prior to the survey. The diagnosis questions are also virtually the same throughout. In case of the medication phrasing slight differences in again the time frame of the question occurs. While most countries specify a time period of two weeks, others ask for current treatment. We assumed this did not affect the cascades analysis. The survey questions on lifestyle advice are again almost the same throughout, except for Chile and

Marshall Islands, in which case we do not have data on this variable, and Tonga, which did not ask about diet advice received.

***Essay 2 Survey Questions***

| **Variable** | **STEPS surveys** | **ENSANUT 2018 (Mexico survey)*** |
|---|---|---|
| Statin use | Are you currently taking statins (Lovastatin/Simvastatin/Atorvastatin or any other statin) regularly to prevent or treat heart disease? | Do you take any of the following medications:<br>pravastatin, atorvastatin, simvastatin, rosuvastatin, pitavastatin, ezetimibe? |
| Prior CVD history | Have you ever had a heart attack or chest pain from heart disease (angina) or a stroke (cerebrovascular accident or incident)? | Has your doctor told you that you have (or had):<br>a) a myocardial infarction or heart attack?<br>b) angina pectoris (chest pain or discomfort, which usually goes away with rest or with medicines)? |

*Questions translated from the original Spanish by the authors.

As shown above, the question on statin use in the 2018-19 Mexico ENSANUT survey specifically mentioned five statins by name as well as a single non-statin cholesterol-lowering medication (ezetimibe, which is a cholesterol absorption inhibitor).

The survey in Iraq only asked participants about statin use conditional on a respondent self-reporting a history of heart disease/stroke. Thus, the Iraq data was only included in the secondary prevention outcome.

As observed above, the underlying surveys did not permit us to differentiate among respondents who had heart disease versus strokes (and whether a stroke was ischemic or hemorrhagic) or whether the ischemic heart disease reflected a prior myocardial infarction and/or chronic angina.

## A.5 Supplementary Statistical Methods

### A.5.1 Essay 1: Mathematical Equation to Regression Specifications

We apply a modified Poisson regression specification to estimate the association between individual-level characteristics and cascade progression using the following framework:

$$CascStage_{ip}^{n} = \alpha + \beta\, IndCharac_i + \delta_c + \varepsilon_{ip} \quad \text{if } CascStage_{is}^{n-1} = 1\,,$$

where

$CascStage_{si}^{n}$ is the binary outcome variable of individual $i$ in primary sampling unit $p$ describing whether the respective cascade stage $n$ was achieved conditional on completion of prior cascade stages. Specifically, the four cascade stages are "Lipids Measured", "Aware of Diagnosis", "Advice or Medication", and "Controlled Disease";

$\alpha$ is the intercept;

$IndCharac_i$ is a vector with characteristics of individual *i*, i.e. age, sex, education, smoking, body mass index, diabetes status, and hypertension status;

$\delta_c$ is a fixed effect for the survey in country $c$; and

$\varepsilon_{ip}$ is an individual level error term with a robust structure, clustering at the primary sampling unit $p$.

### A.5.2 Essay 2:

***Outcomes***

The numerator and denominator for the outcomes are defined below. The numerator was the same for each of the outcomes. The denominator varied depending on whether the outcome was primary or secondary CVD. As described in the methods, we defined these outcomes to be consistent with the monitoring indicator recommended in the WHO NCD Global Monitoring Framework (WHO 2014b), 1/10/2023 8:53:00 AMWHO HEARTS Technical Package for CVD Management in Primary Health Care (WHO 2018), and the WHO-PEN clinical guidelines (WHO 2020b).

**Table: Definitions of outcome denominators**

| Numerator | Outcome | Denominator |
|---|---|---|
| Self-reported statin use | Secondary prevention | Number of non-pregnant adults ages 40-69 years who self report prior CVD |
| | Primary prevention | Number of non-pregnant adults ages 40-69 years without a history of self-reported CVD and either (1) a history of self-reported diabetes or (2) 10-year CVD risk >20% using the 2019 WHO laboratory-based risk equations (Kaptoge et al. 2019) |

For the primary prevention outcome in the main analysis that included a universal indication for a statin among non-pregnant adults 40 years and older with diabetes, we defined diabetes as both (1) an individual's self-reported prior diagnosis of diabetes in the survey and (2) use of either a glucose-lowering medication (oral glucose-lowering medication or insulin) or

biochemical evidence of diabetes as defined by the WHO as detailed below (WHO 2006; 2011).

As described in the methods, we explored drivers of statin use across countries by plotting statin use against several country-level characteristics. The data on each country's per-capita health spending was imported from the World Bank (World Bank 2021a), which uses the WHO Global Health Expenditure Database as its data source (WHO n.d.). The definition of health expenditure is:

"[A]ll activities with the primary purpose of improving, maintaining and preventing the deterioration of the health status of persons and mitigating the consequences of ill-health through the application of qualified health knowledge [medical, paramedical and nursing knowledge, including technology, and traditional, complementary and alternative medicine (TCAM)]." (OECD and WHO 2011)

We chose to use per-capita gross national income (World Bank 2021b) rather than per-capita gross domestic product as this is the economic measure used by the World Bank in country income group classifications (World Bank 2020).

For the NCD policy score, we used the method reported by Allen and colleagues (Allen et al. 2020) with updated data from the 2020 WHO NCD Progress Monitor (WHO 2020b):

"Following the approach used in an internal WHO memo (unpublished), we accorded a value of one point for each fully implemented intervention, half a point for partially implemented interventions, and zero for interventions that had not been implemented or for which there were no data available. We generated national aggregate scores … and transformed these into percentages so that full implementation of every policy was equal to 100%." (Allen et al. 2020)

### *Statistical analysis*

To calculate CVD risk scores using the 2019 WHO laboratory-based risk equations (Kaptoge et al. 2019), we used the *whocvdrisk* package in Stata (Cardiovascular Epidemiology Unit n.d.). To calculate the 2007 WHO/International Society of Hypertension (WHO/ISH) CVD risk scores (WHO 2007; S. Mendis, Lindholm, and Mancia 2007), we used the *whoishRisk* package in R (D. Collins et al. 2016). Both of these CVD risk equations use diabetes status and systolic blood pressure, among other variables, as inputs. As in our prior work (Manne-Goehler et al. 2019; Seiglie et al. 2020; Teufel et al. 2020; Flood et al. 2021), we defined diabetes status by self-reported use of a glucose-lowering medication (oral glucose-lowering medication or insulin) or biochemical evidence of diabetes using the WHO definition: fasting plasma glucose (FPG) ≥7.0 mmol/l (126 mg/dl), random plasma glucose ≥11.1 mmol/l (200 mg/dl), or an HbA1c measurement ≥6.5% (WHO 2006; 2011). We averaged systolic blood pressure blood pressure measurements over multiple readings.

For the within-country regressions of statin use for the secondary prevention of CVD, we limited the models to countries with at least 5 respondents in the survey who self-reported statin use. All regressions were adjusted for sex and age. Age was included in three categories (40-49 years, 50-59 years, and 60-69 years) for all the regressions except for panel B in which it was dichotomized as ≥ 55 years or ≤ 55 years.

For the regression models using the pooled sample, we only included countries with the full suite of individual-level covariates (n=27 countries). Age was included in three categories (40-49 years, 50-59 years, and 60-69 years). The education variable was not available in Tokelau, and the rural residence variable was not available in n=14 countries (Botswana, Ecuador, Eswatini, Kiribati, Lebanon, Myanmar, Nauru, Solomon Islands, Sri Lanka, St. Vincent and the Grenadines, Tajikistan, Timor-Leste, Tokelau, and Tuvalu). We opted to include rural versus urban residence in the main analysis as the variable was available in most of the large countries in our sample that together represent approximately 90% of the underlying population of individuals ages 40-69 years of age.

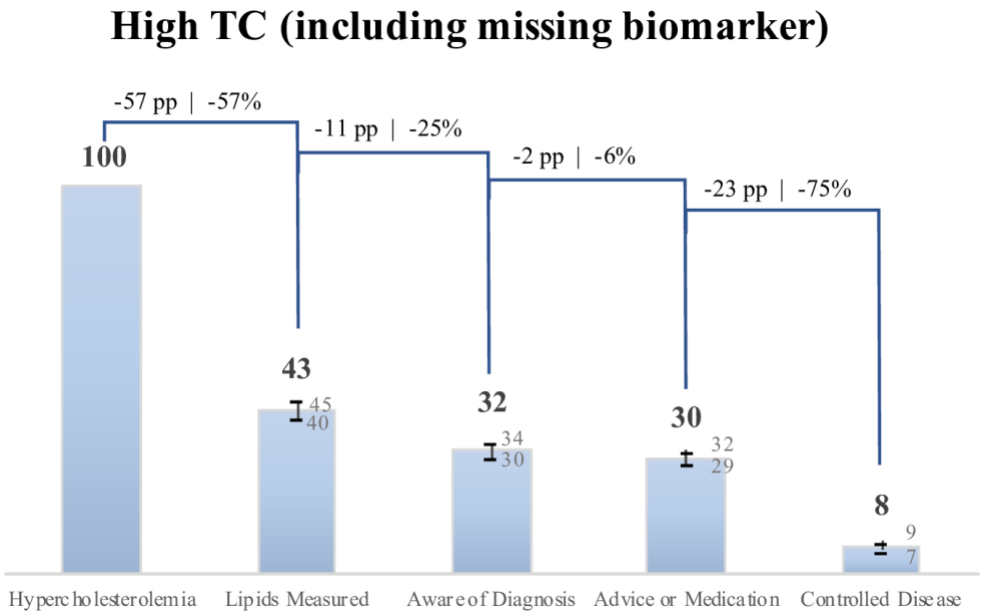
As described in the methods section, in all analyses, we used sampling weights and adjusted for stratification and clustering at the level of the primary sampling unit. We used demographic or risk factor weights (i.e., Step 1 weights in STEP surveys (Riley et al. 2016)) for the secondary prevention outcome. We used subsample weights (i.e., biomarker-based or Step 3 weights in STEPS surveys (Riley et al. 2016) for the primary prevention outcome as availability of biochemical measurements including total cholesterol was required for the calculation of the laboratory-based CVD risk scores. All weights are adjusted for the probability of selection, non-response, and differences between the sample population and the target population. Whenever sampling weights were missing, the average weight was assigned to observations with missing weight values. We rescaled weights such that the sum of weights within each country reflects its population size in relation to the other countries using 2019 population estimates of people 40-69 years produced by the Global Burden of Disease project (Global Burden of Disease Collaborative Network 2020). Whenever observations had to be dropped from the sample because of missingness in covariates, survey weights were rescaled such that the overall relative population weighting across countries remained valid.

We ran the following analyses in R version 4.0.5: (1) WHO ISH risk scores using the *whoishRisk* package (D. Collins et al. 2016) and (2) construction of Figure 2 and Figure 3 using the *ggplot2* package. All other analyses were carried out in Stata version 16.1. The statistical code was reviewed by two authors within the study team (MEM and DF). Replication code is available at the Harvard Dataverse (https://doi.org/10.7910/DVN/BTSHNR). Country-specific contact information regarding data access is provided in Appendix A.2.

## A.6 Supplementary Analyses

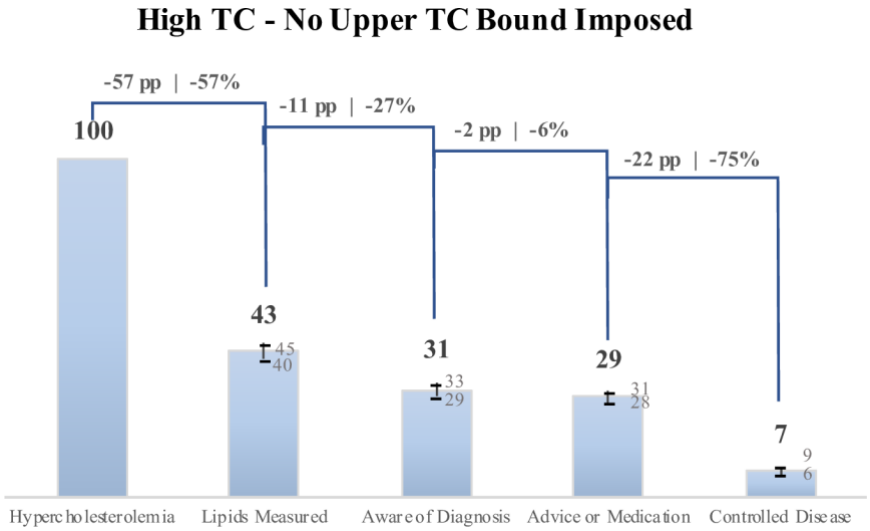
### A.6.1 Essay 1: Figures

Figure A.6 - 1: Cascade of Care of high TC Including Respondents with Missing Biomarker



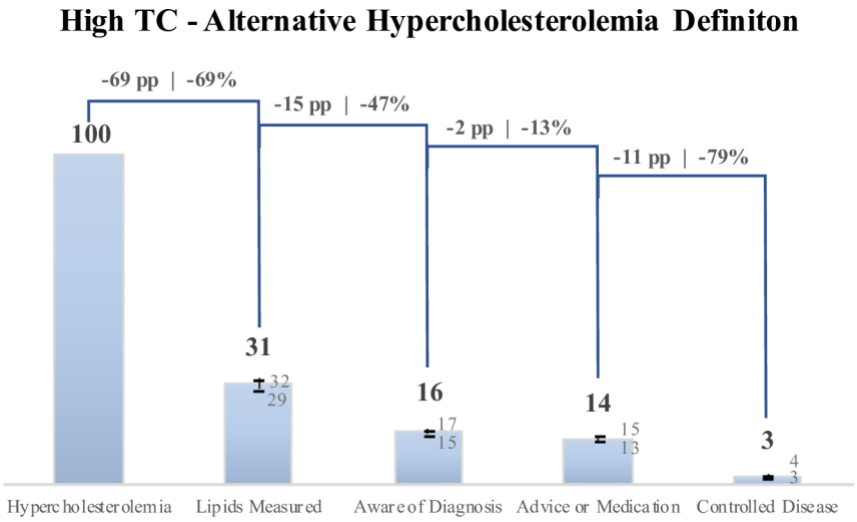

Note: See Note Figure A.6 - 3; Hypercholesterolemia refers to all respondents that are classified as having high TC (≥240 mg/dL) or a self-reported medication status. Also includes respondents for whom no TC measure was available. In those cases hypercholesterolemia is based on the self-reported medication status only.

Figure A.6 - 2: Cascade of Care for High TC, No Upper Bound for Plausible TC Values Imposed



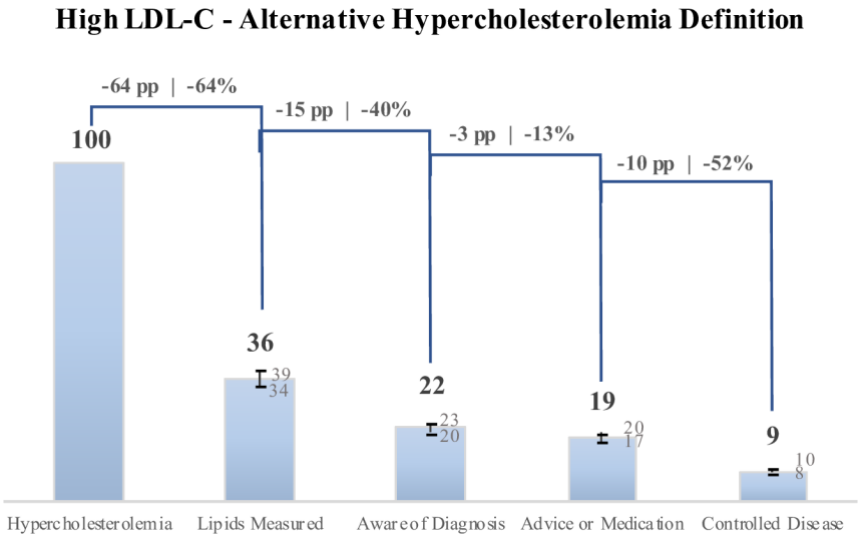

See note Figure A.6 - 3; Hypercholesterolemia refers to all respondents that are classified as having high TC (≥240 mg/dL – including observations with TC values above 300 mg/dl) or a self-reported medication status. Consecutive cascade stages are all based on the denominator of all respondents classified as having hypercholesterolemia.

Figure A.6 - 3: Cascade of Care for High TC with Borderline High TC Values Classified as Hypercholesterolemia



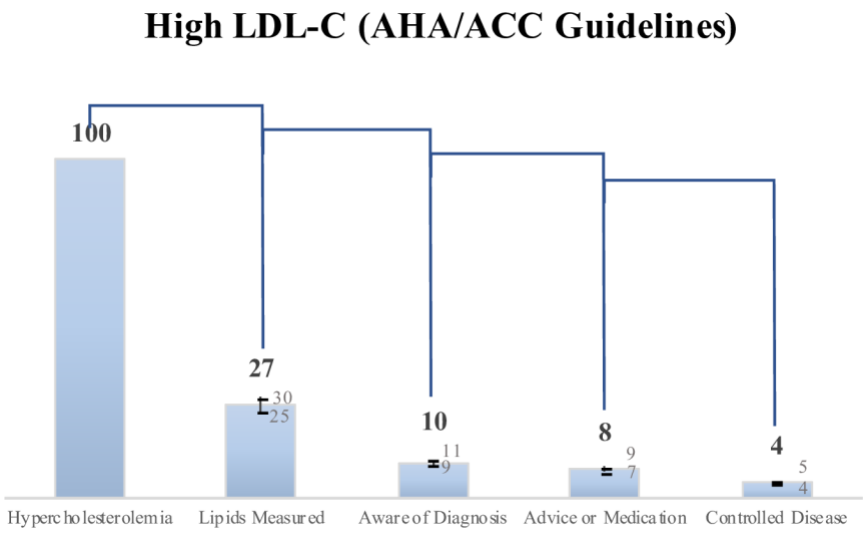

Note: Point estimates are represented by bars and shown in numeric form above bars, 95% confidence intervals are indicated by upper and lower bounds in numeric form and by whiskers. On top, the absolute percentage point drops of each cascade step are shown on the left-hand side and the relative percent drop on the right-hand side. All calculations incorporate Primary Sampling Units and strata to account for the different survey designs of included countries, as well as use sampling weights rescaled such that all countries contribute equally; Hypercholesterolemia refers to all respondents that are classified as having high TC (≥ 200 mg/dL) or a self-reported medication status. Lipids Measured refers to the percentage share of all respondents with high TC that have ever had their lipid status measured as per self-reported information. Accordingly, Aware of Diagnosis refers to the percentage share of all that have (self-reportedly) ever been diagnosed by a medical professional with hypercholesterolemia whereas Advice or Medication refers to those that have received medication or lifestyle advice for their disease. Controlled Disease considers those respondents that have TC and LDL-C values within the range considered normal by ATP III guidelines.

Figure A.6 - 4: Cascade of Care for High LDL-C with Borderline High LDL-C Values Classified as Hypercholesterolemia



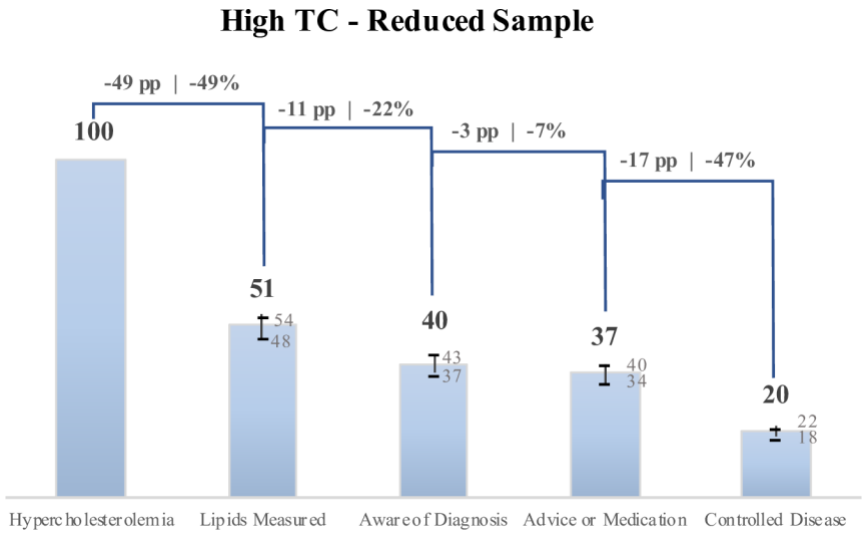

Note: See Note Figure A.6 - 3; Hypercholesterolemia refers to all respondents that are classified as having high LDL-C (≥ 130 mg/dL) or a self-reported medication status.

Figure A.6 - 5: Cascade of Care for High LDL-C based on AHA/ACC Guidelines



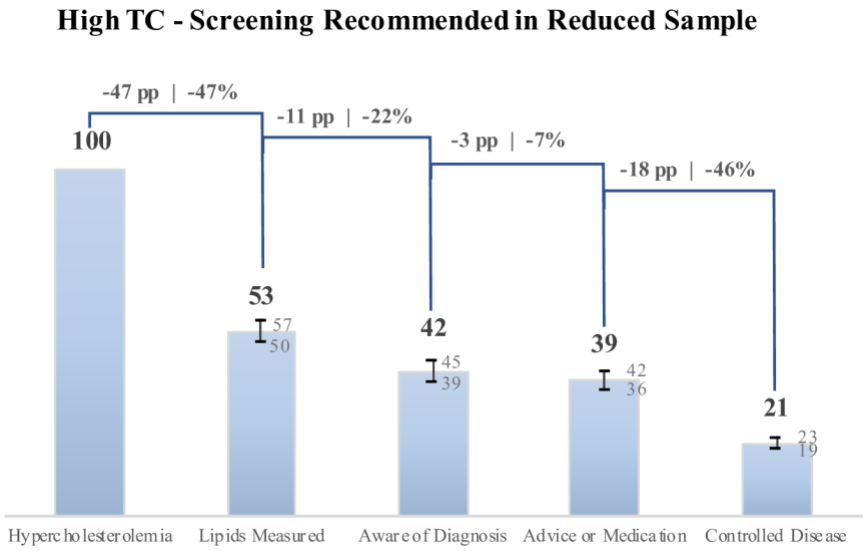

Note: See Note Figure A.6 - 3; Hypercholesterolemia refers to all respondents that are classified as having high LDL-C (≥ 70 mg/dL) or a self-reported medication status.

Figure A.6 - 6: Cascade of Care for High TC in Countries with Non-missing LDL-C Records



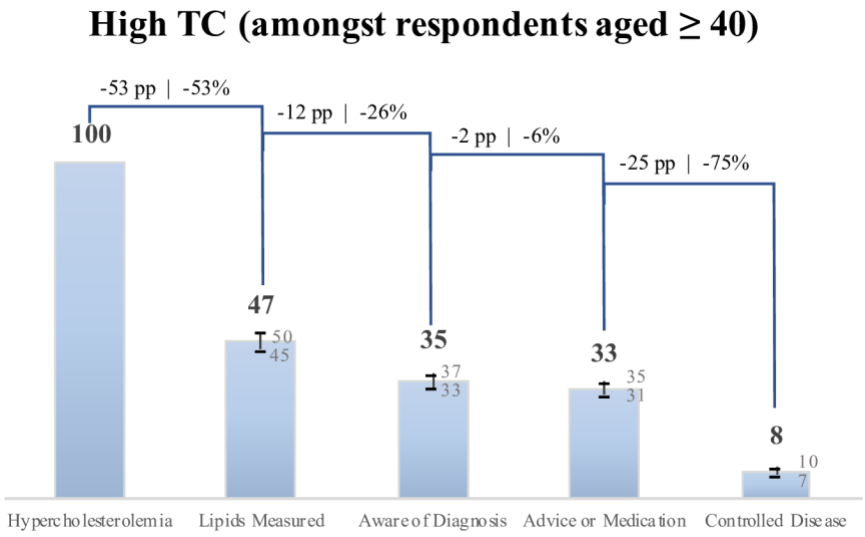

Note: See Note Figure A.6 - 3; Hypercholesterolemia refers to all respondents that are classified as having high TC (≥240 mg/dL) or a self-reported medication status. Included countries are Algeria, Bangladesh, Burkina Faso, Chile, Costa Rica, Iran, Iraq, Lebanon, Mongolia, Morocco, Myanmar, Seychelles, and St. Vincent & the Grenadines.

Figure A.6 - 7: Cascade of Care for High TC in Countries with Non-missing LDL-C Records, Restricted to Screening Recommended Sample



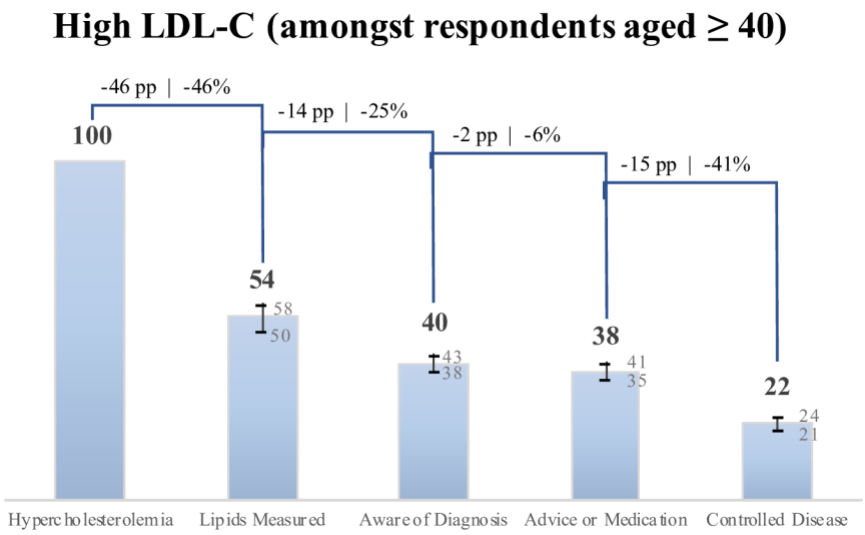

See Note Figure A.6 - 3; Hypercholesterolemia refers to all respondents that are classified as having high TC (≥240 mg/dL) or a self-reported medication status and for whom screening is recommended based on the exhibition of at least one of the following risk factors: age>40; smoking; diabetic; hypertensive; waist circumference≥90 in males; waist circumference≥100 in females. Consecutive cascade stages are all based on the denominator of all respondents classified as having hypercholesterolemia.

Figure A.6 - 8: Cascade of Care for High TC amongst Respondents Aged ≥40



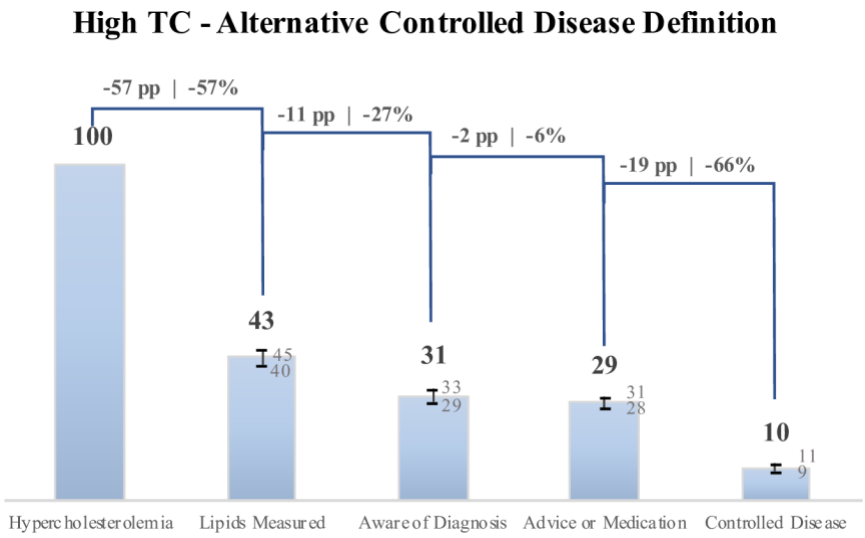

Note: See Note Figure A.6 - 3; Hypercholesterolemia refers to all respondents that are classified as having high TC (≥240 mg/dL) or a self-reported medication status. Cascade restricted to respondents aged 40 or older.

Figure A.6 - 9: Cascade of Care for High LDL-C amongst Respondents Aged ≥40



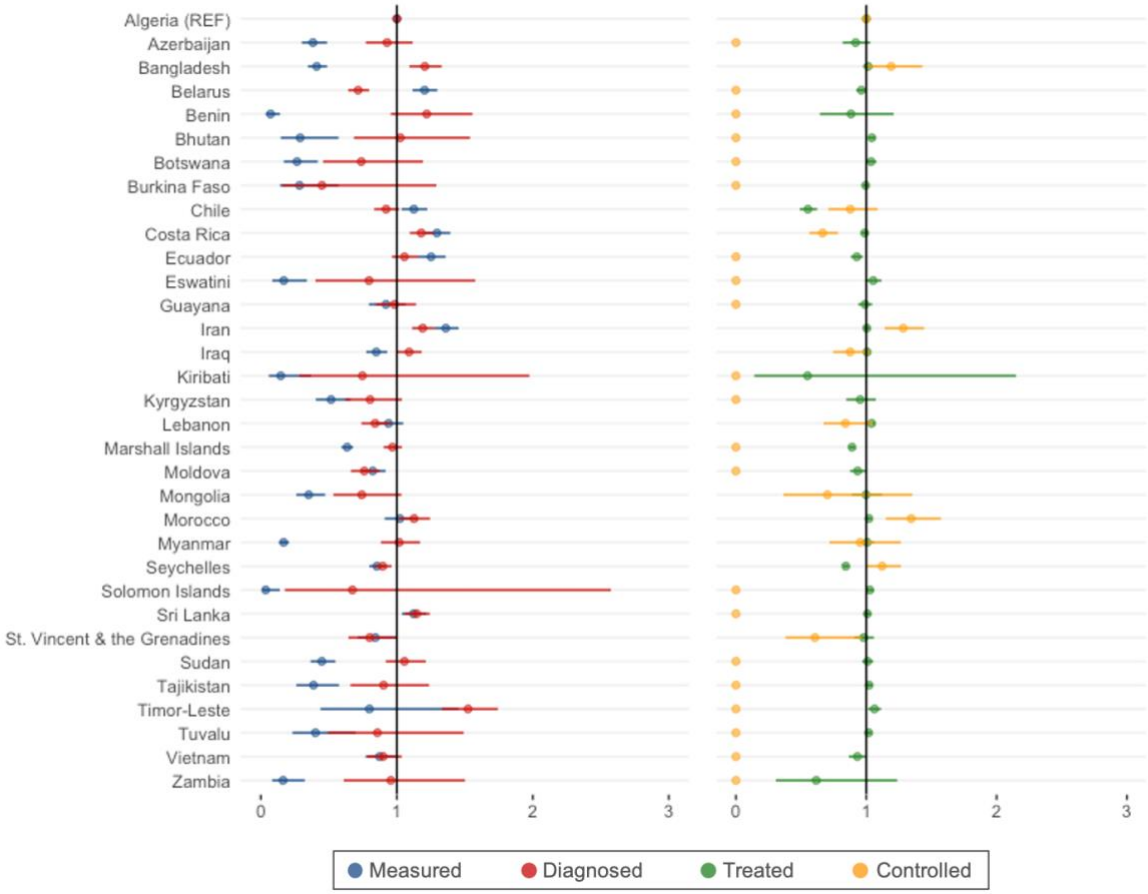

Note: See Note Figure A.6 - 3; Hypercholesterolemia refers to all respondents that are classified as having high LDL-C (≥160 mg/dL) or a self-reported medication status. Cascade restricted to respondents aged 40 or older.

Figure A.6 - 10: Cascade of Care for High TC, Alternative Controlled Disease Definition Applied



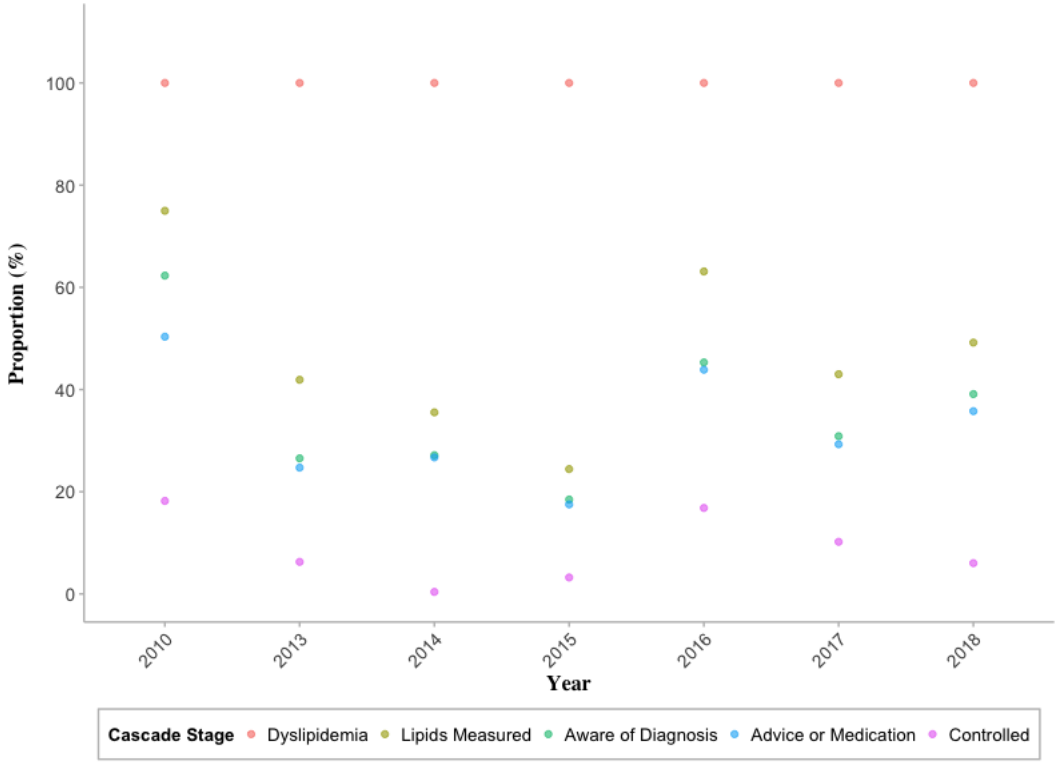

See note Figure A.6 - 3; Hypercholesterolemia refers to all respondents that are classified as having high TC (≥240 mg/dL) or a self-reported medication status. Controlled Disease considers those respondents that have TC and LDL-C values within the range considered normal or borderline high by ATP III guidelines.

Figure A.6 - 11: Country Fixed Effects in Main Multivariable Poisson Regression Specification




Note: Country fixed effects for multivariable Poisson regression models (Table 2.1-2 in main manuscript) with robust error structure, clustering at PSU level, using "Lipids Measured", "Aware of Diagnosis", "Advice or Medication", and "Controlled Disease" as dependent variables, and age, sex, education, smoking, BMI, and comorbid diabetes and hypertension as independent variables. Each cascade stage estimation is conditioned on completion of prior cascade stages. The coefficients indicate risk ratios. The regression samples do not include Tokelau, due to its missing education variable, nor Tonga, due to its missing diabetes variable.

Figure A.6 - 12: Cascade of Care for High TC by Survey Year




See Note Figure A.6 - 3; Hypercholesterolemia refers to all respondents that are classified as having high TC (≥240 mg/dL) or a self-reported medication status.

## A.6.2 Essay 1: Tables

Table A.6 - 1: Summary of 35 population-based surveys conducted in low- and middle-income countries and country-level characteristics

| Country | Year | Sample size[†] | Age Range | Measured Total Cholesterol | Measured LDL Cholesterol | GDP per capita[§] | Health expenditures per capita[#] | World Bank Country Income Classification[*] | WHO Epidemiological Subregion[**] |
|---|---|---|---|---|---|---|---|---|---|
| Algeria | 2016 | 6,132 | 18 - 69 | Yes | Yes | 3,946 | 260 | UMI | Africa |
| Azerbaijan | 2017 | 2,621 | 18 - 69 | Yes | No | 4,147 | 276 | UMI | EME |
| Bangladesh | 2018 | 6,929 | 18 - 69 | Yes | Yes | 1,698 | 42 | LMI | SEAP |
| Belarus | 2016 | 4,744 | 18 - 69 | Yes | No | 5,023 | 298 | UMI | EME |
| Benin | 2015 | 4,761 | 18 - 69 | Yes | No | 1,077 | 31 | LI | Africa |
| Bhutan | 2014 | 2,690 | 18 - 69 | Yes | No | 2,505 | 80 | LMI | SEAP |
| Botswana | 2014 | 3,367 | 15 - 69 | Yes | No | 7,781 | 419 | UMI | Africa |
| Burkina Faso | 2013 | 4,440 | 25 - 64 | Yes | Yes | 787 | 44 | LI | Africa |
| Chile | 2009/10 | 2,704 | ≥ 15 | Yes | Yes | 12,860 | 871 | UMI | The Americas |
| Costa Rica | 2010 | 2,606 | ≥ 20 | Yes | Yes | 8,199 | 664 | UMI | The Americas |
| Ecuador | 2018 | 3,986 | 18-69 | Yes | No | 6,296 | 516 | UMI | The Americas |
| Eswatini | 2014 | 2,889 | 15 - 69 | Yes | No | 3,380 | 253 | LMI | Africa |
| Guyana | 2016 | 849 | 18 - 69 | Yes | No | 4,531 | 222 | UMI | The Americas |
| Iran[***] | 2016 | 19,349 | ≥ 18 | Yes | Yes | 5,253 | 454 | UMI | EME |
| Iraq | 2015 | 3,629 | ≥ 18 | Yes | Yes | 4,990 | 154 | UMI | EME |
| Kiribati | 2015/16 | 1,162 | 18 - 69 | Yes | No | 1,585 | 145 | LMI | SEAP |
| Kyrgyzstan | 2013 | 2,495 | 25 - 64 | Yes | No | 1,282 | 106 | LMI | EME |
| Lebanon | 2017 | 1,152 | 18 - 69 | Yes | Yes | 7,801 | 719 | UMI | EME |
| Marshall Islands | 2017 | 2,716 | ≥ 18 | Yes | No | 3,667 | 588 | UMI | SEAP |
| Moldova | 2013 | 3,695 | 18 - 69 | Yes | No | 3,322 | 232 | LMI | EME |
| Mongolia | 2013 | 1,883 | 15 - 64 | Yes | Yes | 4,366 | 178 | LMI | SEAP |
| Morocco | 2017 | 4,668 | ≥ 18 | Yes | Yes | 3,036 | 161 | LMI | EME |
| Myanmar | 2014 | 7,736 | 25 - 64 | Yes | Yes | 1,252 | 53 | LMI | SEAP |
| Seychelles | 2013 | 1,189 | 25 - 64 | Yes | Yes | 14,765 | 497 | UMI | Africa |
| Solomon Islands | 2015 | 1,671 | 18 - 69 | Yes | No | 1,914 | 103 | LMI | SEAP |
| Sri Lanka | 2014/15 | 4,460 | 18 - 69 | Yes | No | 3,844 | 139 | LMI | SEAP |
| St. Vincent & the Grenadines | 2013 | 1,010 | 18 - 69 | Yes | Yes | 6,597 | 289 | UMI | The Americas |
| Sudan | 2015 | 6,760 | 18 - 69 | Yes | No | 1,910 | 158 | LMI | EME |
| Tajikistan | 2016 | 3,595 | 18 - 69 | Yes | No | 803 | 56 | LMI | EME |
| Timor-Leste | 2014 | 1,012 | 18 - 69 | Yes | No | 3,336 | 78 | LMI | SEAP |
| Tokelau | 2014 | 511 | 15-64 | Yes | No | NA | NA | UMI | SEAP |
| Tonga | 2017 | 2,595 | 18 - 69 | Yes | No | 4,217 | 222 | UMI | SEAP |
| Tuvalu | 2015 | 2,431 | 18 - 69 | Yes | No | 3,198 | 536 | UMI | SEAP |
| Vietnam | 2015 | 2,981 | 18 - 69 | Yes | No | 2,085 | 117 | LMI | SEAP |
| Zambia | 2017 | 3,635 | 18 - 69 | Yes | No | 1,535 | 68 | LMI | Africa |

[†] Number of participants with at least one non-missing lipid biomarker, aged ≥15 years and non-pregnant. Unweighted.

[§] GDP per capita in (latter) survey year (in current US$) from World Bank national accounts data and OECD National Accounts data files.

[#] Current expenditures on health per capita in (latter) survey year (in current US$) from World Health Organization Global Health Expenditure database

[*] World Bank income classification in survey year: LI - Low income; LMI - Lower-middle income; UMI - Upper-middle income

[**] WHO epidemiological subregion according to WHO/ISH risk charts: EME - Eastern Mediterranean & Europe; SEAP - S.E. Asia & Western Pacific

[***] Lipid measures were only carried out on respondents of 25 years of age or older

Table A.6 - 2: High TC and High LDL-C Prevalences by Age Cohort

| | Total Cholesterol Sample* | | LDL Cholesterol Sample** | |
|---|---|---|---|---|
| | Prevalence | Confidence Interval | Prevalence | Confidence Interval |
| Overall | 7.1 | [6.8 , 7.4] | 7.5 | [7.1 , 7.9] |
| By Age | | | | |
| 15 - 24 y/o | 1.6 | [1.2 , 2.2] | 2.0 | [1.4 , 2.8] |
| 25 - 34 y/o | 3.4 | [2.9 , 4.1] | 3.8 | [3.1 , 4.5] |
| 35 - 44 y/o | 5.8 | [5.3 , 6.3] | 6.1 | [5.5 , 6.7] |
| 45 - 54 y/o | 10.8 | [10 , 11.6] | 10.6 | [9.6 , 11.7] |
| 55 - 64 y/o | 14.4 | [13.3 , 15.5] | 14.2 | [12.9 , 15.6] |
| 65+ y/o | 14.8 | [13.2 , 16.6] | 16.3 | [13.6 , 19.4] |

Note:
Prevalences account for sampling design with survey weights re-scaled by the survey's sample size such that all countries contribute to estimates according to their population size.
* Includes respondents from all 32 countries with a valid total cholesterol measurement;
** Includes respondents from Algeria, Bangladesh, Burkina Faso, Chile, Costa Rica, Iran, Iraq, Lebanon, Mongolia, Morocco, Myanmar, Seychelles, and St. Vincent & the Grenadines with a valid LDL-C measurement

Table A.6 - 3: Socio-demographic sample characteristics for respondents with TC and LDL-C in normal ranges and no self-reported medication use

| | **Total Cholesterol Sample*** Normal TC | | **LDL Cholesterol Sample**** Normal LDL-C | |
|---|---|---|---|---|
| | Number of Observations† | Percentage or Mean‡ | Number of Observations† | Percentage or Mean‡ |
| Female | 118264 | 50 | 52016 | 52 |
| Age(mean) | 118265 | 39 | 52017 | 40 |
| 15 - 24 y/o | 12096 | 16 | 12202 | 13 |
| 25 - 34 y/o | 28735 | 27 | 29043 | 27 |
| 35 - 44 y/o | 28732 | 23 | 29421 | 24 |
| 45 - 54 y/o | 23997 | 18 | 25275 | 18 |
| 55 - 64 y/o | 17429 | 12 | 18915 | 12 |
| 65+ y/o | 7314 | 5 | 7869 | 5 |
| Education | | | | |
| Less than primary school | 23660 | 21 | 24110 | 26 |
| Less than secondary school | 35936 | 34 | 37030 | 39 |
| Secondary completed or higher | 57022 | 45 | 59794 | 36 |
| BMI | | | | |
| Normal | 51219 | 53 | 52385 | 49 |
| Underweight | 8092 | 10 | 8210 | 9 |
| Overweight | 32648 | 25 | 34053 | 27 |
| Obese | 24309 | 13 | 25956 | 15 |
| Smoking# | 117630 | 20 | 51682 | 20 |
| Diabetic | 111825 | 7 | 51098 | 8 |
| Hypertensive | 117105 | 25 | 51501 | 25 |
| Screening recommended§ | 118265 | 66 | 52017 | 69 |

* Includes respondents from all 32 countries with a valid total cholesterol measurement

** Includes respondents from Algeria, Bangladesh, Burkina Faso, Chile, Costa Rica, Iran, Iraq, Lebanon, Mongolia, Morocco, Myanmar, Seychelles, and St. Vincent & the Grenadines with a valid LDL-C measurement

† Unweighted

‡ Values account for sampling design with survey weights re-scaled by the survey's sample size such that all countries contribute to estimates according to their population size

# Respondents that are currently smoking or were smoking within past 12 months are classified as smoking (as per WHO PEN Protocol 1)

§ According to the PEN protocol, screening is recommended whenever the respondent exhibits at least one of the following risk factors: age >= 40; smoking; diabetic; hypertensive; waist circumference >= 90 in males; waist circumference >=100 in females

Table A.6 - 4: Cascade of Care Disaggregated for Medication and Lifestyle Advice Stage

| | High TC | | High LDL-C | |
|---|---|---|---|---|
| | Percent | 95% CI | Percent | 95% CI |
| Hypercholesterolemia | 100 | | 100 | |
| Lipids Measured | 43 | [40 , 45] | 47 | [44 , 50] |
| Aware of Diagnosis | 31 | [29 , 33] | 36 | [33 , 38] |
| Medication | 24 | [22 , 26] | 29 | [27 , 32] |
| Controlled Disease | 7 | [6 , 8] | 19 | [18 , 21] |
| Advice | 25 | [23 , 27] | 26 | [24 , 28] |
| Controlled Disease | 6 | [5 , 7] | 15 | [14 , 17] |
| Only Medication | 5 | [3 , 7] | 7 | [6 , 8] |
| Controlled Disease | 1 | [1 , 2] | 4 | [3 , 5] |
| Only Advice | 5 | [4 , 6] | 4 | [3 , 5] |
| Controlled Disease | 0 | [0 , 0] | 0 | [0 , 0] |

Note: Hypercholesterolemia refers to all respondents that are classified as having high TC (≥240 mg/dL) or a self-reported medication status in the first column and high LDL-C (≥160 mg/dL) or a self-reported medication status in the second column. Medication refers to those that have received medication for their high cholesterol (independent of whether lifestyle advice was also received) and advice refers to those that have received lifestyle advice (independent of whether medication was also received). Only Medication refers to having received medication, but not lifestyle advice. Only advice refers to having received lifestyle advice, but not medication. Controlled Disease considers those respondents that have TC and LDL-C values within the range considered normal by ATP III guidelines. All cascade stages are restricted on reaching the prior cascade stages. All calculations incorporate Primary Sampling Units and strata to account for the different survey designs of included countries, as well as use sampling weights rescaled such that all countries contribute equally.

Table A.6 - 5: Cascade of Care by Region

| | Number of Observations With Biomarker * | Prevalence of Hypercholesterolemia† | | Number of Observations With Hyper-cholesterolemia** | Lipids Measured†‡ | | Aware of Diagnosis†‡ | | Advice or Medication†‡ | | Controlled Disease†‡ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Percent | 95% CI | | Percent | 95% CI | Percent | 95% CI | Percent | 95% CI | Percent | 95% CI |
| Africa | | | | | | | | | | | | |
| High TC | 26413 | 4.8 | [2.3,9.6] | 1198 | 29 | [21,40] | 22 | [15,30] | 20 | [15,28] | 7 | [4,13] |
| High LDL-C | 8560 | 9.8 | [4.1,21.6] | 756 | 41 | [31,52] | 27 | [22,33] | 25 | [21,29] | 15 | [13,18] |
| The Americas | | | | | | | | | | | | |
| High TC | 11154 | 15.1 | [13.5,16.9] | 1983 | 66 | [61,71] | 50 | [45,55] | 44 | [39,48] | 9 | [7,11] |
| High LDL-C | 5862 | 16.8 | [14.3,19.8] | 1310 | 63 | [57,70] | 49 | [42,55] | 42 | [35,49] | 16 | [13,20] |
| S.E. Asia & Western Pacific | | | | | | | | | | | | |
| High TC | 39765 | 6.3 | [5.7, 7] | 2966 | 34 | [30,38] | 25 | [21,29] | 23 | [20,27] | 2 | [1,2] |
| High LDL-C | 15582 | 7.1 | [6, 8.2] | 1204 | 15 | [12,19] | 10 | [8,13] | 10 | [8,13] | 6 | [5,8] |
| Eastern Mediterranean & Europe | | | | | | | | | | | | |
| High TC | 51708 | 8.5 | [8,9] | 4590 | 52 | [49,55] | 37 | [34,39] | 36 | [33,38] | 14 | [13,15] |
| High LDL-C | 28328 | 13.8 | [12.7,14.9] | 3045 | 63 | [59,66] | 51 | [48,55] | 51 | [47,54] | 35 | [32,38] |

Note:
* Number of observations, aged 15+ and nonpregnant, with a valid measurement of TC in the case of High TC and LDL-C in the case of High LDL-C
** Number of all respondents classified as having dyslipidemia based on TC / LDL-C measures or a self-reported medication status (defined by exceeding ATP III guideline cutoffs, ie.TC≥240 mg/dL / LDL-C≥160 mg/dL or respondent taking lipid medication)
† Adjusted for sampling design
‡ See note Table A

Table A.6 - 6: Cascade of Care by World Income Classification

| | Number of Observations With Biomarker* | Prevalence of Hypercholesterolemia† | | Number of Observations With Hyper-cholesterolemia** | Lipids Measured†‡ | | Aware of Diagnosis†‡ | | Advice or Medication†‡ | | Controlled Disease†‡ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Percent | 95% CI | | Percent | 95% CI | Percent | 95% CI | Percent | 95% CI | Percent | 95% CI |
| Low Income | | | | | | | | | | | | |
| High TC | 9201 | 2.2 | [1.8,2.6] | 256 | 13 | [6 , 24] | 8 | [3 , 20] | 8 | [3 , 20] | 0 | [0 , 0] |
| High LDL-C | 1374 | 1.1 | [0.6,1.9] | 16 | 9 | [1 , 58] | 0 | [0 , 0] | 0 | [0 , 0] | 0 | [0 , 0] |
| Lower-middle Income | | | | | | | | | | | | |
| High TC | 58668 | 4.3 | [3.9,4.7] | 3343 | 29 | [27 , 32] | 22 | [19 , 25] | 21 | [19 , 24] | 4 | [4 , 5] |
| High LDL-C | 20171 | 5.9 | [5.1,6.7] | 1347 | 28 | [25 , 32] | 22 | [19 , 25] | 21 | [19 , 25] | 17 | [14 , 20] |
| Upper-middle Income | | | | | | | | | | | | |
| High TC | 61171 | 11.9 | [10.8,13.2] | 7138 | 59 | [56 , 61] | 43 | [40 , 45] | 39 | [37 , 42] | 11 | [9 , 13] |
| High LDL-C | 36787 | 16.4 | [14.7,18.4] | 4952 | 61 | [57 , 65] | 47 | [43 , 51] | 43 | [38 , 48] | 23 | [21 , 25] |

Note:

* Number of observations, aged 15+ and nonpregnant, with a valid measurement of TC in the case of High TC and LDL-C in the case of High LDL-C

** Number of all respondents classified as having dyslipidemia based on TC / LDL-C measures or a self-reported medication status (defined by exceeding ATP III guideline cutoffs, ie.TC≥240 mg/dL / LDL-C≥160 mg/dL or respondent taking lipid medication)

† Adjusted for sampling design

‡ See note Table A

Table A.6 - 7: Cascade of Care by Country

| | Number of Observations With Biomarker* | Prevalence of Hyper-cholesterolemia† | | Number of Observations With Hyper-cholesterolemia** | Lipids Measured†‡ | | Aware of Diagnosis†‡ | | Advice or Medication†‡ | | Controlled Disease†‡ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Percent | 95% CI | | Percent | 95% CI | Percent | 95% CI | Percent | 95% CI | Percent | 95% CI |
| Algeria | | | | | | | | | | | | |
| High TC | 6132 | 6.1 | [5.4 , 6.9] | 459 | 63 | [57,69] | 49 | [44,54] | 47 | [42,52] | 27 | [23,32] |
| High LDL-C | 6008 | 6.1 | [5.4 , 6.8] | 448 | 62 | [56,67] | 47 | [42,53] | 46 | [41,52] | 28 | [23,33] |
| Azerbaijan | | | | | | | | | | | | |
| High TC | 2621 | 5.4 | [4.5 , 6.6] | 193 | 28 | [20,37] | 18 | [12,26] | 16 | [10,24] | 0 | [0,0] |
| Bangladesh | | | | | | | | | | | | |
| High TC | 6929 | 4.9 | [4.2 , 5.8] | 414 | 20 | [16,26] | 18 | [14,23] | 18 | [14,22] | 12 | [9,17] |
| High LDL-C | 6762 | 5.0 | [4.4 , 5.8] | 405 | 19 | [15,24] | 16 | [12,21] | 15 | [12,20] | 12 | [9,16] |
| Belarus | | | | | | | | | | | | |
| High TC | 4744 | 9.9 | [8.8 , 11.1] | 583 | 88 | [83,91] | 47 | [42,52] | 45 | [40,50] | 0 | [0,0] |
| Benin | | | | | | | | | | | | |
| High TC | 4761 | 3.5 | [2.7 , 4.5] | 220 | 4 | [2,10] | 4 | [1,10] | 3 | [1,9] | 0 | [0,0] |
| Bhutan | | | | | | | | | | | | |
| High TC | 2683 | 1.5 | [1.1 , 2.2] | 46 | 14 | [5,35] | 9 | [4,23] | 9 | [4,23] | 0 | [0,0] |
| Botswana | | | | | | | | | | | | |
| High TC | 3367 | 2.7 | [1.8 , 3.8] | 104 | 36 | [19,59] | 28 | [12,54] | 28 | [12,54] | 0 | [0,0] |
| Burkina Faso | | | | | | | | | | | | |
| High TC | 4440 | 0.8 | [0.6 , 1.2] | 36 | 21 | [8 , 43] | 13 | [4 , 37] | 13 | [4 , 37] | 0 | [0 , 0] |
| High LDL-C | 1374 | 1.1 | [0.6 , 1.9] | 16 | 9 | [1 , 58] | 0 | [0 , 0] | 0 | [0 , 0] | 0 | [0 , 0] |
| Chile | | | | | | | | | | | | |
| High TC | 2704 | 14.8 | [12.4,17.6] | 465 | 68 | [58 , 77] | 51 | [41 , 61] | 30 | [22 , 39] | 16 | [11 , 23] |
| High LDL-C | 2628 | 13.3 | [11.2,15.7] | 408 | 65 | [54 , 75] | 51 | [41 , 62] | 34 | [24 , 45] | 19 | [12 , 27] |

| | Number of Observations With Biomarker* | Prevalence of Hyper-cholesterolemia† | | Number of Observations With Hyper-cholesterolemia** | Lipids Measured†‡ | | Aware of Diagnosis†‡ | | Advice or Medication†‡ | | Controlled Disease†‡ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Costa Rica | | | | | | | | | | | | |
| High TC | 2606 | 26.2 | [21.3,31.8] | 774 | 82 | [73 , 89] | 74 | [66 , 80] | 71 | [64 , 77] | 20 | [16 , 25] |
| High LDL-C | 2395 | 26.9 | [21.1,33.6] | 795 | 82 | [74 , 88] | 72 | [66 , 78] | 69 | [63 , 76] | 22 | [18 , 26] |
| Ecuador | | | | | | | | | | | | |
| High TC | 3986 | 11.7 | [10.6,13] | 497 | 78 | [74 , 82] | 60 | [55 , 65] | 54 | [48 , 59] | 0 | [0 , 0] |
| Eswatini | | | | | | | | | | | | |
| High TC | 2889 | 2.0 | [1.5,2.7] | 76 | 17 | [8 , 34] | 13 | [5 , 31] | 13 | [5 , 31] | 0 | [0 , 0] |
| Guyana | | | | | | | | | | | | |
| High TC | 849 | 15.4 | [12.7,18.6] | 143 | 53 | [42 , 63] | 36 | [27 , 47] | 35 | [25 , 46] | 0 | [0 , 0] |
| Iran | | | | | | | | | | | | |
| High TC | 19349 | 9.7 | [9.2,10.3] | 1869 | 89 | [88 , 91] | 80 | [78 , 83] | 79 | [76 , 81] | 57 | [54 , 60] |
| High LDL-C | 19068 | 9.9 | [9.4,10.5] | 1894 | 89 | [87 , 90] | 78 | [76 , 81] | 76 | [74 , 79] | 57 | [54 , 60] |
| Iraq | | | | | | | | | | | | |
| High TC | 3629 | 14.1 | [12.6,15.8] | 623 | 55 | [49 , 60] | 47 | [41 , 52] | 45 | [40 , 51] | 22 | [18 , 28] |
| High LDL-C | 3538 | 14.7 | [13.2,16.4] | 634 | 51 | [46 , 57] | 43 | [38 , 49] | 42 | [37 , 48] | 22 | [18 , 27] |
| Kiribati | | | | | | | | | | | | |
| High TC | 1162 | 5.1 | [2.1 , 12.1] | 55 | 2 | [1 , 9] | 1 | [0 , 5] | 0 | [0 , 0] | 0 | [0 , 0] |
| Kyrgyzstan | | | | | | | | | | | | |
| High TC | 2495 | 3.8 | [3.1,4.6] | 116 | 37 | [26 , 48] | 24 | [15 , 35] | 23 | [14 , 34] | 0 | [0 , 0] |
| Lebanon | | | | | | | | | | | | |
| High TC | 1152 | 28.1 | [24.8,31.7] | 394 | 46 | [37 , 56] | 27 | [21 , 33] | 27 | [21 , 33] | 12 | [8 , 17] |
| High LDL-C | 1133 | 28.1 | [24.7,31.6] | 374 | 45 | [36 , 54] | 27 | [21 , 34] | 27 | [21 , 33] | 12 | [9 , 17] |
| Marshall Islands | | | | | | | | | | | | |
| High TC | 2716 | 5.4 | [4.6,6.3] | 147 | 49 | [41 , 57] | 36 | [28 , 44] | 32 | [24 , 40] | 0 | [0 , 0] |
| Moldova | | | | | | | | | | | | |
| High TC | 3695 | 6.7 | [5.7,7.9] | 321 | 55 | [47 , 62] | 30 | [23 , 37] | 28 | [22 , 36] | 0 | [0 , 0] |

| | Number of Observations With Biomarker* | Prevalence of Hyper-cholesterolemia† | | Number of Observations With Hyper-cholesterolemia** | Lipids Measured†‡ | | Aware of Diagnosis†‡ | | Advice or Medication†‡ | | Controlled Disease†‡ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mongolia | | | | | | | | | | | | |
| High TC | 1883 | 4.4 | [2.8,6.8] | 82 | 29 | [19 , 42] | 21 | [10 , 38] | 19 | [10 , 33] | 6 | [2 , 17] |
| High LDL-C | 1658 | 9.4 | [6.7,12.9] | 155 | 19 | [13 , 28] | 10 | [6 , 18] | 9 | [5 , 16] | 4 | [1 , 9] |
| Morocco | | | | | | | | | | | | |
| High TC | 4668 | 2.3 | [2,2.8] | 148 | 71 | [63 , 79] | 63 | [54 , 71] | 63 | [54 , 71] | 49 | [41, 58] |
| High LDL-C | 4589 | 2.4 | [2,2.9] | 143 | 66 | [56 , 74] | 56 | [47 , 65] | 56 | [47 , 65] | 49 | [40, 58] |
| Myanmar | | | | | | | | | | | | |
| High TC | 7736 | 6.3 | [5.2,7.6] | 678 | 8 | [5 , 13] | 6 | [4 , 9] | 6 | [4 , 9] | 3 | [2 , 4] |
| High LDL-C | 7162 | 6.8 | [5.6,8.2] | 644 | 8 | [5 , 12] | 5 | [3 , 8] | 5 | [3 , 8] | 3 | [2 , 4] |
| Seychelles | | | | | | | | | | | | |
| High TC | 1189 | 16.8 | [14.7,19.1] | 225 | 59 | [52 , 66] | 43 | [36 , 50] | 36 | [30 , 43] | 23 | [17, 29] |
| High LDL-C | 1178 | 22.3 | [19.9,24.9] | 292 | 52 | [46 , 58] | 33 | [28 , 39] | 28 | [23 , 33] | 17 | [13, 22] |
| Solomon Islands | | | | | | | | | | | | |
| High TC | 1666 | 6.5 | [5.3,7.9] | 115 | 1 | [0 , 6] | 0 | [0 , 2] | 0 | [0 , 2] | 0 | [0 , 0] |
| Sri Lanka | | | | | | | | | | | | |
| High TC | 4460 | 9.8 | [8.8,10.9] | 558 | 73 | [67 , 77] | 60 | [55 , 65] | 59 | [54 , 64] | 0 | [0 , 0] |
| St. Vincent & The Grenadines | | | | | | | | | | | | |
| High TC | 1009 | 7.6 | [5.6,10.2] | 104 | 51 | [31 , 70] | 30 | [20 , 42] | 29 | [20 , 41] | 9 | [3 , 19] |
| High LDL-C | 839 | 10.3 | [7.6,13.9] | 107 | 43 | [30 , 57] | 23 | [15 , 33] | 22 | [15 , 32] | 8 | [3 , 16] |
| Sudan | | | | | | | | | | | | |
| High TC | 6760 | 3.1 | [2.6,3.7] | 273 | 27 | [20 , 34] | 20 | [15 , 27] | 20 | [15 , 27] | 0 | [0 , 0] |
| Tajikistan | | | | | | | | | | | | |
| High TC | 2595 | 1.5 | [1,2.2] | 70 | 22 | [12 , 37] | 14 | [7 , 26] | 14 | [7 , 26] | 0 | [0 , 0] |
| Timor-Leste | | | | | | | | | | | | |
| High TC | 2431 | 0.8 | [0.5,1.3] | 19 | 42 | [21 , 66] | 42 | [21 , 66] | 42 | [21 , 66] | 0 | [0 , 0] |

| | Number of Observations With Biomarker* | Prevalence of Hyper-cholesterolemia† | | Number of Observations With Hyper-cholesterolemia** | Lipids Measured†‡ | | Aware of Diagnosis†‡ | | Advice or Medication†‡ | | Controlled Disease†‡ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tokelau | | | | | | | | | | | | |
| High TC | 511 | 14.2 | [6.6 , 27.7] | 87 | 57 | [29 , 82] | 31 | [14 , 55] | 29 | [16 , 46] | 0 | [0 , 0] |
| Tonga | | | | | | | | | | | | |
| High TC | 3595 | 11.2 | [9 , 13.9] | 436 | 60 | [52 , 67] | 40 | [34 , 45] | 38 | [32 , 44] | 0 | [0 , 0] |
| Tuvalu | | | | | | | | | | | | |
| High TC | 1012 | 3.4 | [2.2 , 5.1] | 35 | 36 | [24 , 49] | 29 | [16 , 48] | 29 | [16 , 48] | 0 | [0 , 0] |
| Vietnam | | | | | | | | | | | | |
| High TC | 2981 | 8.4 | [7.2 , 9.7] | 294 | 46 | [39 , 54] | 28 | [23 , 35] | 24 | [19 , 30] | 0 | [0 , 0] |
| Zambia | | | | | | | | | | | | |
| High TC | 3635 | 1.5 | [1.1 , 1.9] | 78 | 5 | [2 , 11] | 3 | [1 , 7] | 1 | [0 , 5] | 0 | [0 , 0] |

Note:

* Number of observations, aged 15+ and nonpregnant, with a valid measurement of TC in the case of High TC and LDL-C in the case of High LDL-C

** Number of all respondents classified as having dyslipidemia based on TC / LDL-C measures or a self-reported medication status (defined by exceeding ATP III guideline cutoffs, ie.TC≥240 mg/dL / LDL-C≥160 mg/dL or respondent taking lipid medication)

† Adjusted for sampling design

‡ See note Table A

Table A.6 - 8: Predictors of Cascade Progression – Univariable, Poisson

| | Measured | | | Diagnoses | | | Treated | | | Controlled | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RR | | P | RR | | P | RR | | P | RR | | P |
| Age | N = 11767 | | | N = 6823 | | | N = 5176 | | | N = 4842 | | |
| 15-24 years | REF | | | REF | | | REF | | | REF | | |
| 25-34 years | 1.20 | [0.96,1.49] | 0.12 | 1.07 | [0.82,1.38] | 0.62 | 0.94 | [0.84,1.05] | 0.27 | 1.13 | [0.60,2.12] | 0.71 |
| 35-44 years | 1.77 | [1.43,2.18] | <0.001 | 1.30 | [1.02,1.64] | 0.03 | 0.99 | [0.91,1.09] | 0.91 | 1.30 | [0.72,2.36] | 0.38 |
| 45-54 years | 2.08 | [1.69,2.56] | <0.001 | 1.44 | [1.14,1.82] | 0.002 | 1.01 | [0.92,1.11] | 0.83 | 1.38 | [0.76,2.49] | 0.29 |
| 55-64 years | 2.33 | [1.90,2.87] | <0.001 | 1.52 | [1.21,1.92] | <0.001 | 1.03 | [0.94,1.13] | 0.55 | 1.45 | [0.80,2.61] | 0.22 |
| 65 or older | 2.33 | [1.90,2.87] | <0.001 | 1.49 | [1.18,1.88] | <0.001 | 1.05 | [0.96,1.15] | 0.32 | 1.64 | [0.91,2.96] | 0.10 |
| Sex | N = 11766 | | | N = 6822 | | | N = 5175 | | | N = 4841 | | |
| Male | REF | | | REF | | | REF | | | REF | | |
| Female | 1.06 | [1.03,1.10] | <0.001 | 1.01 | [0.99,1.04] | 0.31 | 0.99 | [0.98,1.01] | 0.30 | 0.92 | [0.87,0.97] | 0.002 |
| Education | N = 11479 | | | N = 6631 | | | N = 5026 | | | N = 4696 | | |
| Less than primary school | REF | | | REF | | | REF | | | REF | | |
| Less than secondary school | 0.96 | [0.93,1.00] | 0.04 | 0.99 | [0.96,1.02] | 0.58 | 1.00 | [0.98,1.01] | 0.60 | 0.98 | [0.91,1.05] | 0.53 |
| Secondary school completed or higher | 1.05 | [1.01,1.09] | 0.02 | 0.95 | [0.92,0.99] | 0.006 | 0.98 | [0.96,1.00] | 0.01 | 0.94 | [0.88,1.02] | 0.13 |
| Smoking Status | N = 11762 | | | N = 6819 | | | N = 5173 | | | N = 4839 | | |
| Past or Never | REF | | | REF | | | REF | | | REF | | |
| Current | 0.89 | [0.85,0.93] | <0.001 | 0.93 | [0.89,0.98] | 0.003 | 0.97 | [0.95,0.99] | 0.01 | 1.01 | [0.92,1.11] | 0.82 |
| BMI | N = 11520 | | | N = 6660 | | | N = 5043 | | | N = 4714 | | |
| Normal Weight | REF | | | REF | | | REF | | | REF | | |
| Underweight | 0.68 | [0.57,0.80] | <0.001 | 0.98 | [0.85,1.14] | 0.80 | 0.98 | [0.91,1.06] | 0.68 | 1.16 | [0.91,1.47] | 0.23 |
| Overweight | 1.12 | [1.08,1.16] | <0.001 | 1.09 | [1.05,1.13] | <0.001 | 0.99 | [0.97,1.01] | 0.38 | 1.02 | [0.95,1.10] | 0.59 |
| Obese | 1.24 | [1.20,1.29] | <0.001 | 1.11 | [1.07,1.15] | <0.001 | 1.00 | [0.98,1.02] | 0.90 | 0.99 | [0.92,1.07] | 0.82 |

| | Measured | | | Diagnoses | | | Treated | | | Controlled | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RR | | P | RR | | P | RR | | P | RR | | P |
| Diabetic | N = 11080 | | | N = 6401 | | | N = 4863 | | | N = 4537 | | |
| | 1.30 | [1.27,1.34] | <0.001 | 1.14 | [1.11,1.16] | <0.001 | 1.04 | [1.02,1.05] | <0.001 | 1.24 | [1.17,1.31] | <0.001 |
| Hypertensive | N = 11700 | | | N = 6790 | | | N = 5153 | | | N = 4821 | | |
| | 1.31 | [1.27,1.35] | <0.001 | 1.14 | [1.11,1.18] | <0.001 | 1.05 | [1.03,1.07] | <0.001 | 1.11 | [1.05,1.18] | <0.001 |

Exponentiated coefficients; 95% confidence intervals in brackets

Table A.6 - 9: Predictors of Cascade Progression – Multivariable Linear Probability Specification

| | Measured | | | Diagnosed | | | Treated | | | Controlled | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LP | | P | LP | | P | LP | | P | LP | | P |
| Age | | | | | | | | | | | | |
| 15-24 years | | REF | | | REF | | | REF | | | REF | |
| 25-34 years | 0.05 | [-0.02,0.11] | 0.14 | 0.06 | [-0.09,0.20] | 0.44 | -0.08 | [-0.18,0.01] | 0.08 | 0.04 | [-0.13,0.21] | 0.66 |
| 35-44 years | 0.15 | [0.09,0.21] | <0.001 | 0.15 | [0.02,0.29] | 0.03 | -0.05 | [-0.13,0.03] | 0.24 | 0.07 | [-0.09,0.23] | 0.37 |
| 45-54 years | 0.21 | [0.15,0.27] | <0.001 | 0.2 | [0.07,0.34] | 0.003 | -0.04 | [-0.11,0.04] | 0.35 | 0.09 | [-0.07,0.24] | 0.28 |
| 55-64 years | 0.27 | [0.21,0.33] | <0.001 | 0.23 | [0.10,0.36] | 0.001 | -0.02 | [-0.10,0.05] | 0.55 | 0.1 | [-0.06,0.25] | 0.21 |
| 65 or older | 0.30 | [0.24,0.36] | <0.001 | 0.21 | [0.08,0.35] | 0.002 | -0.01 | [-0.09,0.06] | 0.73 | 0.16 | [-0.00,0.31] | 0.05 |
| Sex | | | | | | | | | | | | |
| Male | | REF | | | REF | | | REF | | | REF | |
| Female | 0.03 | [0.01,0.05] | 0.002 | 0.01 | [-0.02,0.03] | 0.52 | -0.01 | [-0.03,0.01] | 0.21 | -0.04 | [-0.07,-0.01] | 0.003 |
| Education | | | | | | | | | | | | |
| Less than primary school | | REF | | | REF | | | REF | | | REF | |
| Less than secondary school | 0.03 | [0.01,0.05] | 0.01 | 0.01 | [-0.02,0.04] | 0.51 | 0.01 | [-0.01,0.02] | 0.45 | 0.01 | [-0.03,0.05] | 0.61 |
| Secondary school completed or higher | 0.11 | [0.09,0.14] | <0.001 | 0.01 | [-0.03,0.04] | 0.67 | 0.00 | [-0.02,0.02] | 0.96 | 0.00 | [-0.04,0.04] | 0.90 |
| Smoking | | | | | | | | | | | | |
| Past or Never | | REF | | | REF | | | REF | | | REF | |
| Current | -0.02 | [-0.05,0.00] | 0.08 | -0.02 | [-0.06,0.01] | 0.16 | -0.03 | [-0.05,-0.00] | 0.03 | 0.01 | [-0.04,0.05] | 0.76 |
| BMI | | | | | | | | | | | | |
| Normal | | REF | | | REF | | | REF | | | REF | |
| Underweight | -0.08 | [-0.13,-0.03] | 0.001 | 0.01 | [-0.10,0.11] | 0.89 | -0.02 | [-0.09,0.06] | 0.64 | 0.04 | [-0.05,0.13] | 0.41 |
| Overweight | 0.03 | [0.01,0.05] | 0.001 | 0.06 | [0.03,0.08] | <0.001 | -0.01 | [-0.03,0.01] | 0.22 | 0.01 | [-0.02,0.05] | 0.43 |

| | Measured | | | Diagnosed | | | Treated | | | Controlled | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LP | | P | LP | | P | LP | | P | LP | | P |
| Obese | 0.08 | [0.06,0.10] | <0.001 | 0.05 | [0.03,0.08] | <0.001 | -0.01 | [-0.03,0.01] | 0.48 | 0.00 | [-0.04,0.04] | 0.98 |
| Diabetes | 0.11 | [0.10,0.13] | <0.001 | 0.07 | [0.05,0.10] | <0.001 | 0.02 | [0.01,0.04] | 0.001 | 0.09 | [0.06,0.11] | <0.001 |
| Hypertension | 0.08 | [0.06,0.09] | <0.001 | 0.06 | [0.04,0.09] | <0.001 | 0.03 | [0.02,0.05] | <0.001 | 0.02 | [-0.01,0.05] | 0.16 |
| *N* | 10575 | | | 6073 | | | 4601 | | | 4283 | | |

95% confidence intervals in brackets

Table A.6 - 10: Predictors of Cascade Progression - Multivariable Basic Poisson Specification

| | Measured | | | Diagnosed | | | Treated | | | Controlled | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RR | | P | RR | | P | RR | | P | RR | | P |
| Age | | | | | | | | | | | | |
| 15-24 years | REF | | | REF | | | REF | | | REF | | |
| 25-34 years | 1.16 | [0.91,1.48] | 0.24 | 1.11 | [0.83,1.47] | 0.49 | 0.90 | [0.82,0.99] | 0.02 | 1.24 | [0.64,2.41] | 0.53 |
| 35-44 years | 1.87 | [1.47,2.39] | <0.001 | 1.36 | [1.04,1.76] | 0.02 | 0.95 | [0.88,1.02] | 0.15 | 1.45 | [0.78,2.70] | 0.24 |
| 45-54 years | 2.36 | [1.85,3.00] | <0.001 | 1.46 | [1.12,1.90] | 0.005 | 0.96 | [0.90,1.04] | 0.33 | 1.53 | [0.83,2.82] | 0.17 |
| 55-64 years | 2.8 | [2.20,3.55] | <0.001 | 1.50 | [1.15,1.95] | 0.002 | 0.97 | [0.90,1.04] | 0.41 | 1.36 | [0.74,2.51] | 0.32 |
| 65 or older | 3.47 | [2.73,4.41] | <0.001 | 1.50 | [1.15,1.95] | 0.003 | 0.97 | [0.91,1.04] | 0.44 | 1.66 | [0.90,3.06] | 0.10 |
| Sex | | | | | | | | | | | | |
| Male | REF | | | REF | | | REF | | | REF | | |
| Female | 1.02 | [0.99,1.06] | 0.20 | 0.99 | [0.96,1.01] | 0.34 | 0.98 | [0.96,1.00] | 0.03 | 0.76 | [0.71,0.82] | <0.001 |
| Education | | | | | | | | | | | | |
| Less than primary school | REF | | | REF | | | REF | | | REF | | |
| Less than secondary school | 1.04 | [0.99,1.09] | 0.15 | 0.94 | [0.91,0.98] | 0.003 | 0.97 | [0.95,0.99] | 0.001 | 0.74 | [0.68,0.80] | <0.001 |
| Secondary school completed or higher | 1.23 | [1.16,1.30] | <0.001 | 0.86 | [0.82,0.89] | <0.001 | 0.94 | [0.92,0.96] | <0.001 | 0.46 | [0.40,0.52] | <0.001 |
| *N* | 11478 | | | 6630 | | | 5025 | | | 4695 | | |

Exponentiated coefficients;
95% confidence intervals in brackets

Table A.6 - 11: Analysis of Deviance for Essay 2 Main Modified Poisson Regression Specifications (Table 2.1-2)

| | Measured | | | Diagnosed | | | Treated | | | Controlled | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Degrees of Freedom | X2 | p-value | Degrees of Freedom | X2 | p-value | Degrees of Freedom | X2 | p-value | Degrees of Freedom | X2 | p-value |
| Age | 5 | 837 | <0.001 | 5 | 64 | <0.001 | 5 | 18 | 0.002 | 5 | 78 | <0.001 |
| Sex | 1 | 0 | 0.88 | 1 | 0 | 0.52 | 1 | 2 | 0.16 | 1 | 22 | <0.001 |
| Education | 2 | 140 | <0.001 | 2 | 69 | <0.001 | 2 | 31 | <0.001 | 2 | 203 | <0.001 |
| Smoking | 1 | 17 | <0.001 | 1 | 16 | <0.001 | 1 | 20 | <0.001 | 1 | 1 | 0.29 |
| BMI | 3 | 292 | <0.001 | 3 | 15 | 0.002 | 3 | 3 | 0.37 | 3 | 11 | 0.008 |
| Diabetes | 1 | 135 | <0.001 | 1 | 93 | <0.001 | 1 | 37 | <0.001 | 1 | 50 | <0.001 |
| Hypertension | 1 | 8 | 0.003 | 1 | 9 | 0.003 | 1 | 23 | <0.001 | 1 | 10 | 0.001 |

Note: Analysis of Deviance for the main modified Poisson regression specifications with outcomes and “Lipids Measured”, “Aware of Diagnosis”, “Advice or Medication”, and “Controlled Disease” as dependent variables; Wald statistic; terms added sequentially (first to last)

Table A.6 - 12: Missingness in Predictor Variables Amongst Participants with Hypercholesterolemia, by Country

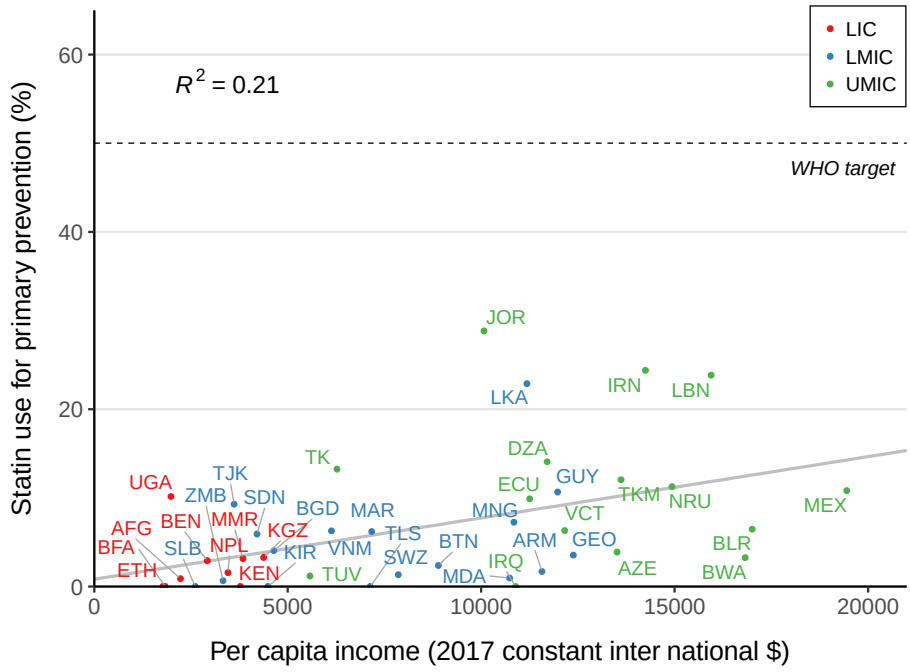
| | Sex | | Age | | Education | | BMI | | Smoking | | Diabetes | | Hypertension | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | N | % | N | % | N | % | N | % |
| Algeria | | 0 | | 0 | 3 | 0.6 | 22 | 4.1 | 2 | 0 | 39 | 7.2 | | 0 |
| Azerbaijan | | 0 | | 0 | 1 | 0.5 | 7 | 3.6 | | 0 | 2 | 1.0 | 1 | 0.5 |
| Bangladesh | | 0 | | 0 | 2 | 0.4 | 17 | 3.3 | | 0 | | 0 | 2 | 0.4 |
| Belarus | | 0 | | 0 | | 0 | 3 | 0.5 | | 0 | 25 | 4.3 | | 0 |
| Benin | | 0 | | 0 | | 0 | 17 | 7.2 | | 0 | | 0 | | 0 |
| Bhutan | | 0 | | 0 | | 0 | 5 | 9.8 | | 0 | | 0 | | 0 |
| Botswana | | 0 | | 0 | | 0 | 2 | 1.9 | | 0 | 4 | 3.8 | | 0 |
| Burkina Faso | | 0 | | 0 | | 0 | 1 | 2.1 | | 0 | 6 | 12.8 | | 0 |
| Chile | | 0 | | 0 | 6 | 1.2 | 13 | 2.5 | 5 | 1.0 | | 0 | 6 | 1.2 |
| Costa Rica | 1 | 0.1 | 15 | 1.6 | 57 | 6.3 | 75 | 8.2 | | 0 | 36 | 4.0 | | 0 |
| Ecuador | | 0 | | 0 | 2 | 0.4 | 17 | 3.3 | | 0 | 7 | 1.4 | 3 | 0.6 |
| Eswatini | | 0 | | 0 | 5 | 6.3 | 10 | 12.5 | 5 | 6 | 2 | 2.5 | 6 | 7.5 |
| Guyana | | 0 | | 0 | 1 | 0.7 | 1 | 0.7 | | 0 | 4 | 2.8 | 1 | 0.7 |
| Iran | | 0 | | 0 | 91 | 4 | 88 | 4.2 | 21 | 1 | 35 | 1.7 | 22 | 1.0 |
| Iraq | | 0 | 3 | 0.4 | | 0 | 25 | 3.3 | | 0 | 3 | 0.4 | 4 | 0.5 |
| Kiribati | | 0 | | 0 | 2 | 3 | 5 | 8.6 | 2 | 3 | 3 | 5.2 | 1 | 1.7 |
| Kyrgyzstan | | 0 | | 0 | | 0 | 15 | 11.6 | | 0 | 1 | 0.8 | 1 | 0.8 |
| Lebanon | | 0 | | 0 | 58 | 14 | 30 | 7.0 | | 0 | 11 | 2.6 | 28 | 6.5 |
| Marshall Islands | | 0 | | 0 | 1 | 1 | 14 | 8.5 | 2 | 1 | 1 | 0.6 | 1 | 0.6 |
| Moldova | | 0 | | 0 | | 0 | 17 | 5.2 | | 0 | | 0 | 6 | 1.8 |
| Mongolia | | 0 | | 0 | | 0 | 6 | 3.3 | | 0 | 4 | 2.2 | 1 | 0.6 |
| Morocco | | 0 | | 0 | | 0 | 11 | 6.3 | | 0 | 7 | 4.0 | | 0 |
| Myanmar | | 0 | | 0 | 5 | 0.6 | 25 | 2.9 | | 0 | 11 | 1.3 | 2 | 0.2 |
| Seychelles | | 0 | | 0 | | 0 | 1 | 0.3 | | 0 | | 0 | | 0 |
| Solomon Islands | | 0 | | 0 | 1 | 0.8 | 5 | 4.2 | 1 | 1 | | 0 | | 0 |
| Sri Lanka | | 0 | | 0 | 1 | 0.2 | 13 | 2.3 | | 0 | 18 | 3.2 | 2 | 0 |
| St. Vincent & the Grenadines | | 0 | | 0 | | 0 | 2 | 1.5 | | 0 | 7 | 5.3 | | 0 |
| Sudan | | 0 | | 0 | | 0 | 28 | 9.3 | | 0 | 15 | 5.0 | | 0 |
| Tajikistan | | 0 | | 0 | | 0 | 2 | 2.8 | | 0 | 4 | 5.6 | 1 | 1.4 |
| Timor-Leste | | 0 | | 0 | | 0 | 4 | 17.4 | | 0 | 3 | 13.0 | | 0 |
| Tokelau | | 0 | | 0 | 88 | 100 | 3 | 3.4 | | 0 | 1 | 1.1 | | 0 |
| Tonga | | 0 | | 0 | | 0 | 31 | 6.9 | | 0 | 450 | 100 | 4 | 1 |

| | Sex | | Age | | Education | | BMI | | Smoking | | Diabetes | | Hypertension | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | N | % | N | % | N | % | N | % |
| Tuvalu | | 0 | | 0 | | 0 | 2 | 5.7 | | 0 | 1 | 2.9 | | 0 |
| Vietnam | | 0 | | 0 | | 0 | 14 | 4.6 | | 0 | | 0 | | 0 |
| Zambia | | 0 | | 0 | | 0 | 4 | 4.9 | | 0 | 5 | 6.1 | 1 | 1.2 |

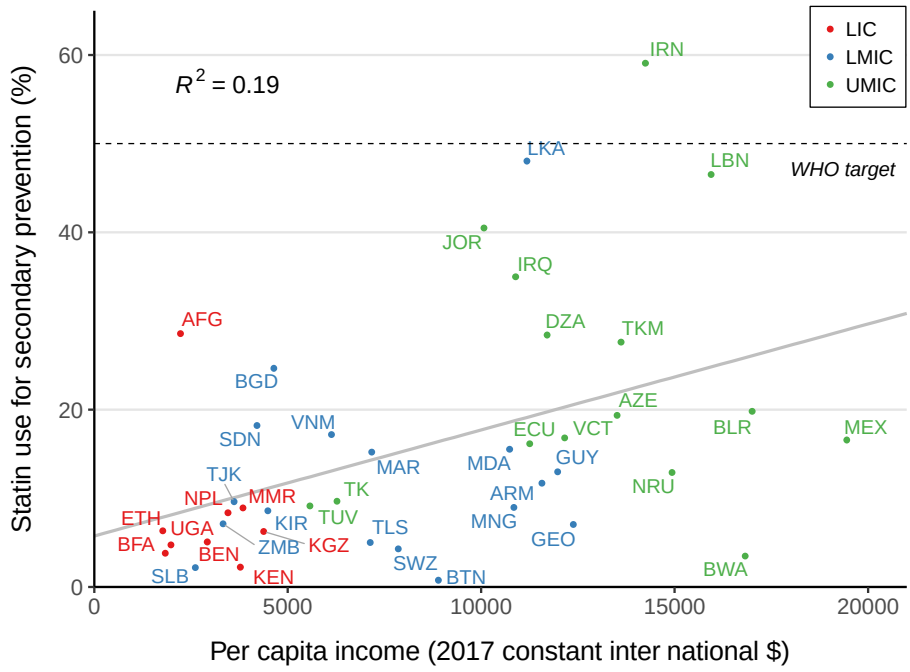
## A.6.3 Essay 2: Figures

Figure A.6 - 13: Statin use by per-capita income

A. Primary prevention



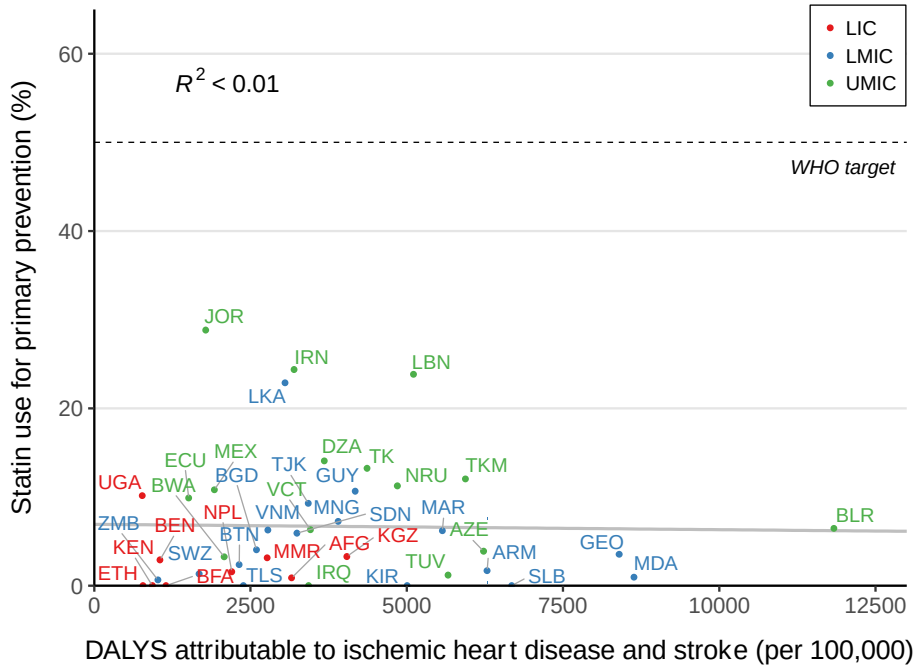

B. Secondary Prevention



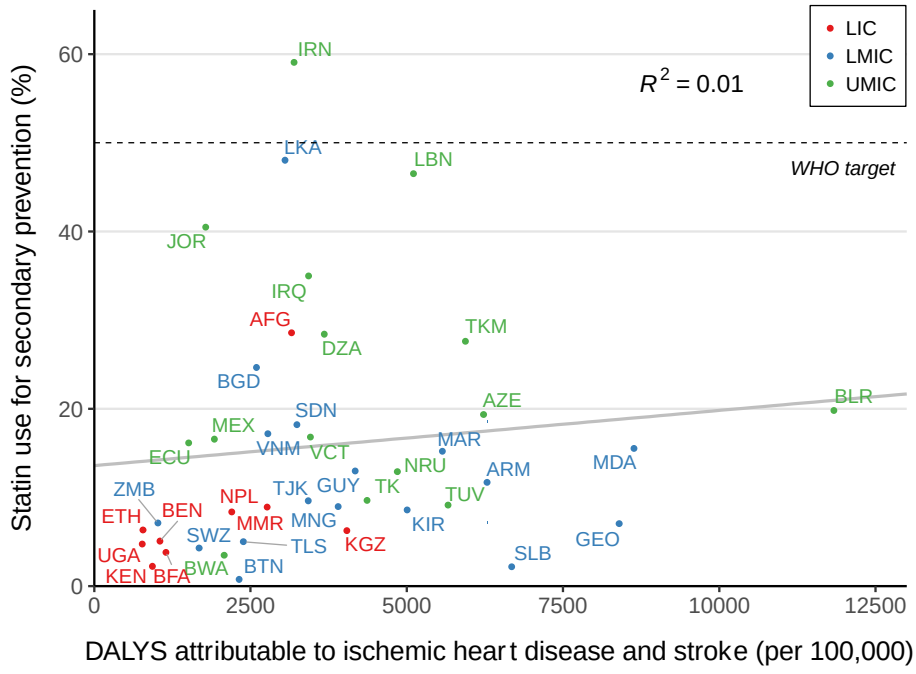

The standardized regression coefficients were 0.46 (95% CI, 0.18 to 0.75) for primary prevention and 0.43 (95% CI, 0.14 to 0.73) for secondary prevention.

Figure A.6 - 14: Statin use by CVD burden

A. Primary prevention



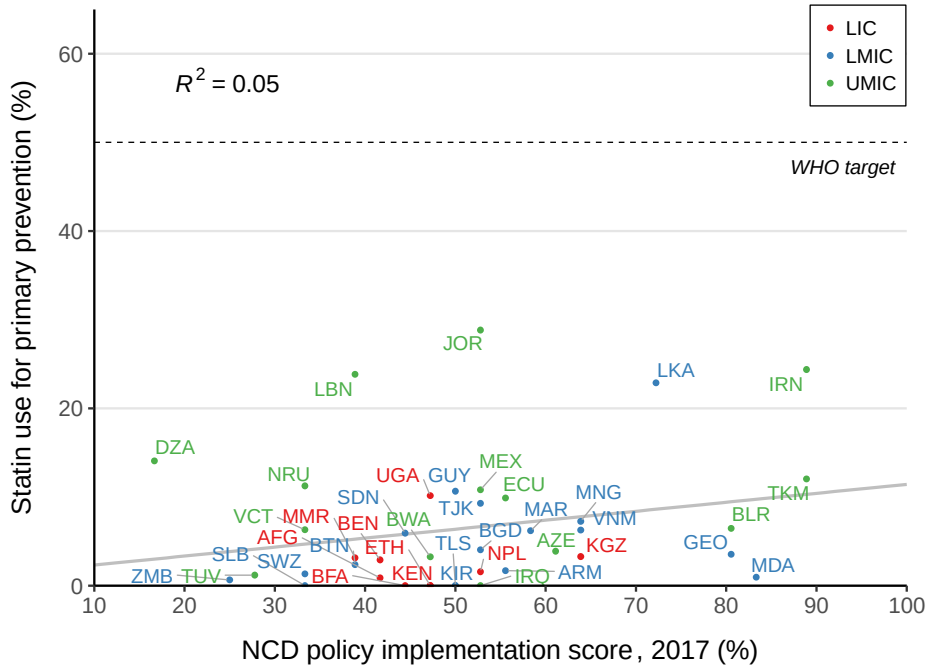

B. Secondary prevention



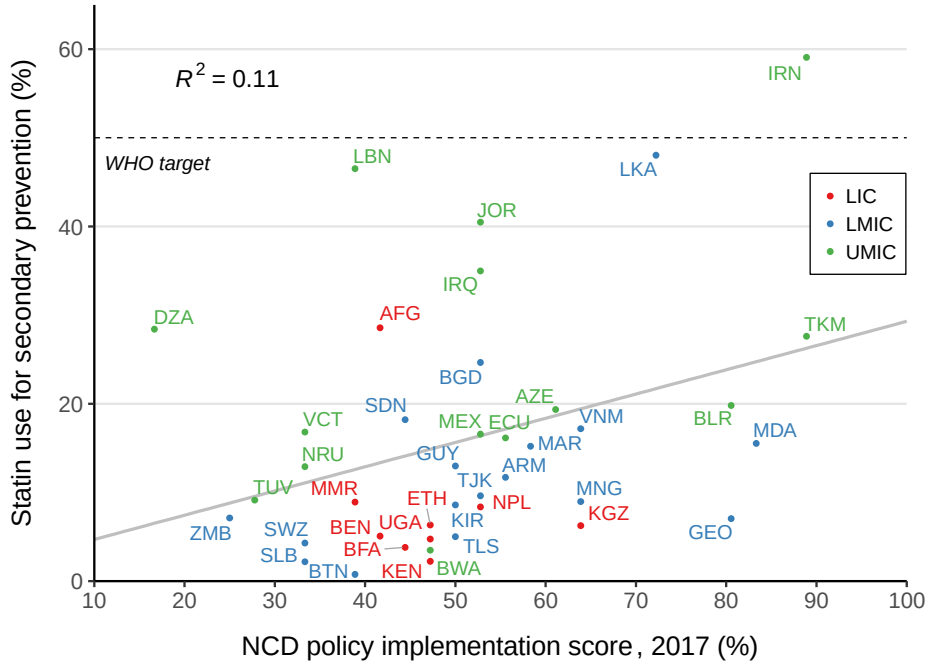

The standardized regression coefficients were -0.02 (95% CI, -0.34 to 0.30) for primary prevention and 0.11 (95% CI, -0.21 to 0.43) for secondary prevention.

Figure A.6 - 15: Statin use by NCD policy commitment

A. Primary prevention




B. Secondary prevention




The standardized regression coefficients were 0.23 (95% CI, -0.09 to 0.55) for primary prevention and 0.34 (95% CI, 0.03 to 0.65) for secondary prevention.

Figure A.6 - 16: Forest plot of statin use for primary prevention by region, income group, and overall among individuals aged ≥40 years with 10-year CVD risk >20% (sensitivity analysis 1)

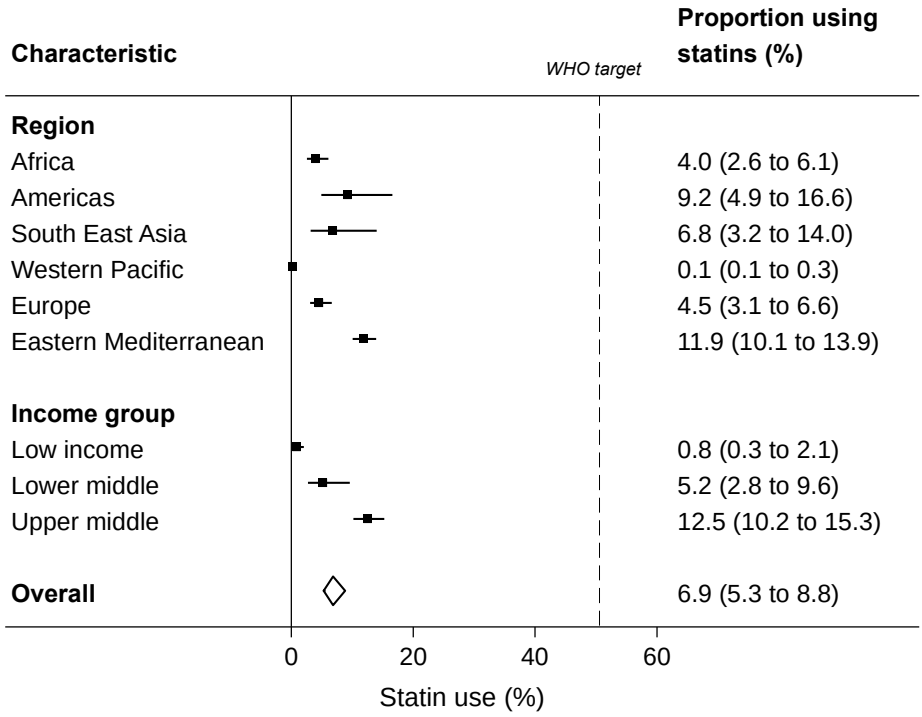



Figure A.6 - 17: Forest plot from multivariable regression of statin use for primary prevention among individuals aged ≥40 years with 10-year CVD risk >20% (sensitivity analysis 1)

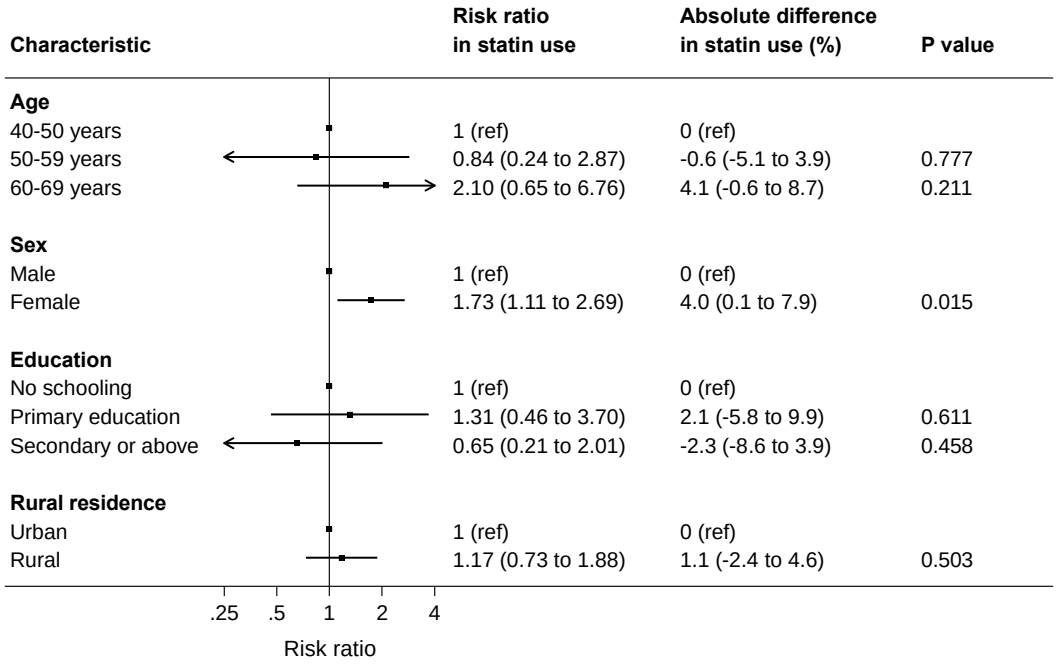


Figure A.6 - 18: Forest plot of statin use for primary CVD prevention by region, income group, and overall using the 2007 WHO/ISH CVD risk charts and a 10-year CVD risk threshold of ≥30% (sensitivity analysis 2)

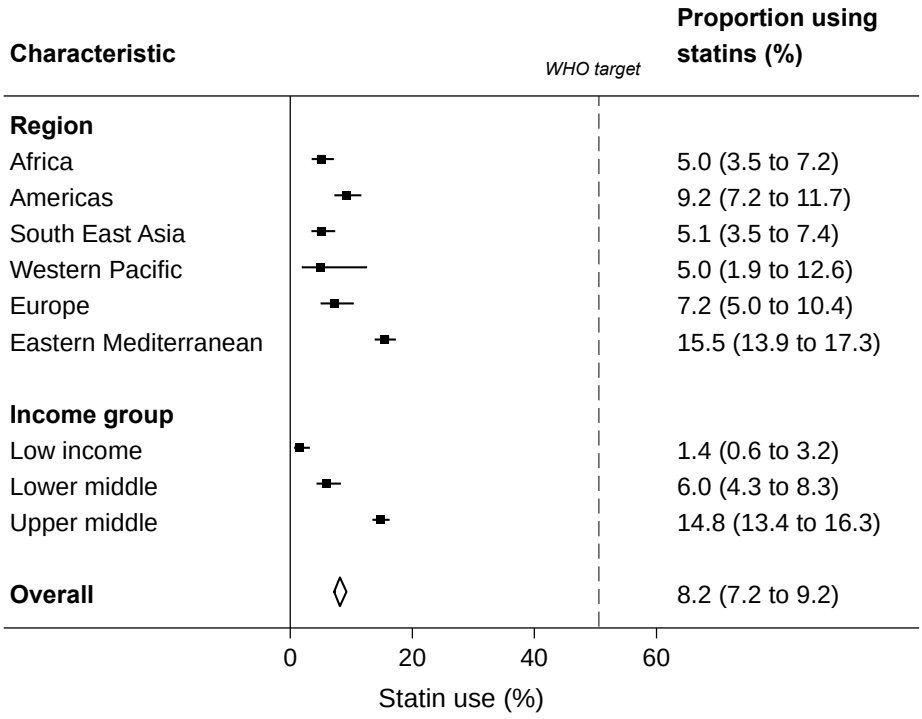



Figure A.6 - 19: Forest plot from multivariable regression of statin use for primary CVD prevention using the 2007 WHO/ISH CVD risk charts and a 10-year CVD risk threshold of ≥30% (sensitivity analysis 2)

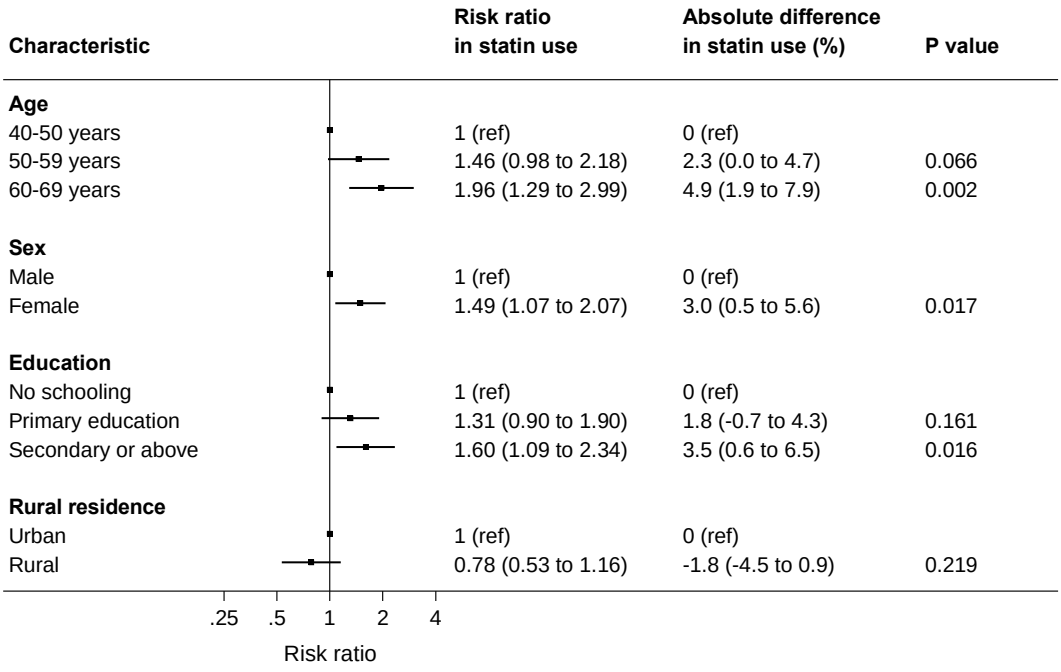
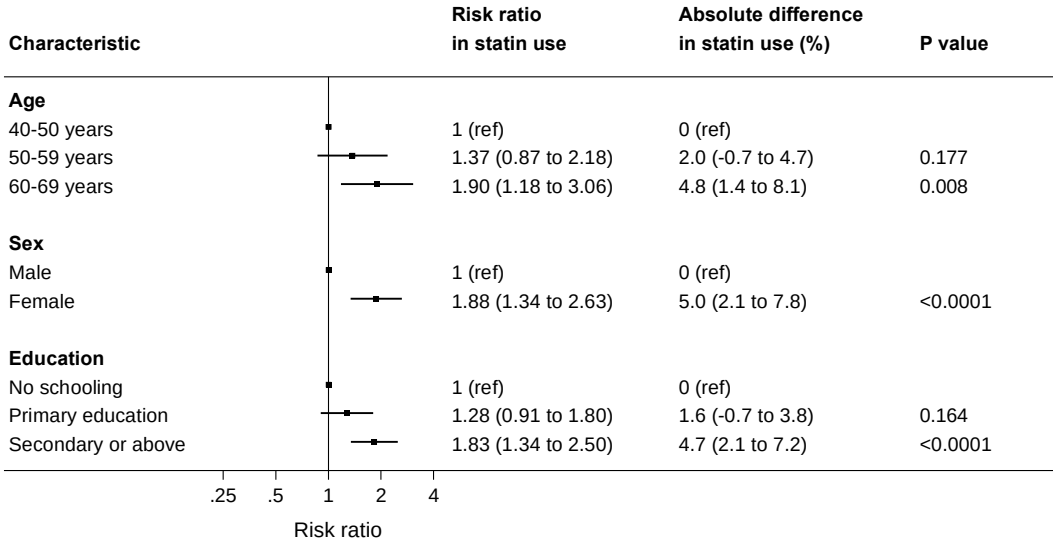


Figure A.6 - 20: Forest plot from multivariable regression of statin use excluding rural vs. urban residence (sensitivity analysis 3)

A. Primary prevention




B. Secondary prevention

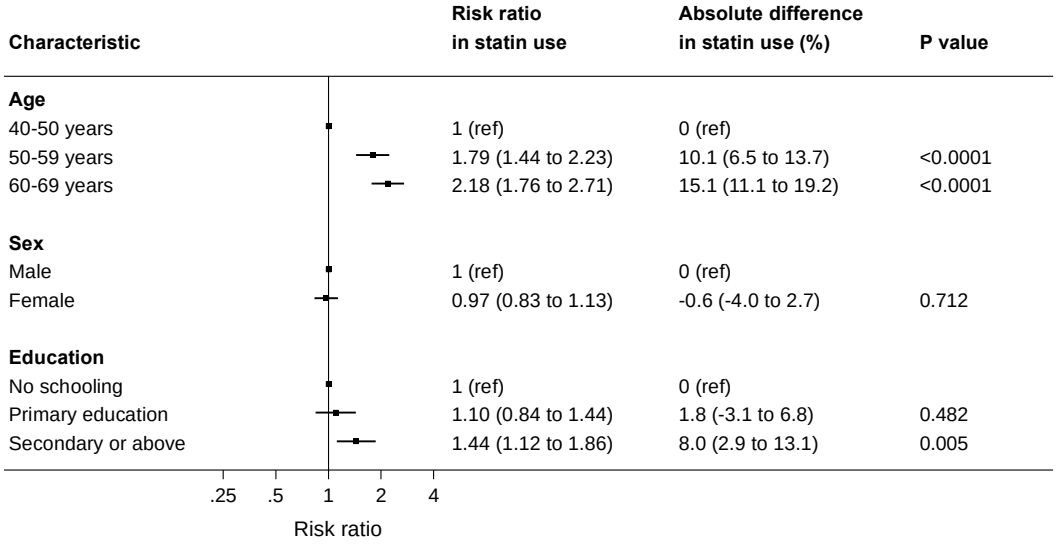
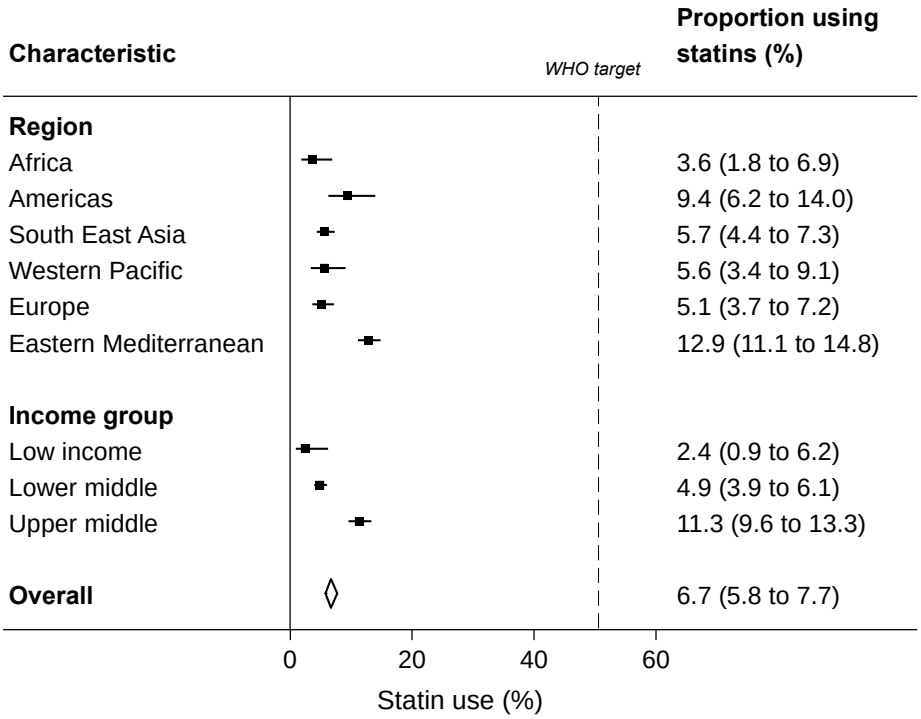


Figure A.6 - 21: Forest plot of statin use by region, income group, and overall using equal country weights (sensitivity analysis 4)

A. Primary prevention




B. Secondary prevention

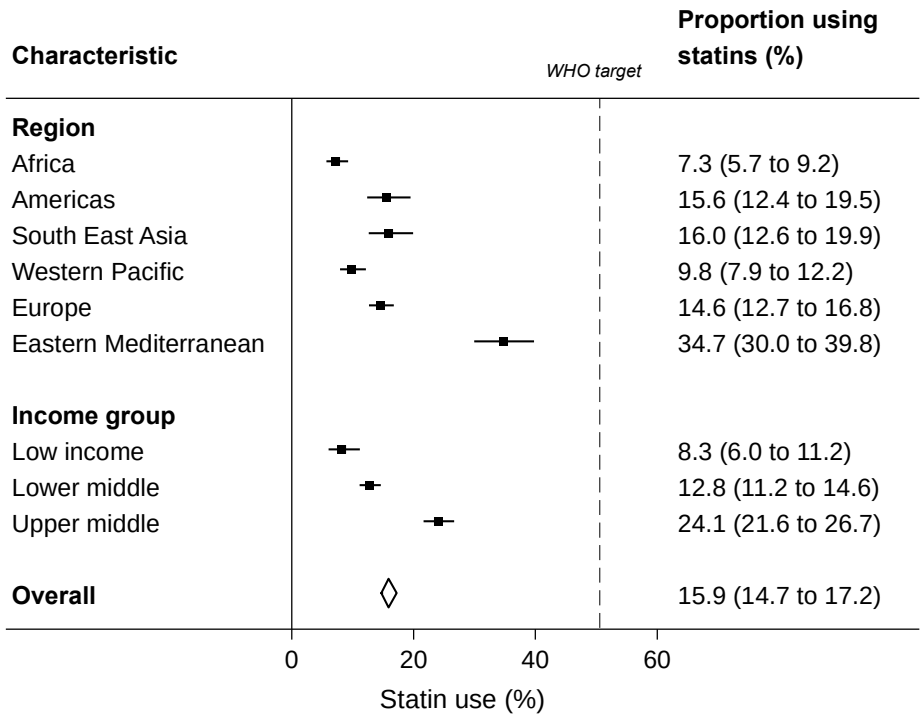
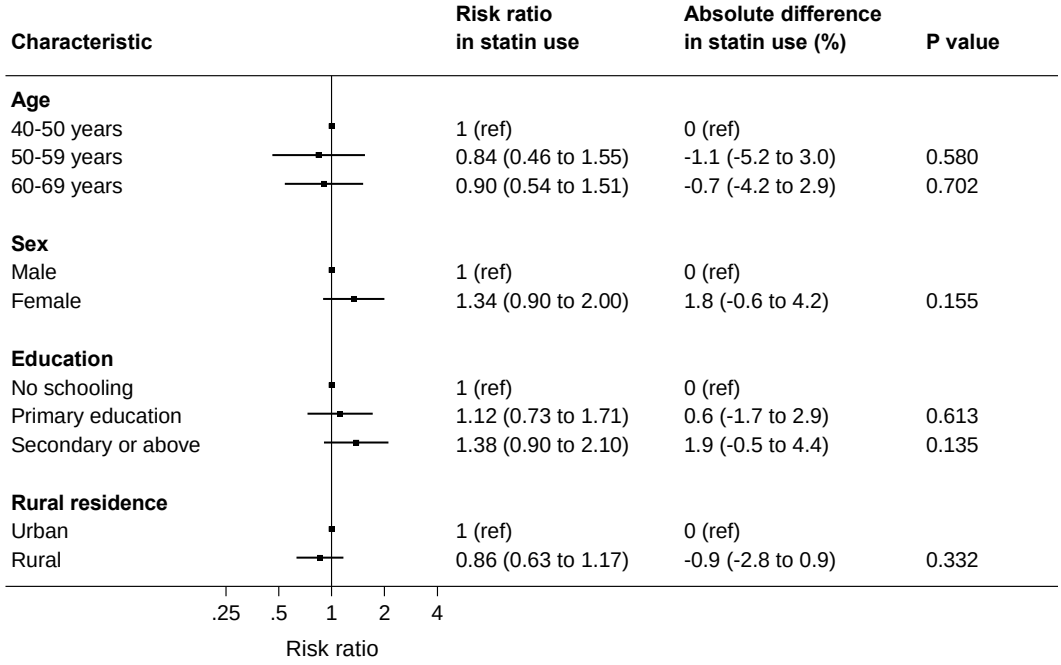
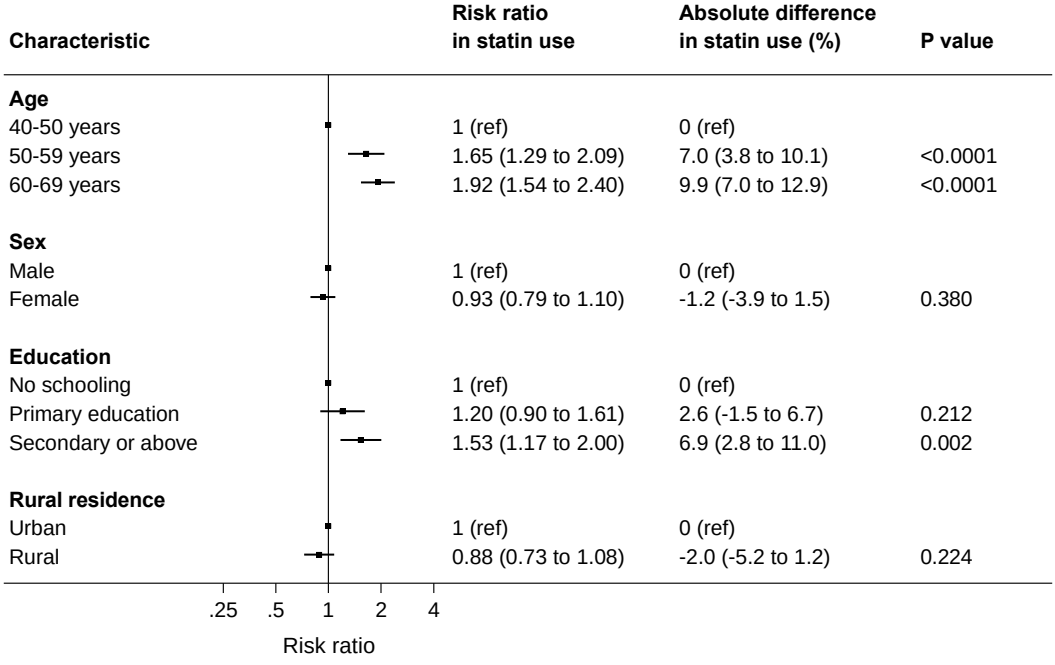


Figure A.6 - 22: Forest plot from multivariable regression of statin use using equal country weights (sensitivity analysis 5)

A. Primary prevention




B. Secondary prevention



### A.6.4 Essay 2: Tables

Table A.6 - 13: Additional details on study sample by country

| Country | Secondary prevention sample, n | Secondary prevention sample, weighted % among total sample | Primary prevention sample, n | Primary prevention sample, % among total sample | Median (IQR) 10-year CVD risk among primary prevention sample[b] |
|---|---|---|---|---|---|
| Afghanistan | 185 | 14.2 (10.0-19.8) | 159 | 11.9 (7.9-17.6) | 21.3 (13.8-26.8) |
| Algeria | 273 | 7.4 (6.3-8.6) | 497 | 16.7 (15.2-18.3) | 20.7 (13.5-25.1) |
| Armenia | 219 | 14.5 (12.3-17.0) | 116 | 14.4 (11.5-17.8) | 25.6 (20.5-33.4) |
| Azerbaijan | 230 | 11.4 (9.4-13.6) | 221 | 12.1 (10.2-14.2) | 25.3 (19.9-34.9) |
| Bangladesh | 505 | 14.7 (12.6-17.0) | 233 | 7.3 (6.1-8.7) | 8.3 (5.4-12.6) |
| Belarus | 381 | 11.1 (9.3-13.3) | 494 | 16.1 (14.5-17.8) | 24.5 (21.7-29.9) |
| Benin | 131 | 5.6 (4.0-7.7) | 37 | 1.7 (1.0-2.6) | 20.1 (8.2-22.6) |
| Bhutan | 11 | 0.8 (0.4-1.7) | 30 | 2.5 (1.5-4.0) | 6.7 (4.1-10.8) |
| Botswana | 109 | 8.3 (5.9-11.4) | 52 | 3.7 (2.4-5.7) | 10.2 (7.3-17.3) |
| Burkina Faso | 133 | 6.8 (5.4-8.5) | 4 | 0.2 (0.1-0.5) | 18.0 (10.4-25.8) |
| Ecuador | 235 | 10.5 (9.0-12.2) | 126 | 7.3 (5.9-9.0) | 6.4 (4.8-9.2) |
| Eswatini | 67 | 6.9 (4.7-10.2) | 54 | 7.0 (4.8-10.1) | 11.2 (8.0-17.1) |
| Ethiopia | 140 | 4.5 (3.5-5.8) | 49 | 1.2 (0.8-1.9) | 8.9 (5.3-13.8) |
| Georgia | 810 | 26.6 (24.1-29.1) | 235 | 13.1 (11.2-15.2) | 24.7 (19.8-34.5) |
| Guyana | 148 | 11.9 (9.4-14.8) | 67 | 17.8 (13.3-23.4) | 9.8 (6.9-15.0) |
| Iran | 348 | 2.5 (2.2-2.8) | 1,349 | 14.0 (13.1-14.9) | 20.3 (14.0-24.6) |
| Iraq | 180 | 10.2 (8.6-12.1) | 352 | 25.5 (22.5-28.7) | 21.0 (14.2-25.9) |
| Jordan | 323 | 11.3 (9.8-13.1) | 339 | 20.7 (17.8-24.0) | 18.1 (12.3-22.8) |
| Kenya | 118 | 6.6 (4.9-8.9) | 37 | 1.7 (1.0-3.1) | 8.8 (5.8-15.8) |
| Kiribati | 92 | 10.4 (6.4-16.5) | 51 | 16.4 (11.0-23.6) | 9.9 (6.1-14.8) |
| Kyrgyzstan | 309 | 16.4 (13.8-19.4) | 98 | 9.4 (6.5-13.6) | 23.9 (15.6-30.1) |
| Lebanon | 67 | 5.9 (4.3-8.0) | 146 | 18.4 (13.6-24.3) | 23.3 (20.5-29.2) |
| Mexico | 519 | 2.4 (2.1-2.8) | 1,082 | 15.5 (14.2-17.0) | 9.4 (5.8-15.4) |
| Moldova | 672 | 19.1 (17.2-21.3) | 314 | 13.5 (11.7-15.6) | 24.6 (21.9-30.7) |
| Mongolia | 643 | 18.1 (16.4-20.0) | 252 | 9.1 (7.9-10.4) | 24.7 (19.1-32.2) |
| Morocco | 108 | 3.8 (3.1-4.6) | 384 | 14.7 (13.3-16.2) | 20.6 (13.8-25.4) |
| Myanmar | 617 | 8.3 (6.7-10.3) | 307 | 5.5 (4.5-6.8) | 8.7 (5.6-13.1) |
| Nauru | 119 | 25.7 (21.6-30.3) | 62 | 24.1 (16.0-34.6) | 8.9 (6.0-11.8) |
| Nepal | 59 | 1.7 (1.1-2.5) | 101 | 4.4 (3.0-6.3) | 11.7 (6.7-20.4) |
| Solomon Islands | 92 | 7.6 (5.0-11.2) | 16 | 1.6 (0.9-3.0) | 20.6 (12.8-23.4) |
| Sri Lanka | 234 | 7.5 (6.4-8.6) | 322 | 13.7 (12.2-15.4) | 8.8 (6.0-12.8) |

| Country | Secondary prevention sample, n | Secondary prevention sample, weighted % among total sample | Primary prevention sample, n | Primary prevention sample, % among total sample | Median (IQR) 10-year CVD risk among primary prevention sample[b] |
|---|---|---|---|---|---|
| St. Vincent & the Grenadines | 118 | 5.4 (3.5-8.0) | 76 | 13.8 (10.9-17.3) | 10.3 (6.3-13.4) |
| Sudan | 76 | 2.1 (1.6-2.8) | 371 | 12.0 (10.5-13.9) | 20.0 (11.9-25.3) |
| Tajikistan | 115 | 8.4 (6.1-11.6) | 84 | 8.2 (6.2-11.0) | 23.9 (20.0-29.8) |
| Timor-Leste | 20 | 1.5 (0.9-2.5) | 12 | 1.0 (0.6-1.8) | 20.3 (13.3-22.7) |
| Tokelau | 22 | 8.8 (5.8-13.1) | 69 | 30.3 (27.2-33.6) | 12.9 (9.8-17.4) |
| Turkmenistan | 277 | 12.4 (10.3-15.0) | 81 | 5.3 (4.0-7.0) | 24.6 (21.1-32.3) |
| Tuvalu | 64 | 13.2 (8.9-19.2) | 63 | 14.8 (9.9-21.5) | 11.6 (7.9-19.4) |
| Uganda | 148 | 11.1 (9.0-13.7) | 10 | 0.8 (0.4-1.8) | 8.7 (4.8-12.0) |
| Vietnam | 241 | 10.0 (8.7-11.6) | 61 | 3.3 (2.4-4.5) | 11.7 (7.8-21.9) |
| Zambia | 71 | 4.2 (3.1-5.6) | 40 | 3.3 (2.2-4.8) | 13.0 (7.9-22.7) |
| **Overall[a]** | **9,229** | **7.9 (7.4-8.3)** | **8,453** | **9.7 (9.3-10.1)** | **18.4 (9.9-24.6)** |

[a]Estimates account for survey design and weighting by each country's 2019 population of individuals 40-69 years of age. [b]As the need for statin therapy for primary prevention includes those with diabetes, not all individuals had >20% or greater 10-year CVD risk.

Table A.6 - 14: Sample characteristics

| Characteristic | Total sample | | Secondary prevention sample | | Primary prevention sample | |
|---|---|---|---|---|---|---|
| **Age** | **n** | **Weighted % (95% CI)** | **n** | **Weighted % (95% CI)** | **n** | **Weighted % (95% CI)** |
| <50 years | 49,466 | 44.9 (44.3-45.5) | 2,777 | 33.1 (31.1-35.1) | 1,440 | 22.8 (20.2-25.7) |
| 50-59 years | 39,829 | 33.0 (32.5-33.6) | 3,378 | 35.3 (33.4-37.4) | 2,917 | 37.6 (34.6-40.7) |
| 60-69 years | 27,154 | 22.1 (21.5-22.7) | 3,074 | 31.6 (29.6-33.6) | 4,096 | 39.6 (36.6-42.6) |
| **Sex** | | | | | | |
| Male | 50,383 | 49.6 (49.0-50.2) | 3,586 | 47.0 (44.7-49.2) | 3,923 | 50.8 (47.7-53.9) |
| Female | 66,066 | 50.4 (49.8-51.0) | 5,643 | 53.0 (50.8-55.3) | 4,530 | 49.2 (46.1-52.3) |
| **Education** | | | | | | |
| No schooling | 24,387 | 28.3 (27.5-29.1) | 1,425 | 28.1 (26.0-30.3) | 1,695 | 20.6 (18.3-23.0) |
| Primary education | 36,980 | 32.8 (32.1-33.5) | 2,640 | 36.1 (34.0-38.3) | 2,767 | 34.7 (31.9-37.6) |
| Secondary or above | 53,443 | 38.9 (38.1-39.6) | 5,058 | 35.8 (33.8-37.8) | 3,834 | 44.7 (41.8-47.7) |
| **Rural vs. urban residence** | | | | | | |
| Urban | 53,489 | 47.4 (46.6-48.2) | 4,158 | 50.7 (48.5-52.8) | 4,536 | 63.5 (61.0-65.9) |
| Rural | 39,713 | 52.6 (51.8-53.4) | 3,100 | 49.3 (47.2-51.5) | 2,477 | 36.5 (34.1-39.0) |
| **Overall** | **116,449** | **100** | **9,229** | **100** | **8,453** | **100** |

Table A.6 - 15: Details on missing data by country

| Country | Missing data on self-reported prior CVD among total sample (unweighted %) | Missing data on statin use among total sample (unweighted %) | Missing data to calculate CVD risk among sample without prior CVD (unweighted %)[a] |
|---|---|---|---|
| Afghanistan | <0.1 | <0.1 | 0.5 |
| Algeria | 0.5 | 0.5 | 2.2 |
| Armenia | <0.1 | <0.1 | 7.3 |
| Azerbaijan | <0.1 | <0.1 | 1.8 |
| Bangladesh | <0.1 | <0.1 | 0.5 |
| Belarus | <0.1 | <0.1 | 1.3 |
| Benin | 0.1 | 0.1 | 1.7 |
| Bhutan | <0.1 | <0.1 | 0.2 |
| Botswana | <0.1 | <0.1 | 2.3 |
| Burkina Faso | 0.1 | 0.1 | 0.9 |
| Ecuador | <0.1 | <0.1 | 1.6 |
| Eswatini | 7.7 | 7.7 | 2.9 |
| Ethiopia | <0.1 | <0.1 | 0.4 |
| Georgia | <0.1 | <0.1 | 3.0 |
| Guyana | <0.1 | <0.1 | 4.6 |
| Iran | 1.8 | 1.8 | 1.3 |
| Iraq | 0.1 | 0.2 | 3.5 |
| Jordan | <0.1 | <0.1 | 2.1 |
| Kenya | 0.1 | <0.1 | 2.7 |
| Kiribati | 1.4 | 1.4 | 6.0 |
| Kyrgyzstan | <0.1 | <0.1 | 1.0 |
| Lebanon | <0.1 | <0.1 | 10.7 |
| Mexico | <0.1 | <0.1 | 4.3 |
| Moldova | 1.2 | 1.2 | 2.6 |
| Mongolia | <0.1 | <0.1 | 2.0 |
| Morocco | <0.1 | <0.1 | 2.0 |
| Myanmar | <0.1 | <0.1 | 1.3 |
| Nauru | 0.4 | 0.4 | 2.7 |
| Nepal | <0.1 | <0.1 | 0.4 |
| Solomon Islands | 0.4 | 0.4 | 2.7 |
| Sri Lanka | 0.3 | 0.3 | 1.4 |
| St. Vincent & the Grenadines | <0.1 | <0.1 | 3.8 |
| Sudan | <0.1 | <0.1 | 1.2 |
| Tajikistan | <0.1 | <0.1 | 1.1 |

| Country | Missing data on self-reported prior CVD among total sample (unweighted %) | Missing data on statin use among total sample (unweighted %) | Missing data to calculate CVD risk among sample without prior CVD (unweighted %)[a] |
|---|---|---|---|
| Timor-Leste | 0.5 | 0.5 | 0.7 |
| Tokelau | <0.1 | <0.1 | 6.8 |
| Turkmenistan | <0.1 | <0.1 | 2.0 |
| Tuvalu | 0.2 | 0.2 | 2.8 |
| Uganda | 0.7 | 0.7 | 2.4 |
| Vietnam | 0.2 | 0.2 | 3.0 |
| Zambia | <0.1 | <0.1 | 1.8 |
| **Overall** | **0.4** | **0.4** | **2.0** |

[a]Denominator refers to all people with biochemical measurements in the total sample.

Table A.6 - 16: Proportion of statin use by country

| Country | Proportion (95% CI) using statins for secondary prevention of CVD | Proportion (95% CI) using statins for primary prevention of CVD |
|---|---|---|
| Afghanistan | 28.6 (13.1-51.4) | 0.9 (0.2-4.5) |
| Algeria | 28.4 (23.2-34.3) | 14.1 (11.2-17.6) |
| Armenia | 11.7 (7.2-18.6) | 1.7 (0.4-7.8) |
| Azerbaijan | 19.4 (13.1-27.6) | 3.9 (1.9-7.9) |
| Bangladesh | 24.7 (16.8-34.6) | 6.4 (2.0-18.6) |
| Belarus | 19.8 (14.9-25.8) | 6.5 (4.2-9.8) |
| Benin | 5.1 (1.7-14.4) | 2.8 (0.4-18.2) |
| Bhutan | 0.8 (0.1-6.5) | 2.4 (0.3-15.7) |
| Botswana | 3.5 (0.7-15.2) | 3.3 (1.0-10.7) |
| Burkina Faso | 3.8 (1.5-9.1) | 0 |
| Ecuador | 16.1 (10.9-23.3) | 8.7 (3.7-19.1) |
| Eswatini | 4.3 (0.8-19.1) | 1.3 (0.2-9.6) |
| Ethiopia | 6.3 (3.0-12.7) | 0 |
| Georgia | 7.0 (5.0-9.7) | 3.6 (1.6-8.0) |
| Guyana | 13.0 (7.9-20.6) | 10.7 (4.9-21.6) |
| Iran | 59.1 (53.7-64.3) | 24.7 (22.3-27.1) |
| Iraq | 35.0 (26.9-44.0) | N/A |
| Jordan | 40.5 (32.5-49.0) | 29.0 (22.3-36.7) |
| Kenya | 2.2 (0.7-7.0) | 0 |
| Kiribati | 8.6 (3.1-21.4) | 0 |
| Kyrgyzstan | 6.3 (3.5-10.8) | 3.3 (1.1-9.6) |
| Lebanon | 46.5 (27.8-66.2) | 25.4 (17.7-35.2) |
| Mexico | 16.6 (11.5-23.2) | 11.3 (9.0-14.1) |
| Moldova | 15.5 (11.5-20.6) | 1.0 (0.4-2.4) |
| Mongolia | 9.0 (6.9-11.6) | 7.3 (4.3-12.0) |
| Morocco | 15.2 (9.5-23.5) | 6.0 (3.9-9.1) |
| Myanmar | 8.9 (6.3-12.4) | 3.2 (1.8-5.6) |
| Nauru | 12.9 (9.0-18.1) | 11.3 (4.0-27.9) |
| Nepal | 8.4 (2.1-28.0) | 1.5 (0.5-5.0) |
| Solomon Islands | 2.2 (0.7-6.4) | 0 |
| Sri Lanka | 48.0 (40.5-55.7) | 23.0 (18.5-28.2) |
| St. Vincent & the Grenadines | 16.8 (9.4-28.2) | 6.3 (1.4-24.3) |
| Sudan | 18.2 (10.2-30.4) | 5.9 (3.3-10.2) |
| Tajikistan | 9.6 (4.8-18.4) | 9.3 (3.6-22.0) |
| Timor-Leste | 5.0 (0.6-30.0) | 0 |
| Tokelau | 9.7 (4.0-21.7) | 13.2 (5.2-29.6) |

| Country | Proportion (95% CI) using statins for secondary prevention of CVD | Proportion (95% CI) using statins for primary prevention of CVD |
|---|---|---|
| Turkmenistan | 27.6 (20.2-36.5) | 12.1 (5.8-23.8) |
| Tuvalu | 9.1 (6.9-11.9) | 1.3 (0.5-3.5) |
| Uganda | 4.7 (1.9-11.2) | 10.1 (1.5-45.1) |
| Vietnam | 17.2 (12.5-23.1) | 6.3 (2.2-16.4) |
| Zambia | 7.1 (2.7-17.3) | 0.6 (0.1-4.6) |

Table A.6 - 17: Risk ratios and average marginal effects from country-level Poisson regression of statin use for secondary prevention between female vs. male sex (reference category)

| Country | Risk ratio (95% CI) | Average marginal effect, % (95% CI) |
|---|---|---|
| **Afghanistan** | 1.26 (0.42-3.73) | 6.4 (-25.2 to 38.1) |
| **Algeria** | 0.75 (0.54-1.04) | -8.1 (-17.4 to 1.3) |
| **Armenia** | 0.33 (0.15-0.77) | -11.3 (-21.2 to -1.3) |
| **Azerbaijan** | 0.76 (0.44-1.33) | -5.3 (-16.1 to 5.5) |
| **Bangladesh** | 0.87 (0.51-1.51) | -3.3 (-16.5 to 9.8) |
| **Belarus** | 1.15 (0.69-1.93) | 2.8 (-7.2 to 12.8) |
| **Benin** | 0.55 (0.08-3.89) | -2.9 (-13.5 to 7.7) |
| **Bhutan** | N/A | N/A |
| **Botswana** | N/A | N/A |
| **Burkina Faso** | 1.62 (0.27-9.69) | 1.7 (-4.5 to 8.0) |
| **Ecuador** | 0.63 (0.32-1.23) | -7.4 (-18.9 to 4.1) |
| **Eswatini** | N/A | N/A |
| **Ethiopia** | 0.71 (0.19-2.70) | -2.1 (-11.1 to 6.9) |
| **Georgia** | 0.46 (0.25-0.88) | -5.3 (-10.1 to -0.5) |
| **Guyana** | 1.31 (0.52-3.31) | 3.4 (-8.2 to 15.0) |
| **Iran** | 0.94 (0.79-1.12) | -3.5 (-13.7 to 6.7) |
| **Iraq** | 1.05 (0.64-1.73) | 1.7 (-16.0 to 19.3) |
| **Jordan** | 0.61 (0.41-0.90) | -18.3 (-31.7 to -4.9) |
| **Kenya** | N/A | N/A |
| **Kiribati** | 0.19 (0.07-0.54) | -16.1 (-31.3 to -0.8) |
| **Kyrgyzstan** | 0.56 (0.23-1.34) | -3.7 (-9.8 to 2.4) |
| **Lebanon** | 1.10 (0.54-2.22) | 4.4 (-28.4 to 37.1) |
| **Mexico** | 0.66 (0.34-1.30) | -6.7 (-17.9 to 4.4) |
| **Moldova** | 0.85 (0.47-1.54) | -2.6 (-12.6 to 7.3) |
| **Mongolia** | 1.52 (0.85-2.73) | 3.6 (-1.3 to 8.5) |
| **Morocco** | 0.88 (0.35-2.22) | -2.0 (-16.6 to 12.6) |
| **Myanmar** | 1.23 (0.63-2.38) | 1.8 (-3.7 to 7.3) |
| **Nauru** | 0.67 (0.29-1.55) | -5.4 (-16.3 to 5.4) |
| **Nepal** | N/A | N/A |
| **Solomon Islands** | N/A | N/A |
| **Sri Lanka** | 0.83 (0.62-1.12) | -8.6 (-22.6 to 5.5) |
| **St. Vincent & the Grenadines** | 1.16 (0.46-2.90) | 2.5 (-12.0 to 17.0) |
| **Sudan** | 0.42 (0.16-1.13) | -15.3 (-34.9 to 4.3) |
| **Tajikistan** | 3.48 (0.96-12.67) | 12.0 (-2.6 to 26.6) |
| **Timor-Leste** | N/A | N/A |

| Country | Risk ratio (95% CI) | Average marginal effect, % (95% CI) |
|---|---|---|
| **Tokelau** | N/A | N/A |
| **Turkmenistan** | 0.81 (0.50-1.31) | -5.9 (-19.8 to 8.0) |
| **Tuvalu** | 2.48 (0.55-11.21) | 6.9 (-3.0 to 16.8) |
| **Uganda** | 0.11 (0.01-0.95) | -10.3 (-21.4 to 0.8) |
| **Vietnam** | 1.33 (0.69-2.56) | 4.8 (-6.0 to 15.6) |
| **Zambia** | 1.29 (0.16-10.41) | 1.8 (-11.8 to 15.4) |

Table A.6 - 18: Risk ratios and average marginal effects from country-level Poisson regression of statin use for secondary prevention between ≥ 55 years vs. ≤ 55 years of age (reference category)

| Country | Risk ratio (95% CI) | Average marginal effect, % (95% CI) |
|---|---|---|
| **Afghanistan** | 0.47 (0.19-1.12) | -19.8 (-40.0 to 0.4) |
| **Algeria** | 2.51 (1.70-3.72) | 26.7 (15.5 to 37.9) |
| **Armenia** | 4.38 (1.04-18.40) | 13.9 (3.4 to 24.5) |
| **Azerbaijan** | 1.49 (0.80-2.76) | 7.5 (-4.0 to 19.1) |
| **Bangladesh** | 2.10 (1.36-3.24) | 17.4 (5.5 to 29.3) |
| **Belarus** | 1.23 (0.63-2.39) | 3.9 (-8.0 to 15.7) |
| **Benin** | 1.76 (0.28-10.94) | 3.0 (-9.0 to 15.0) |
| **Bhutan** | N/A | N/A |
| **Botswana** | N/A | N/A |
| **Burkina Faso** | 1.43 (0.29-7.08) | 1.4 (-5.1 to 8.0) |
| **Ecuador** | 2.88 (1.37-6.08) | 16.2 (4.6 to 27.9) |
| **Eswatini** | N/A | N/A |
| **Ethiopia** | 3.10 (0.75-12.75) | 8.4 (-3.7 to 20.5) |
| **Georgia** | 2.39 (1.16-4.96) | 5.5 (1.3 to 9.7) |
| **Guyana** | 3.78 (1.19-12.02) | 15.3 (1.1 to 29.5) |
| **Iran** | 1.36 (1.07-1.73) | 17.1 (5.0 to 29.2) |
| **Iraq** | 2.12 (1.03-4.37) | 22.2 (4.3 to 40.1) |
| **Jordan** | 2.34 (1.51-3.64) | 30.0 (16.6 to 43.5) |
| **Kenya** | N/A | N/A |
| **Kiribati** | 4.07 (0.83-19.82) | 12.0 (-5.7 to 29.7) |
| **Kyrgyzstan** | 2.41 (0.99-5.88) | 5.4 (-0.5 to 11.2) |
| **Lebanon** | 1.72 (0.70-4.27) | 24.9 (-16.7 to 66.6) |
| **Mexico** | 0.86 (0.43-1.72) | -2.4 (-14.2 to 9.3) |
| **Moldova** | 1.02 (0.63-1.63) | 0.3 (-7.0 to 7.5) |
| **Mongolia** | 1.72 (1.00-2.96) | 5.2 (-0.2 to 10.6) |
| **Morocco** | 2.19 (0.72-6.67) | 11.3 (-2.9 to 25.4) |
| **Myanmar** | 0.72 (0.36-1.45) | -2.8 (-8.5 to 2.9) |
| **Nauru** | 1.41 (0.43-4.55) | 4.5 (-10.9 to 20.0) |
| **Nepal** | N/A | N/A |
| **Solomon Islands** | N/A | N/A |
| **Sri Lanka** | 2.34 (1.59-3.44) | 35.9 (22.8 to 49.0) |
| **St. Vincent & the Grenadines** | 5.26 (1.63-16.96) | 22.8 (4.7 to 40.9) |
| **Sudan** | 0.70 (0.22-2.17) | -6.3 (-25.9 to 13.4) |
| **Tajikistan** | 1.53 (0.38-6.15) | 4.2 (-8.7 to 17.1) |

| Country | Risk ratio (95% CI) | Average marginal effect, % (95% CI) |
|---|---|---|
| **Timor-Leste** | N/A | N/A |
| **Tokelau** | N/A | N/A |
| **Turkmenistan** | 1.23 (0.75-2.02) | 5.7 (-7.5 to 18.8) |
| **Tuvalu** | 0.15 (0.01-1.96) | -15.9 (-41.8 to 10.0) |
| **Uganda** | 0.59 (0.10-3.41) | -2.3 (-9.7 to 5.2) |
| **Vietnam** | 3.13 (1.50-6.55) | 18.1 (7.0 to 29.3) |
| **Zambia** | 3.88 (0.68-22.27) | 9.4 (-4.6 to 23.4) |

Table A.6 - 19: Risk ratios and average marginal effects from country-level Poisson regression of statin use for secondary prevention between ≥ secondary education vs ≤ primary school (reference category)

| Country | Risk ratio (95% CI) | Average marginal effect, % (95% CI) |
|---|---|---|
| **Afghanistan** | 2.05 (1.03-4.08) | 27.3 (1.3 to 53.2) |
| **Algeria** | 0.93 (0.58-1.50) | -2.0 (-15.0 to 10.9) |
| **Armenia** | 0.46 (0.09-2.39) | -13.6 (-54.1 to 26.9) |
| **Azerbaijan** | N/A | N/A |
| **Bangladesh** | 1.31 (0.72-2.40) | 7.4 (-9.7 to 24.5) |
| **Belarus** | 1.28 (0.74-2.21) | 4.7 (-5.1 to 14.4) |
| **Benin** | N/A | N/A |
| **Bhutan** | N/A | N/A |
| **Botswana** | N/A | N/A |
| **Burkina Faso** | 10.03 (2.86-35.13) | 21.8 (-6.7 to 50.4) |
| **Ecuador** | 1.86 (0.92-3.75) | 10.4 (-2.0 to 22.9) |
| **Eswatini** | N/A | N/A |
| **Ethiopia** | 0.33 (0.03-3.46) | -4.4 (-11.4 to 2.6) |
| **Georgia** | 0.39 (0.11-1.42) | -11.1 (-34.0 to 11.9) |
| **Guyana** | 0.98 (0.36-2.68) | -0.2 (-13.2 to 12.8) |
| **Iran** | 1.12 (0.93-1.36) | 7.0 (-4.5 to 18.5) |
| **Iraq** | 1.02 (0.55-1.89) | 0.7 (-21.1 to 22.4) |
| **Jordan** | 1.36 (0.87-2.13) | 13.8 (-8.4 to 36.0) |
| **Kenya** | N/A | N/A |
| **Kiribati** | 1.45 (0.26-8.04) | 3.6 (-14.6 to 21.8) |
| **Kyrgyzstan** | 0.26 (0.05-1.21) | -17.0 (-51.0 to 17.0) |
| **Lebanon** | 1.11 (0.49-2.53) | 4.8 (-34.0 to 43.6) |
| **Mexico** | 1.52 (0.82-2.81) | 6.9 (-3.1 to 16.8) |
| **Moldova** | 3.26 (0.42-25.39) | 10.8 (0.6 to 21.0) |
| **Mongolia** | 1.68 (0.65-4.32) | 3.8 (-1.9 to 9.4) |
| **Morocco** | 2.76 (1.19-6.41) | 17.8 (-1.1 to 36.6) |
| **Myanmar** | 2.54 (1.05-6.16) | 9.3 (0.3 to 18.3) |
| **Nauru** | 1.83 (0.52-6.47) | 6.8 (-5.8 to 19.4) |
| **Nepal** | N/A | N/A |
| **Solomon Islands** | N/A | N/A |
| **Sri Lanka** | 1.64 (1.17-2.31) | 21.7 (8.6 to 34.9) |
| **St. Vincent & the Grenadines** | 1.67 (0.44-6.28) | 9.9 (-16.8 to 36.7) |
| **Sudan** | 6.21 (1.91-20.14) | 38.9 (10.9 to 67.0) |
| **Tajikistan** | 4.17 (1.31-13.30) | 17.0 (-2.7 to 36.7) |

| Country | Risk ratio (95% CI) | Average marginal effect, % (95% CI) |
|---|---|---|
| **Timor-Leste** | N/A | N/A |
| **Tokelau** | N/A | N/A |
| **Turkmenistan** | N/A | N/A |
| **Tuvalu** | 5.71 (0.62-52.29) | 12.8 (-1.7 to 27.3) |
| **Uganda** | 1.25 (0.22-7.22) | 1.1 (-7.4 to 9.6) |
| **Vietnam** | 1.20 (0.61-2.36) | 2.6 (-6.7 to 11.9) |
| **Zambia** | 3.55 (0.84-15.01) | 11.6 (-8.7 to 31.8) |

Table A.6 - 20: Risk ratios and average marginal effects from country-level Poisson regression of statin use for secondary prevention between rural vs. urban residence (reference category)

| Country | Risk ratio (95% CI) | Average marginal effect, % (95% CI) |
|---|---|---|
| **Afghanistan** | 1.41 (0.46-4.37) | 9.5 (-21.6 to 40.6) |
| **Algeria** | 0.54 (0.30-0.95) | -15.2 (-26.5 to -4.0) |
| **Armenia** | 1.07 (0.44-2.56) | 0.7 (-9.7 to 11.2) |
| **Azerbaijan** | 1.44 (0.69-3.00) | 7.1 (-7.0 to 21.2) |
| **Bangladesh** | 0.96 (0.55-1.67) | -1.1 (-15.0 to 12.7) |
| **Belarus** | 0.56 (0.32-0.99) | -11.0 (-22.1 to 0.2) |
| **Benin** | 0.13 (0.03-0.70) | -9.9 (-24.9 to 5.0) |
| **Bhutan** | N/A | N/A |
| **Botswana** | N/A | N/A |
| **Burkina Faso** | 0.59 (0.09-3.82) | -2.2 (-10.4 to 6.1) |
| **Ecuador** | N/A | N/A |
| **Eswatini** | N/A | N/A |
| **Ethiopia** | 0.37 (0.11-1.21) | -7.2 (-17.0 to 2.7) |
| **Georgia** | 0.98 (0.50-1.95) | -0.1 (-4.9 to 4.7) |
| **Guyana** | 1.08 (0.33-3.52) | 0.9 (-13.8 to 15.7) |
| **Iran** | 0.93 (0.75-1.16) | -4.1 (-16.5 to 8.3) |
| **Iraq** | 1.09 (0.53-2.22) | 2.9 (-23.5 to 29.4) |
| **Jordan** | 1.24 (0.80-1.91) | 9.2 (-10.9 to 29.3) |
| **Kenya** | N/A | N/A |
| **Kiribati** | N/A | N/A |
| **Kyrgyzstan** | 0.48 (0.15-1.51) | -5.1 (-14.1 to 3.9) |
| **Lebanon** | N/A | N/A |
| **Mexico** | 0.69 (0.35-1.37) | -5.3 (-15.0 to 4.3) |
| **Moldova** | 0.66 (0.37-1.20) | -6.5 (-14.9 to 1.9) |
| **Mongolia** | 0.80 (0.46-1.40) | -1.9 (-6.6 to 2.8) |
| **Morocco** | 0.16 (0.02-1.19) | -15.9 (-26.4 to -5.4) |
| **Myanmar** | N/A | N/A |
| **Nauru** | N/A | N/A |
| **Nepal** | N/A | N/A |
| **Solomon Islands** | N/A | N/A |
| **Sri Lanka** | N/A | N/A |
| **St. Vincent & the Grenadines** | N/A | N/A |
| **Sudan** | 0.28 (0.08-1.03) | -20.3 (-41.1 to 0.5) |
| **Tajikistan** | N/A | N/A |
| **Timor-Leste** | N/A | N/A |

| Country | Risk ratio (95% CI) | Average marginal effect, % (95% CI) |
|---|---|---|
| **Tokelau** | N/A | N/A |
| **Turkmenistan** | 0.96 (0.54-1.71) | -1.1 (-16.8 to 14.6) |
| **Tuvalu** | N/A | N/A |
| **Uganda** | 0.92 (0.15-5.51) | -0.4 (-9.3 to 8.5) |
| **Vietnam** | 0.44 (0.22-0.88) | -14.1 (-24.6 to -3.5) |
| **Zambia** | 0.10 (0.02-0.57) | -15.9 (-33.4 to 1.6) |

## A.7 STROBE Checklist

### A.7.1 Essay 1

| | Item No | Recommendation |
|---|---|---|
| **Title and abstract** | 1 | (*a*) Indicate the study's design with a commonly used term in the title or the abstract **The title of Essay 1 includes this information.** |
| | | (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found<br>**This information is included in the abstract of Essay 1.** |
| **Introduction** | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported<br>**This information is contained throughout the introduction of Essay 1.** |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses<br>**This information is provided in the final paragraph of the introduction of Essay 1.** |
| **Methods** | | |
| Study design | 4 | Present key elements of study design early in the paper<br>**This information is provided in the Methods section, in the subsection on Data Sources and Cascade Construction of Essay 1.** |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection<br>**This information is provided in the Methods, in the subsection on Data Sources of Essay 1.** |
| Participants | 6 | (*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up<br>**This information is provided in the Methods section, in the subsection on Data Sources of Essay 1.** |
| | | (*b*) For matched studies, give matching criteria and number of exposed and unexposed<br>**We did not use a matched design in Essay 1.** |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable<br>**Please see Methods, subsections on Cascade Construction and Statistical Analysis of Essay 1.** |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group<br>**This information is contained in the Methods section, under the subheadings Data Sources and Cascade Construction of Essay 1.** |
| Bias | 9 | Describe any efforts to address potential sources of bias<br>**This information is provided in the Methods section, under the subheading Cascade Construction and Statistical Analyses of Essay 1.** |
| Study size | 10 | Explain how the study size was arrived at |

| | | |
|---|---|---|
| | | **This information can be found in Methods, under the section on Data Sources of Essay 1.** |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why<br>**Please see the Methods section for this information, under the subheadings Data Sources, Cascade Construction, and Statistical Analysis of Essay 1.** |
| Statistical methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding **Please see Methods, in the subsection Statistical Analyses of Essay 1.** |
| | | (*b*) Describe any methods used to examine subgroups and interactions<br>**Please see Methods, in the subsection Statistical Analyses of Essay 1.** |
| | | (*c*) Explain how missing data were addressed<br>**Please see Methods, in the subsection Cascade Construction of Essay 1** |
| | | (*d*) If applicable, explain how loss to follow-up was addressed<br>**This is not applicable as Essay 1 did not have loss to follow-up.** |
| | | (*e*) Describe any sensitivity analyses<br>**This information is provided in the Methods section under the subheading Statistical Analysis of Essay 1.** |
| **Results** | | |
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed<br>**Please see A.1 for details on the survey search process.** |
| | | (b) Give reasons for non-participation at each stage<br>**Please see A.1 for details on the survey search process including reasons for exclusion.** |
| | | (c) Consider use of a flow diagram<br>**We have not used a flow diagram in Essay 1.** |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders<br>**This information is provided in Table** 2.1-1**.** |
| | | (b) Indicate number of participants with missing data for each variable of interest **This information is provided in Table A.6 - 15.** |
| | | (c) Summarise follow-up time (eg, average and total amount)<br>**The survey years are provided in the Data Sources Section of Essay 1 and Table A.6 - 1. There are no formal follow-up times in Essay 1.** |
| Outcome data | 15* | Report numbers of outcome events or summary measures over time<br>**This information is provided in Results Section, subsection Sample Characteristics of Essay 1, and Table** 2.1-1**.** |
| Main results | 16 | (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included |

| | | |
|---|---|---|
| | | **This information is provided in Table** 2.1-2**, Figure 2.1-1: Cascades of Care by** Biomarker **, and Figure 2.1-1: Cascades of Care by** Biomarker **.** |
| | | (*b*) Report category boundaries when continuous variables were categorized<br>**These are reported in Table** 2.1-2**.** |
| | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period<br>**This is not applicable to Essay 1.** |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses<br>**These results are reported in A.5 and A.6.** |
| **Discussion** | | |
| Key results | 18 | Summarise key results with reference to study objectives<br>**This information can be found in paragraphs 1-6 of the Discussion section of Essay 1.** |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias<br>**This information can be found in paragraph 7 of the Discussion section of Essay 1.** |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence<br>**This information can be found in the Discussion section, paragraphs 2-6 of Essay 1.** |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results<br>**This information can be found in the Discussion, in paragraph 2-6 of Essay 1**. |
| **Other information** | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based<br>**We have provided this information in the section titled "Funding" following Essay 1.** |

## A.7.2 Essay 2

| | Item No | Recommendation |
|---|---|---|
| **Title and abstract** | 1 | (*a*) Indicate the study's design with a commonly used term in the title or the abstract<br>**This information is provided in the Title and Abstract of Essay 2.** |
| | | (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found<br>**This information is provided throughout the Abstract of Essay 2.** |
| **Introduction** | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported<br>**This information is provided throughout the Introduction of Essay 2.** |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses<br>**This information is stated in the final paragraph of the Introduction of Essay 2.** |
| **Methods** | | |
| Study design | 4 | Present key elements of study design early in the paper<br>**Study design is presented throughout the Methods section of Essay 2 and Appendix A.1-5.** |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection<br>**This information is provided in the first paragraph of the Methods section of Essay 2, and in Appendix A.1.** |
| Participants | 6 | (*a*) Give the eligibility criteria, and the sources and methods of selection of participants<br>**This information is provided in the second and third paragraph of the Methods section of Essay 2, and in Appendix A.1-3.** |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable<br>**This information is provided in the Methods under the Outcomes and Statistical Analysis subsections of Essay 2, and in Appendix A.1.** |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group<br>**This information is provided in the Methods under the Outcomes subsection of Essay 2, and in Appendix A.1-5.** |

| | | |
|---|---|---|
| Bias | 9 | Describe any efforts to address potential sources of bias<br>**This information is described in the Methods under the Statistical Analysis subsection of Essay 2.** |
| Study size | 10 | Explain how the study size was arrived at<br>**This information is provided in the Methods under the Sample subsection of Essay 2, and in Appendix A.1.** |
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why<br>**This information is described in the Methods under the Statistical Analysis subsection of Essay 2 and in Appendix A.1.** |
| Statistical methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding<br>**This information is provided in the Methods, throughout the Statistical Analysis subsection of Essay 2.** |
| | | (*b*) Describe any methods used to examine subgroups and interactions<br>**This information is provided in the Methods, throughout the Statistical Analysis subsection of Essay 2.** |
| | | (*c*) Explain how missing data were addressed<br>**This information is provided in the Methods, in the penultimate paragraph of the Statistical Analysis subsection of Essay 2.** |
| | | (*d*) If applicable, describe analytical methods taking account of sampling strategy<br>**This information is provided in the Methods under the Sample subsection of Essay 2, and in Appendix A.1.** |
| | | (*e*) Describe any sensitivity analyses<br>**This information is provided in the Methods, in the penultimate paragraph of the Statistical Analysis subsection of Essay 2.** |
| **Results** | | |
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed<br>**This information is reported in the Results under the Sample characteristics subsection of Essay 2, and in Appendix A.1.** |
| | | (b) Give reasons for non-participation at each stage<br>**This information is reported in Appendix A.1.** |
| | | (c) Consider use of a flow diagram<br>**This information is reported in Appendix A.1.** |

| | | |
|---|---|---|
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders<br>**This information is provided in Table 2.2-1, in the Results under the Sample characteristics subsection of Essay 2, and in Appendix A.6.3.** |
| | | (b) Indicate number of participants with missing data for each variable of interest<br>**This information is provided in the Results under the Sample characteristics subsection of Essay 2, and in Appendix A.6.3.** |
| Outcome data | 15* | Report numbers of outcome events or summary measures<br>**This information is provided in Table 2.2-1, in the Results under the Estimates of statin use subsection of Essay 2, and in Appendix A.6.3.** |
| Main results | 16 | **(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included**<br>**This information is provided in Figure 2.2-1 to Figure 2.2-4 and throughout the Results section of Essay 2.** |
| | | (*b*) Report category boundaries when continuous variables were categorized<br>**This information is provided in Figure 2.2-1 to Figure 2.2-4, Appendix A.6.3-4, and throughout the Results section of Essay 2.** |
| | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period<br>**Throughout Essay 2 we use both risk ratios and average marginal effects.** |
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses<br>**This information is provided in the Results section under the Sensitivity analyses subsection of Essay 2, and in Appendix A.6.3-4.** |
| **Discussion** | | |
| Key results | 18 | Summarise key results with reference to study objectives<br>**This information is provided throughout the Discussion of Essay 2.** |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias<br>**This information is provided in the final paragraph the Discussion of Essay 2.** |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence<br>**This information is provided throughout the Discussion of Essay 2.** |

| | | |
|---|---|---|
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results<br>**This information is provided throughout the Discussion of Essay 2.** |
| **Other information** | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based<br>**This information is provided in the Funding Support and Disclosures sections of Essay 2** |

# B. Appendix for Essay 3

## B.1 Wording of messages

Table B.1 - 1: Wording of messages

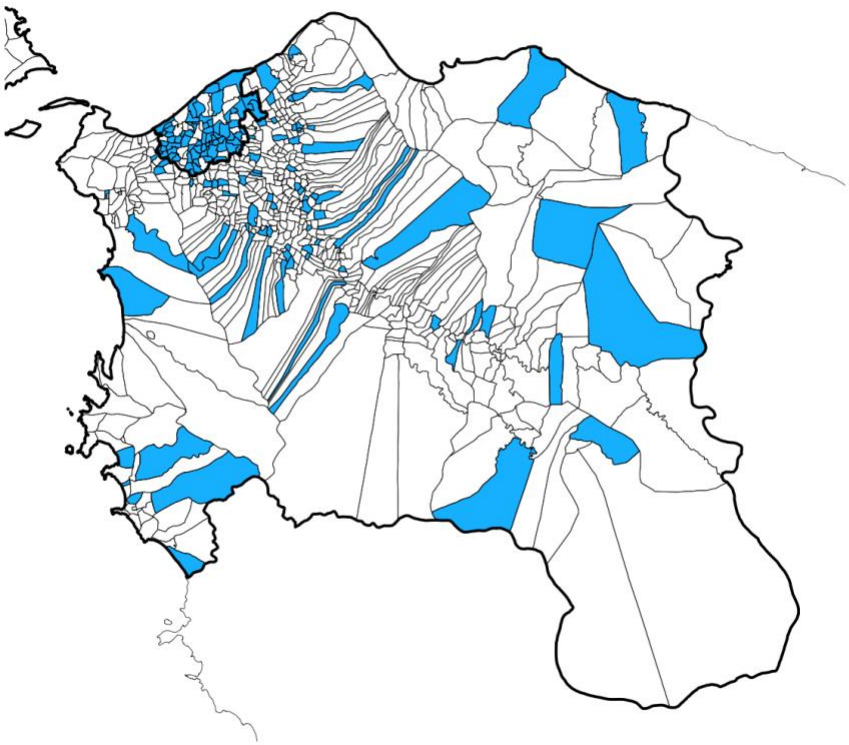
| Message (English) | Message (Indonesian) | Sending date |
|---|---|---|
| Greetings [Mr/Ms] [name], do you know that diabetes does not always show symptoms but can be treated better if detected earlier. Check for FREE at POSBINDU [date] | Salam [Pak/Ibu] [name], tahukah Anda diabetes tdk selalu menunjukan gejala namun dapat diobati lbh baik jika diketahui lbh awal. Periksa GRATIS di POSBINDU [date] | 5 days before the first village screening date |
| Greetings [Mr/Ms] [name], do you know that people over 40 years old have a high risk of diabetes & hypertension? Ask kader / PKM & check for FREE at POSBINDU [date] | Salam [Pak/Ibu] [name], tahukah Anda umur diatas 40 tahun memiliki risiko tinggi diabetes & darah tinggi? Tanyakan Kader/PKM & Periksa GRATIS di POSBINDU tgl [date] | 3 days before the first village screening date |
| Greetings [Mr / Mrs] [name], remember to benefit from a FREE diabetes and hypertension CHECK in POSBINDU tomorrow morning at [place within the village]. Contact nearest kader or PKM. | Salam [Pak/Ibu] [name], Jangan Lupa untuk PERIKSA Darah Tinggi dan Diabetes GRATIS di POSBINDU Besok pagi di [place within village]. Hubungi Kader dan PKM terdekat | 1 day before the first village screening date |
| Greetings [Mr/Ms] [name], remember that hypertension does not always show symptoms but can be treated if detected earlier. Check for FREE at POSBINDU [date] | Salam [Pak/Ibu] [name], ingatlah darah tinggi tdk selalu menunjukan gejala namun dapat diobati lbh baik jika diketahui lbh awal. Periksa GRATIS di POSBINDU [date] | 5 days before the second village screening date |
| Greetings [Mr/Ms] [name], remember that people over 40 years old have a high risk of diabetes & hypertension. Ask Cadre / PKM & check for FREE at POSBINDU date [date] | Salam [Pak/Ibu] [name], ingatlah umur diatas 40 tahun memiliki risiko tinggi diabetes & darah tinggi. Tanyakan Kader/PKM & Periksa GRATIS di POSBINDU tgl [date] | 3 days before the second village screening date |
| Greetings [Mr / Mrs] [name], remember to benefit from a FREE diabetes and hypertension CHECK in POSBINDU morning at [place within the village]. Contact nearest kader or PKM. | Salam [Pak/Ibu] [name], Jangan Lupa untuk PERIKSA Darah Tinggi dan Diabetes GRATIS di POSBINDU Besok pagi di [place within village]. Hubungi Kader dan PKM terdekat | 1 day before the second village screening date |

## B.2 Data collection details

Table B.2 - 1: Data collection timeline

| | 2019 | | | 2020 | | | |
|---|---|---|---|---|---|---|---|
| **Month** | **October** | **November** | **December** | **January** | **February** | **March** | **April** |
| Qualitative pre-studies | | | | | | | |
| Baseline data collection (enrolment) | | | | | | | |
| Treatment allocation | | | | X | | | |
| Pilot Intervention | | | | X | | | |
| Intervention | | | | | | | |
| Endline data collection | | | | | | | |

Figure B.2 - 1: Sample villages



Note: Boundaries of the city Banda Aceh and the district Aceh Besar are in bold. Taken from the supplementary material in Chavarría et al. (2021).

### B.2.1 Inclusion Criteria

We targeted the population at high risk for NCDs, who do not yet adhere to the recommended screening schedule. Based on this, we formulated six inclusion and exclusion criteria:

1. The respondent must be between 40 and 70 years old. The WHO PEN Protocol for essential NCD interventions for primary health care in low-resource settings specifies that individuals over 40 years old should undergo routine screening for hypertension and diabetes (WHO 2010).
2. The respondent cannot already be diagnosed with diabetes or hypertension, as this would render screening unnecessary.
3. The respondent did not undergo diabetes screening within the last year. Individuals that have done so seem to be adhering to recommended screening schedules, and would therefore not fall within our target population. Hypertension screening is not included in this restriction, as blood pressure checks are usually carried out whenever individuals visit a community health center and are hence much more common in this context.
4. The respondent must not be in regular care for another disease. If they are in regular contact with health system services, a lack of NCD screening may not stem from a lack of demand but rather from further downstream health system failures, which we do not aim to address in our intervention.
5. The respondent must be reachable via phone and text messages on either their own or another household member's phone.
6. The respondent must be at home at the time of the interview. Logistically, it was not feasible to re-visit households. Furthermore, seeking out respondents outside of their home would have violated the comparability of interview conditions across our sample. For instance, respondents might feel most comfortable answering sensitive questions regarding their health in their own home. This criterion might bear the risk to exclude the working population, which we sought to reduce by extending the enumeration time to the evening and the weekends. Overall, this might not be as severe in our age group as in younger age groups, as some are retired already or work from home.

### B.2.2 Random walk scheme

Taken from the supplementary material in Chavarría et al. (2021).
The enumerators conducted the random walk according to the following instructions to ensure that the walk yields a representative sample of the target population:

1. Get permission and number of village subdivisions from the village head.
2. Ask for a description of the village boundaries, including remote houses.
3. Get the total number of houses in the village and divide this number by 100. This number indicates the skip-pattern of houses. It takes into account the aim of having around 20 respondents per village that should be evenly distributed throughout the village, how many interviews one enumerator can do in one day, and the likelihood of finding a household member that meets the inclusion criteria.
4. Then, randomly select which village subdivision to visit first and at which house (a random number between 1 and the skip number) to begin with. The count begins from the point of entry to the respective subdivision.
5. If a person is at home, check and record the eligibility and conduct the interview if the criteria are fulfilled and the respondent is willing to.
6. After each contact, continue with the next house according to the skip pattern.
7. In case of an empty house, contact the direct neighbor until an occupied house was found and record the number of empty houses.
8. When walking, turn left on every turn and only count houses to your left. Whenever you reach the end of the village subdivision or the road, turn around and continue.
9. One village was considered finished if 20 interviews were conducted or all houses that should be contacted according to the skip pattern were contacted.

Table B.2 - 2: Overview of baseline contacts

| | **Total** | **Of all contacts** | | | **Of all consenting** | | **Of all eligible** | | |
|---|---|---|---|---|---|---|---|---|---|
| | Contacts | Empty houses | Refusal/ busy/ other | Consent | Eligible | Ineligible | Refusal | Incomplete | Complete |
| **N** | 15,128 | 7,682 | 946 | 6,500 | 2,115 | 4,385 | 11 | 98 | 2,006 |
| | **Of all ineligible** | | | | | | | | |
| | No member 40-70 | | No member 40-70 present | | No phone access | | No member without diagnosis/ screening/care | | |
| **N** | 1,589 | | 414 | | 270 | | 2,112 | | |

Note: Disaggregation of the number of contacts and respondents at baseline. Contacts refer to all dwelling units drawn by the random walk within the villages. Empty houses are dwellings where no one was present at the first contact, including dwellings which might not be inhabited. Refusal/busy/other denotes to reasons for non-participation stated at the first contact. Consent signifies that at least one household member agreed to respond to the screening questions to assess eligibility. Eligible refers to all contacts where at least one eligible member was present. Ineligible are all contacts where no member was eligible or no eligible member was present. Refusal denotes those (eligible) contacts for which no eligible member was willing to participate in the study. Incomplete denotes the interviews which were missing information on the telephone number. Complete refers to all conducted interviews with information on the telephone number. The columns 'no member 40-70' till 'no phone access' refer to the household eligibility criteria, the last column to the individual-level criteria (if multiple members were eligible, one was randomly selected). Among individuals, ineligibility could occur due to previous hypertension or diabetes diagnosis (59.36%), being in continued care (8.42%), being tested for diabetes in the last year (31.98%), or not answering one of the eligibility questions (0.24%). Taken from the supplementary material in Chavarría et al. (2021).

### B.2.3 Power Calculations

*The following procedure of power calculation was set in the pre-analysis plan and under the assumption of an in-person endline data collection, which we had to deviate from due to the start of the COVID-19 pandemic.*

The sample size was determined based on sufficient statistical power to determine a meaningful change in the primary outcome, screening uptake. Prior to baseline data collection, we could approximate the base levels of diabetes and hypertension separately from the most recent round of the Indonesian health survey Riskesdas (Riskesdas 2018). This data supplies self-reported figures on whether the individual respondent attends screening regularly, irregularly or never, where regularly is defined as according to the doctor's advice for patients and once a year for the non-diagnosed. As our outcome is measured during approximately two months, the most appropriate base value is the *regular* category. The national average of the age group between 45 and 74 years is 5.2% for diabetes and 16.7% for hypertension screening[19]. As there are no previous studies on the effect of text message reminders on diabetes and hypertension screening, the minimum detectable effect size was approximated from studies that measure the effect of text message reminders on the initial take-up of other health services. A review on vaccination uptake found an average effect size of 4.5 percentage points (Jacobson Vann et al. 2018). With a power of 80% and 5% significance, a sample size of 1,800 individuals would be required to detect such an effect for both diabetes and hypertension screening. We would be able to detect a 4.4 percentage point increase for blood pressure measurement and a 2.6 percentage point increase in blood glucose measurement.[20] This implies that we would be able to detect a significant effect on any screening if at least 24 more respondents of the treatment group attend diabetes screening during the intervention period compared to the control group at the same time. With this sample size, we will also be likely to detect a small change in the secondary knowledge outcomes. For the SMS knowledge, the mean points of the treatment group need to be 0.1 points higher than for the control group, which means that on average every tenth respondent needs to know one item more. For the broader health knowledge index, we will be able to detect a 0.56 point difference, which means that on average about every other individual in the treatment group needs to know at least one item more than the control group. As these changes are smaller than a meaningful effect that we would expect to be a channel for the primary outcome, we expect to be able to detect every meaningful effect of the intervention on health knowledge.

We account for potential sample reductions by over-sampling by about 15%. The main reason for a high over-sampling rate is that we rely on functioning phone numbers for the intervention. The over-sampling also accounts for respondents that need to be excluded from the treatment group because the messages could not be delivered to their mobile phone. One reason might be that the respondent changed his/her telephone number, which is common in this context. We tried to avoid this by asking for a contact number that is likely to be active until April 2020, and by planning a short duration between baseline interview and intervention. Another reason might be a typo when entering the phone number. Non-compliance might be a problem if the respondent does not own a mobile phone and the stated contact person does not transfer the message. We minimize this by specifically asking for a contact person from whom a message can be received and by including the name of the recipient in each message. Finally, we expect attrition at endline as it is likely that some respondents either cannot be found or are unavailable or unwilling to participate in a second interview. However, we expect overall attrition to be low: at baseline, each respondent has agreed to a second interview, we have taken detailed information on the place of residence (name, address, and geolocation), and we can contact him/her through the mobile phone number.

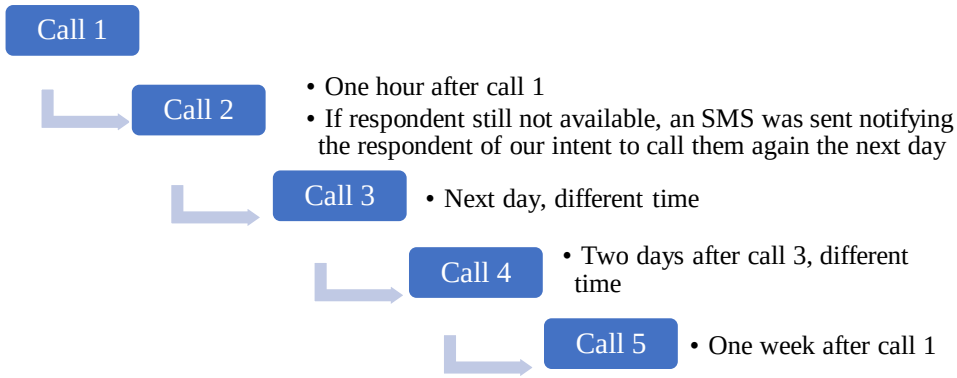
[19] From our baseline data, we know that slightly more individuals (23%) had a blood pressure check during the previous year. This would increase the minimal detectable effect size by 0.5 percentage points.

[20] We used the 3ie Sample size and minimum detectable effect calculator as described in Djimeu and Houndolo (2016). For screening uptake, we used the formula for binary outcomes and for the knowledge index the formula for continuous outcomes.

### B.2.4 Calling procedure at endline

Taken from the supplementary material in Chavarría et al. (2021).
The telephone interviews were scheduled according to the call pattern that is displayed below. Initially, each respondent received five calls, which were staggered with time delays of one hour to three days any at varying times of the day. After the second unanswered call, a standardized text message was sent announcing another call on the following day. Whenever feasible, the same enumerator who had visited the respondent during the baseline survey was deployed to call them during the phone interview, in order to maximize the response rate as well as the respondents' trust towards the enumerator. In the end of the data collection period, each number that was not answered during five calls received one additional call from another interviewer (with a different telephone number).

Figure B.2 - 2: Call Pattern at endline



## B.3 Variable definitions

### B.3.1 Knowledge Indices

Table B.3 - 1: Composition SMS knowledge index

| ***Question*** | ***Coding*** |
|---|---|
| "One can feel whether one experiences diabetes/ hypertension " | 0 if (strongly) agree, 1 if (strongly) disagree |
| "It makes a difference to start diabetes/ hypertension treatment early" | 0 if (strongly) disagree, 1 if (strongly) agree |
| Which risk factors of diabetes/ hypertension do you know? | 1 if mentioned age, 0 otherwise |
| Have you ever heard of *Posbindu*? | 0 if (strongly) disagree, 1 if (strongly) agree |

Note: Each question with diabetes / hypertension is included for both diseases separately. "Don't know" coded as 0.

Table B.3 - 2: Composition knowledge index

| ***Question*** | ***Coding*** |
|---|---|
| "Which risk factors of diabetes / hypertension do you know?" | 1 count for each correctly identified factor |
| Do you know someone with diabetes/ hypertension? | Binary variable for the answers: Family member, friend, neighbour, other, none. |
| Which complications of disease diabetes/ hypertension do you know? | 1 count for each correctly identified factor |
| "Who do you think should be screened?" | 0 if "everyone who feels sick", 1 if "everyone" or "people at risk" |
| Which ways of controlling diabetes/ hypertension do you know? | 1 count for each correctly identified factor |
| "It makes a difference to start treatment early" | 0 if (strongly) disagree, 1 if (strongly) agree |
| "There is nothing one can do to prevent diabetes/ hypertension, it is destiny." | 0 if (strongly) agree, 1 if (strongly) disagree |
| "One can feel whether you experience diabetes/ hypertension " | 0 if (strongly) agree, 1 if (strongly) disagree |
| "Checking your level regularly helps to detect diabetes/ hypertension early" | 0 if (strongly) disagree, 1 if (strongly) agree |
| "Diabetes/ hypertension is treatable" | 0 if (strongly) disagree, 1 if (strongly) agree |

Note: Each question with diabetes / hypertension is included for both diseases separately. "Don't know" coded as 0.

## B.4 Intervention piloting

We piloted the messages in January 2020 to find out whether the contents were understandable, deemed trustworthy, and to assess whether the time of sending (morning/evening) and order of information (age as risk factor/having it without feeling it) mattered. However, the messages were not sent according to the time schedule of the intervention, i.e., not 5, 3 and 1 day before a Posbindu date. The messages 1 and 2 were sent to the respondents on two consecutive days, and respondents were interviewed via phone a few days after. In 10 out of 14 cases, the phone was answered on the designated survey day (no second contact attempts on another day were made). The messages were received in 9 out of 10 cases, although in two cases they were received by the children of the main respondent and were not yet transferred to him/her. In both cases, the Posbindu dates were a few weeks ahead, so the children might not have felt the urgency to deliver the message directly. We assumed that this would be different when the dates are close by.

Qualitative semi-structured interviews were conducted with the remaining eight respondents. All respondents confirmed that they trusted the message. Reasons stated were the connection to the interview conducted two months before, the mentioning of a public program (Posbindu) and the kaders, the mentioning of the respondent's name, and confirmation of the content by the kader. Most respondents remembered that the messages were reminding them to go to Posbindu, and some specifically mentioned the Posbindu date. Three respondents could recall that the messages contained information regarding diseases, and two additional respondents recalled information regarding risk factors. The respondents liked in particular that the messages served as reminders, and two respondents explicitly stated that they liked how the messages were written. Time of message sending and order of the messages did not appear to make a difference in how the messages were perceived.

While experimenter demand biases are always a concern in these types of interviews, we believe them to be minimal here. First of all, respondents may feel less inclined to cater to experimenter demand during phone interviews, as they are less personal than in-home visits. This was confirmed by our enumerators, who qualitatively assessed that respondents were likely to report their true opinions. Second of all, respondents always gave specific reasons and arguments for their opinions, making them more credible.

## B.5 Sample characteristics and attrition

Table B.5 - 1: Baseline balance across treatment and control group

| | Control group | | | Treatment group | | | |
|---|---|---|---|---|---|---|---|
| | Mean | Standard deviation | N | Mean | Standard deviation | N | p-value |
| Age | 50.35 | 8.25 | 1,002 | 49.91 | 8.08 | 1,003 | 0.221 |
| Female | 0.64 | 0.48 | 1,001 | 0.64 | 0.48 | 1,003 | 0.936 |
| Highest level of schooling | | | | | | | 0.876 |
| None | 0.05 | 0.22 | 49 | 0.05 | 0.22 | 49 | |
| Primary | 0.25 | 0.43 | 253 | 0.24 | 0.42 | 236 | |
| Junior Secondary | 0.21 | 0.41 | 215 | 0.22 | 0.41 | 219 | |
| Senior Secondary | 0.35 | 0.48 | 346 | 0.35 | 0.48 | 348 | |
| Tertiary | 0.14 | 0.35 | 139 | 0.15 | 0.36 | 152 | |
| Wealth quintile | | | | | | | 0.611 |
| 1 | 0.22 | 0.42 | 225 | 0.21 | 0.41 | 213 | |
| 2 | 0.20 | 0.40 | 203 | 0.18 | 0.39 | 182 | |
| 3 | 0.19 | 0.39 | 192 | 0.20 | 0.40 | 200 | |
| 4 | 0.19 | 0.39 | 188 | 0.20 | 0.40 | 198 | |
| 5 | 0.19 | 0.39 | 193 | 0.21 | 0.41 | 211 | |
| Own phone | 0.58 | 0.49 | 995 | 0.62 | 0.49 | 1,000 | 0.044 |
| Posbindu in own village | 0.90 | 0.30 | 1,002 | 0.90 | 0.30 | 1,004 | 0.666 |
| Ever had blood pressure or blood glucose checked | 0.58 | 0.49 | 999 | 0.59 | 0.49 | 1,002 | 0.610 |
| Disease knowledge index | 18.30 | 5.53 | 925 | 17.97 | 5.42 | 936 | 0.190 |
| Patience | 5.73 | 2.83 | 1,002 | 5.70 | 2.86 | 1,004 | 0.823 |
| Willingness to take risks | 4.57 | 2.66 | 1,002 | 4.45 | 2.62 | 1,004 | 0.298 |
| Joint F-test | | | | 0.868 | | | |

Note: Means, standard deviation and number of observations of main respondent characteristics by treatment group; p-values based on t-tests of difference in mean between treatment and control group, except in the case of education and wealth quintile, where we used Pearson chi-squared tests due to the categorical nature of the variables.

Table B.5 - 2: Comparison of sample characteristics to SUSENAS

| | SUSENAS Banda Aceh, Aceh Besar | Baseline | Endline |
|---|---|---|---|
| Age | 50.5935 | 50.1203 | 49.9404 |
| | (0.3088) | (0.1826) | (0.2306) |
| Above 50 | 0.4878 | 0.4656 | 0.4592 |
| | (0.0207) | (0.0111) | (0.0142) |
| Female | 0.5239 | 0.6379*** | 0.6224** |
| | (0.0207) | (0.0107) | (0.0161) |
| Education | | | |
| - Up to primary | 0.2424 | 0.2926** | 0.2720*** |
| | (0.0188) | (0.0100) | (0.0162) |
| - Lower secondary | 0.2347 | 0.2164 | 0.2188 |
| | (0.0179) | (0.0092) | (0.0120) |
| - Upper secondary and above | 0.5229 | 0.4910 | 0.5092** |
| | (0.0207) | (0.0109) | (0.0194) |
| Wealth above median | | 0.4923 | 0.5082** |
| | | (0.0112) | (0.0201) |
| Banda Aceh | 0.4074 | 0.4372 | 0.4511* |
| | (0.0182) | (0.0061) | (0.0220) |
| N | 863 | 2,006 | 1,412 |

Note: SUSENAS samples are obtained from SUSENAS 2017 and restricted to respondents aged 40 – 70 with a mobile phone in the household. Standard errors accounting for survey design (sampling weights in SUSENAS, district stratification in both samples, PSU when comparing base- and endline sample) below mean; stars indicate significant difference from mean listed in previous column based on adjusted Wald test, * 0.1 ** 0.05 *** 0.01. Columns on SUSENAS and Baseline as in (Chavarría et al. 2021).

### B.5.1 Attrition

We test for differential attrition using three approaches. First, we test whether attrition differs across treatment and control group:

$$Attrit_i = \alpha + \beta T_i + \omega_{ij} \quad \text{(A1)}$$

Second, we analyze attrition based on the set of baseline characteristics used for testing balance across treatment and control group – namely age, sex, education, wealth quintile, knowledge index, time preferences, risk preferences, phone ownership and *Posbindu* in own village:

$$y_i = \alpha + \beta Attrit_i + \omega_{ij} \quad \text{(A2)}$$

Third, we examine whether these baseline characteristics of attrited treated individuals are significantly different from the attrited control individuals, restricting the sample to attriting respondents only:

$$(y_i | Attrit = 1) = \alpha + \beta T_i + \omega_{ij} \quad \text{(A3)}$$

Table B.5 - 3: Attrition I: between treatment and control group

| | (1)<br>Attrition |
|---|---|
| Treated | 0.0273 |
| | (0.0206) |
| Observations | 2006 |

Note: Regression of a binary attrition indicator (not re-interviewed at endline) on a binary treatment indicator (equation A1).
Standard errors clustered at the phone-number level in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Table B.5 - 4: Attrition II: endline sample compared to those lost to follow-up

| | (1)<br>Age | (2)<br>Female | (3)<br>Education | (4)<br>Wealth quintile | (5)<br>Baseline disease knowledge | (6)<br>Willingness to take risks | (7)<br>Patience | (8)<br>Own phone | (9)<br>Own Posbindu |
|---|---|---|---|---|---|---|---|---|---|
| Attrition | 0.638 | 0.055** | -0.218*** | -0.182** | -1.041*** | -0.057 | -0.111 | -0.200*** | 0.008 |
| | (0.406) | (0.023) | (0.056) | (0.071) | (0.284) | (0.129) | (0.138) | (0.024) | (0.015) |
| Obs. | 2005 | 2004 | 2006 | 2005 | 1861 | 2006 | 2006 | 1995 | 2006 |

Note: Separate regressions of each characteristic on the binary attrition indicator (not re-interviewed at endline) (equation A2).
Standard errors clustered at the phone-number level in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Table B.5 - 5: Attrition III: between treatment and control in those lost to follow-up

| | (1)<br>Age | (2)<br>Female | (3)<br>Education | (4)<br>Wealth quintile | (5)<br>Baseline disease knowledge | (6)<br>Willingness to take risks | (7)<br>Patience | (8)<br>Own phone | (9)<br>Own *Posbindu* |
|---|---|---|---|---|---|---|---|---|---|
| Treated | 0.131 | 0.060 | 0.047 | 0.042 | -0.849* | -0.236 | -0.246 | 0.065 | 0.029 |
| | (0.690) | (0.038) | (0.096) | (0.119) | (0.487) | (0.218) | (0.230) | (0.041) | (0.024) |
| Observations | 594 | 593 | 594 | 594 | 532 | 594 | 594 | 590 | 594 |

Note: Separate regressions of each characteristic on the binary treatment indicator in the sample that was not re-interviewed at endline (equation A3).
Standard errors clustered at the phone-number level in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Table B.5 - 6: Role of phone ownership for attrition

| | (1)<br>Own phone | (2)<br>Attrition |
|---|---|---|
| Age | -0.008*** | -0.000 |
| | (0.001) | (0.001) |
| Female | -0.113*** | 0.032 |
| | (0.021) | (0.021) |
| Primary | 0.088* | -0.142*** |
| | (0.050) | (0.054) |
| Junior Secondary | 0.156*** | -0.155*** |
| | (0.053) | (0.056) |
| Senior Secondary | 0.360*** | -0.120** |
| | (0.051) | (0.055) |
| Higher | 0.517*** | -0.145** |
| | (0.053) | (0.060) |
| Wealth quintile 2 | 0.011 | 0.001 |
| | (0.033) | (0.033) |
| Wealth quintile 3 | 0.043 | -0.048 |
| | (0.033) | (0.031) |
| Wealth quintile 4 | 0.042 | -0.012 |
| | (0.033) | (0.033) |
| Wealth quintile 5 | 0.079** | -0.028 |
| | (0.034) | (0.034) |
| Own phone | | -0.161*** |
| | | (0.023) |
| Observations | 1991 | 1991 |

Note: Regression of the binary phone ownership indicator (column 1) and the binary attrition indicator (column 2) on the respective characteristics in the whole intervention sample. Reference categories: No formal education, wealth quintile 1; Coefficient estimates for education in column (2) are statistically not distinguishable from each other. Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

## B.6 Main tables and robustness checks

Table B.6 - 1: Treatment effects on screening uptake, with and without covariates

| | (1) ITT | (2) ITT | (3) LATE | (4) LATE | (5) Any other member | (6) Any other member |
|---|---|---|---|---|---|---|
| Treated | 0.0576** | 0.0656*** | 0.142 | 0.170* | 0.0152 | 0.0106 |
| | (0.0257) | (0.0254) | (0.0959) | (0.0959) | (0.0250) | (0.0250) |
| Covariates | No | Yes | No | Yes | No | Yes |
| Observations | 1386 | 1386 | 1175 | 1175 | 1070 | 1070 |
| Control group mean | 0.331 | 0.331 | 0.357 | 0.357 | 0.205 | 0.205 |

Note: Results of regressing the binary screening uptake indicator following equation 1 for the message recipient (columns 1 and 2) and any other household member (columns 5, 6) and the local average treatment effect following equation 3 (columns 3, 4); if covariates are included, they are message recipient age, gender, wealth and phone ownership; standard errors clustered at the phone-number level in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table B.6 - 2: Adjustments for multiple hypothesis testing in main specification for primary and secondary outcomes.

| | (1) Screening uptake (ITT) | (2) Screening uptake (LATE) | (3) Spillovers | (4) SMS Knowledge | (5) General Knowledge |
|---|---|---|---|---|---|
| Treated | 0.066 | 0.170 | 0.011 | -0.002 | -0.336 |
| | (0.010)*** | (0.076)* | (0.672) | (0.962) | (0.340) |
| | [0.090]* | [0.227] | [0.808] | [0.962] | [0.510] |
| Covariates | Yes | Yes | Yes | Yes | Yes |
| Observations | 1386 | 1175 | 1070 | 1088 | 1042 |

Note: Results of regressing the binary screening uptake indicator following equation 1 for the message recipient (col 1) and any other household member (col 3), the respective knowledge index (col 4, 5), and the local average treatment effect following equation 3 (col 2); controlling for message recipient age, gender, wealth, and phone ownership; unadjusted p-values in parentheses, adjusted q-values following the Benjamini-Hochberg method for the 9 main hypotheses in square brackets. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table B.6 - 3: Adjustments for multiple hypothesis testing in main specification of heterogeneity analysis

| | Screening uptake | Screening uptake |
|---|---|---|
| Willingness to take risk | 0.082 | |
| | (0.105) | |
| | [0.236] | |
| Patience | | 0.118 |
| | | (0.037)** |
| | | [0.165] |
| Treated x Willingness to take risk | -0.004 | |
| | (0.719) | |
| | [0.808] | |
| Treated x Patience | | -0.009 |
| | | (0.301) |
| | | [0.510] |
| Covariates | Yes | Yes |
| Observations | 1386 | 1386 |

Note: Treatment coefficients from estimating equation 4 controlling for message recipient age, gender, wealth, and phone ownership; unadjusted p-values in parentheses, adjusted q-values following the Benjamini-Hochberg method for the 9 main hypotheses in square brackets. * p < 0.1, ** p < 0.05, *** p < 0.01

Table B.6 - 4: Binary outcomes with probit and logit specifications.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | Screening uptake | | Heterogeneity: Risk | | Heterogeneity: Time | | Spillover | |
| | Probit | Logit | Probit | Logit | Probit | Logit | Probit | Logit |
| Treated | 0.182*** | 0.301*** | 0.229 | 0.375 | 0.332** | 0.546** | 0.033 | 0.063 |
| | (0.070) | (0.116) | (0.141) | (0.231) | (0.158) | (0.260) | (0.088) | (0.153) |
| Preference | | | 0.019 | 0.031 | 0.022 | 0.036 | | |
| | | | (0.019) | (0.032) | (0.018) | (0.029) | | |
| Treated x | | | -0.010 | -0.016 | -0.026 | -0.043 | | |
| Preference | | | (0.027) | (0.044) | (0.025) | (0.040) | | |
| Covariates | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 1386 | 1386 | 1386 | 1386 | 1386 | 1386 | 1065 | 1065 |

Note: Results of regressing the binary screening uptake indicator following equation 1 for the message recipient (col 1, 2) and any other household member (col 7, 8), as well as heterogeneous treatment effects along a continuous risk and time preference scale following equation 4; controlling for message recipient age, gender, wealth and phone ownership; each model is separately estimated using probit and logit; standard errors clustered at the phone-number level in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01

Table B.6 - 5: Knowledge outcomes measured through PCA

| | SMS knowledge (PCA) | SMS knowledge (PCA) | Disease knowledge (PCA) | Disease knowledge (PCA) |
|---|---|---|---|---|
| Treated | 0.0215 | 0.00198 | -0.0328 | -0.0551 |
| | (0.0596) | (0.0581) | (0.0612) | (0.0594) |
| Covariates | No | Yes | No | Yes |
| Obs. | 1088 | 1088 | 1042 | 1042 |
| Control group mean | -0.00301 | -0.00301 | 0.0215 | 0.0215 |

Note: Regressions for an alternative definition of both knowledge indices via Principal Component Analysis; if covariates are included, they are message recipient age, gender, wealth, and phone ownership; standard errors clustered at the phone-number level in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Table B.6 - 6: Treatment effect on each element of the SMS knowledge index

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | Feel it | | Early treatment | | Age risk | | Knows |
| | Hypertension | Diabetes | Hypertension | Diabetes | Hypertension | Diabetes | Posbindu |
| Treated | 0.0051 | -0.0133 | 0.0040 | -0.0033 | -0.0171 | 0.0178 | 0.0047 |
| | (0.0089) | (0.0156) | (0.0109) | (0.0129) | (0.0173) | (0.0163) | (0.0171) |
| Covar. | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs. | 1088 | 1088 | 1088 | 1088 | 1088 | 1088 | 1088 |
| C. mean | 0.0185 | 0.0775 | 0.9613 | 0.9502 | 0.1015 | 0.0664 | 0.9151 |

Note: Regressions of the components of the SMS knowledge index as defined in Table B.3 - 1 on the binary treatment indicator controlling for message recipient age, gender, wealth, and phone ownership; standard errors clustered at the phone-number level in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Table B.6 - 7: Treatment effect on each element of the disease knowledge index (Hypertension)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number of | | | Share with correct answer | | | | | | |
| | Risk Factors | Compli-cations | Control | Target group | Start early | Destiny | Feel it | Regular checks | Treatable | Know someone |
| Treated | -0.0627 | 0.0311 | -0.0959 | -0.0044 | 0.0026 | 0.0010 | 0.0072 | -0.0134 | -0.0022 | 0.0014 |
| | (0.0680) | (0.0439) | (0.0705) | (0.0306) | (0.0106) | (0.0283) | (0.0140) | (0.0101) | (0.0189) | (0.0251) |
| Covar. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs. | 1042 | 1042 | 1042 | 1042 | 1042 | 1042 | 1042 | 1042 | 1042 | 1042 |
| C. mean | 2.1612 | 1.1478 | 2.1440 | 0.5566 | 0.9655 | 0.2917 | 0.9424 | 0.9789 | 0.8983 | 0.7908 |

Note: Regressions of the components of the disease knowledge index as defined in Table B.3 - 2 on the binary treatment indicator controlling for message recipient age, gender, wealth, and phone ownership; the outcomes in columns 1-3 are the number of correct items and binary measures in columns 4-10; standard errors clustered at the phone-number level in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Table B.6 - 8: Treatment effect on each element of the general knowledge index (Diabetes)

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number of | | | Share with correct answer | | | | | | |
| | Risk Factors | Compli-cations | Control | Target group | Start early | Destiny | Feel it | Regular checks | Treat–able | Know someone |
| Treated | -0.0623 | -0.1026 | -0.0722 | 0.0138 | -0.0047 | 0.0072 | 0.0258 | 0.0061 | 0.0172 | 0.0321 |
| | (0.0607) | (0.0706) | (0.0628) | (0.0307) | (0.0125) | (0.0278) | (0.0226) | (0.0105) | (0.0268) | (0.0297) |
| Covar. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs. | 1042 | 1042 | 1042 | 1042 | 1042 | 1042 | 1042 | 1042 | 1042 | 1042 |
| C. mean | 1.8330 | 1.6046 | 1.7697 | 0.5182 | 0.9559 | 0.2726 | 0.8292 | 0.9655 | 0.7486 | 0.6180 |

Note: Regressions of the components of the disease knowledge index as defined in Table B.3 - 2 on the binary treatment indicator controlling for message recipient age, gender, wealth, and phone ownership; the outcomes in columns 1-3 are the number of correct items and binary measures in columns 4-10; standard errors clustered at the phone-number level in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Table B.6 - 9: Different versions of spillover analysis

| | Any member (main | Member 40-70 | Other phone owner |
|---|---|---|---|

| | | | |
|---|---|---|---|
| specification) | | | |
| Treated | 0.0106 | 0.0134 | 0.0167 |
| | (0.0250) | (0.0308) | (0.0305) |
| Other's phone | | | 0.0399 |
| | | | (0.0392) |
| Treated x other's phone | | | -0.0180 |
| | | | (0.0530) |
| | | | 0.0399 |
| Covariates | Yes | Yes | Yes |
| Obs. | 1070 | 727 | 1070 |
| Mean | 0.205 | 0.212 | 0.205 |

Note: Results of regressing the binary indicator of household member screening uptake (col 1), screening uptake among other household members aged 40-70 years (col 2) on the binary treatment indicator following equation 1, and the heterogeneous treatment effect of the binary phone ownership indicator, which takes value 1 if the intervention was either received on a family phone or the private phone of another household member, and zero if it belongs to the message recipient; controlling for age, gender, wealth and phone ownership; standard errors clustered at the phone-number level in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

## Table B.6 - 10: Treatment effect on screening uptake by month

| | (1) January | (2) February | (3) March | (4) April |
|---|---|---|---|---|
| Treated | 0.0156 | 0.0363 | 0.0560*** | 0.0068 |
| | (0.0159) | (0.0228) | (0.0201) | (0.0090) |
| Covariates | Yes | Yes | Yes | Yes |
| Obs. | 1386 | 1386 | 1386 | 1386 |
| Control group mean | 0.0895 | 0.2216 | 0.1435 | 0.0256 |

Note: Results of regressing different binary screening uptake indicators on the binary treatment indicator (equation 1), controlling for age, gender, wealth and phone ownership; the outcome indicator takes the value 1 only if the individual indicated to have gone to screening in the respective month and zero otherwise; standard errors clustered at the phone-number level in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

## Table B.6 - 11: Treatment effect on screening uptake by location

| | (1) Went on correct date to Posbindu | (2) Posbindu | (3) Puskesmas | (4) Private doctor/midwife |
|---|---|---|---|---|
| Treated | 0.0067 | 0.0081 | 0.0298* | 0.0201 |
| | (0.0177) | (0.0178) | (0.0158) | (0.0162) |
| Covariates | Yes | Yes | Yes | Yes |
| Obs. | 1386 | 1386 | 1386 | 1386 |
| Control group mean | 0.1335 | 0.1335 | 0.0810 | 0.0895 |

Note: Results of regressing different binary screening uptake indicators on the binary treatment indicator (equation 1), controlling for age, gender, wealth and phone ownership; the outcome indicator takes the value 1 only if the individual indicated to have gone to screening in the respective facility and zero otherwise; the screening outcome in col 1 additionally conditions on the correct month; standard errors clustered at the phone-number level in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table B.6 - 12: Treatment effect on disaggregated screening outcome: kind of check done

| | (1) Medical history | (2) Physical measurement | (3) Blood pressure | (4) Blood glucose | (5) Other blood check |
|---|---|---|---|---|---|
| Treated | 0.0420** | 0.0151 | 0.0652** | 0.0302 | 0.0091 |
| | (0.0176) | (0.0165) | (0.0254) | (0.0200) | (0.0134) |
| Covariates | Yes | Yes | Yes | Yes | Yes |
| Obs. | 1386 | 1386 | 1386 | 1386 | 1386 |
| Mean | 0.1023 | 0.1009 | 0.3295 | 0.1548 | 0.0639 |

Note: Results of regressing different binary screening indicators on the binary treatment indicator (equation 1), controlling for age, gender, wealth and phone ownership; the outcome indicator takes the value 1 only if the individual indicated that at the screening visit the respective check was conducted and zero if the respondent either did not go for screening or did not get the respective check done despite going for screening; standard errors clustered at the phone-number level in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01.

Table B.6 - 13: Characteristics of sub-groups of treatment group who remember receiving messages on NCDs and specific elements of these messages

| | | | | Remembers content on: | | | |
|---|---|---|---|---|---|---|---|
| | Total treatment | Received message | LATE definition | Screening need | Posbindu logistics | Posbindu free | Age risk |
| **Demographics** | | | | | | | |
| Age | 49.52 | 48.31*** | 48.45 | 47.64 | 48.36 | 48.42 | 49.60* |
| | (7.85) | (7.55) | (7.43) | (7.29) | (6.76) | (7.54) | (8.01) |
| Female | 0.61 | 0.56* | 0.56 | 0.54 | 0.60 | 0.55 | 0.56 |
| | (0.49) | (0.50) | (0.50) | (0.50) | (0.49) | (0.50) | (0.50) |
| Education | | | | | | | |
| - None | 0.03 | 0.02 | 0.02 | 0.01 | 0.00 | 0.00 | 0.02 |
| | (0.18) | (0.12) | (0.13) | (0.11) | (0.00) | (0.00) | (0.13) |
| - Primary | 0.24 | 0.18** | 0.18 | 0.15 | 0.19 | 0.19 | 0.18 |
| | (0.42) | (0.39) | (0.38) | (0.36) | (0.40) | (0.39) | (0.39) |
| - Lower Secondary | 0.21 | 0.18 | 0.17 | 0.20 | 0.21 | 0.17 | 0.11 |
| | (0.41) | (0.39) | (0.38) | (0.40) | (0.41) | (0.38) | (0.31) |
| - Higher Secondary | 0.36 | 0.43*** | 0.43 | 0.42 | 0.42 | 0.45 | 0.38 |
| | (0.48) | (0.50) | (0.50) | (0.50) | (0.50) | (0.50) | (0.49) |
| - Tertiary | 0.17 | 0.20 | 0.21 | 0.22 | 0.18 | 0.19 | 0.31** |
| | (0.37) | (0.40) | (0.41) | (0.42) | (0.39) | (0.39) | (0.47) |
| Banda Aceh | 0.52 | 0.50 | 0.50 | 0.51 | 0.44 | 0.31*** | 0.51 |
| **SMS-related characteristics** | | | | | | | |
| Phone owner | 0.68 | 0.80*** | 0.80 | 0.79 | 0.81 | 0.77 | 0.80 |
| | (0.47) | (0.40) | (0.40) | (0.41) | (0.40) | (0.43) | (0.40) |
| Messages | | | | | | | |
| - daily | 0.48 | 0.57*** | 0.58 | 0.66** | 0.58 | 0.60 | 0.61 |
| | (0.50) | (0.50) | (0.50) | (0.48) | (0.50) | (0.49) | (0.49) |
| - < daily | 0.36 | 0.39 | 0.38 | 0.30** | 0.36 | 0.38 | 0.39 |
| | (0.48) | (0.49) | (0.49) | (0.46) | (0.48) | (0.49) | (0.49) |
| - never | 0.16 | 0.04*** | 0.04 | 0.04 | 0.06 | 0.02 | 0.00* |
| | (0.37) | (0.19) | (0.20) | (0.19) | (0.24) | (0.13) | (0.00) |
| Messenger use | 0.47 | 0.48 | 0.49 | 0.61*** | 0.55 | 0.56 | 0.52 |
| | (0.50) | (0.50) | (0.50) | (0.49) | (0.50) | (0.50) | (0.51) |
| Prefers less SMS | | | | | | | |
| - in general | 0.15 | 0.22*** | 0.23 | 0.23 | 0.29* | 0.14** | 0.24 |
| | (0.36) | (0.42) | (0.42) | (0.42) | (0.46) | (0.35) | (0.43) |
| - advertisement | 0.60 | 0.57 | 0.57 | 0.61 | 0.54 | 0.66* | 0.53 |
| | (0.49) | (0.50) | (0.50) | (0.49) | (0.50) | (0.48) | (0.50) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| - no | 0.25 | 0.21* | 0.20 | 0.16 | 0.17 | 0.21 | 0.22 |
| | (0.44) | (0.41) | (0.40) | (0.37) | (0.38) | (0.41) | (0.42) |
| **Baseline characteristics** | | | | | | | |
| Disease knowledge | 18.42 | 19.58*** | 19.72 | 19.99 | 19.10 | 19.87 | 20.00 |
| | (5.30) | (4.88) | (5.00) | (5.20) | (4.42) | (4.99) | (4.44) |
| H- feel it | 0.12 | 0.10 | 0.11 | 0.10 | 0.07 | 0.06 | 0.09 |
| | (0.33) | (0.30) | (0.31) | (0.30) | (0.26) | (0.24) | (0.29) |
| D- feel it | 0.19 | 0.19 | 0.20 | 0.23 | 0.13 | 0.16 | 0.18 |
| | (0.39) | (0.39) | (0.40) | (0.42) | (0.34) | (0.37) | (0.39) |
| H- start early | 0.95 | 0.96 | 0.95 | 0.93* | 1.00** | 0.95 | 0.98 |
| | (0.22) | (0.20) | (0.21) | (0.25) | (0.00) | (0.21) | (0.13) |
| D- start early | 0.94 | 0.94 | 0.94 | 0.92 | 0.99** | 0.94 | 0.96 |
| | (0.24) | (0.23) | (0.24) | (0.27) | (0.12) | (0.25) | (0.19) |
| H- age risk | 0.06 | 0.05 | 0.05 | 0.07 | 0.03 | 0.05 | 0.02 |
| | (0.23) | (0.22) | (0.21) | (0.25) | (0.17) | (0.21) | (0.13) |
| D- age risk | 0.04 | 0.05 | 0.06 | 0.09** | 0.06 | 0.06 | 0.04 |
| | (0.20) | (0.22) | (0.24) | (0.29) | (0.23) | (0.25) | (0.19) |
| Knows Posbindu | 0.50 | 0.56* | 0.56 | 0.53 | 0.53 | 0.63 | 0.64 |
| | (0.50) | (0.50) | (0.50) | (0.50) | (0.50) | (0.49) | (0.49) |
| Ever screened | 0.59 | 0.61 | 0.57*** | 0.56 | 0.65 | 0.64 | 0.64 |
| | (0.49) | (0.49) | (0.50) | (0.50) | (0.48) | (0.48) | (0.49) |
| Last year screened | 0.29 | 0.28 | 0.25* | 0.06*** | 0.15*** | 0.22 | 0.37 |
| | (0.45) | (0.45) | (0.43) | (0.24) | (0.36) | (0.42) | (0.49) |
| *N* | 682 | 199 | 172 | 89 | 72 | 65 | 55 |

Note: Simple means of the respective characteristic across groups: complete treatment group, individuals who stated to have received a message on Posbindu, those who received at least one full message cycle according to the delivery reports and remember any message content (LATE definition) and the four most commonly recalled content elements: the recommendation to take up screening, when and where Posbindu takes place, that Posbindu is free and higher age implies a higher NCD risk. Standard deviations in parentheses below mean; stars indicate the p-value of the two-sample t-test for difference of the respective group and characteristic compared to the rest of the treatment group; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

## B.7 Administrative information

### B.7.1 Funding

This work was supported by the German Research Foundation's Research and Training Group 1723 "Globalization and Development" (DFG: RTG1723).

### B.7.2 Ethics

All necessary ethics approvals are in place.
Ethics approval and confirmation of adherence to European data protection laws issued by University of Göttingen's ethics commission
Ethics approval issued by the ethics board of the nursing faculty of Syiah Kuala University, Banda Aceh, Indonesia

### B.7.3 Declaration of Interest

None.

### B.7.4 Data availability

The data that support the findings of this study are available upon reasonable request in Göttingen Research Online at https://data.goettingen-research-online.de/, DOI 10.25625/SE4IDP, and will be made publicly available after publication of this study. The questionnaires are publicly available in the repository.

### B.7.5 Published Working Paper

Courant Research Centre Discussion Paper No. 284: http://www2.vwl.wiso.uni-goettingen.de/courant-papers/CRC-PEG_DP_284.pdf

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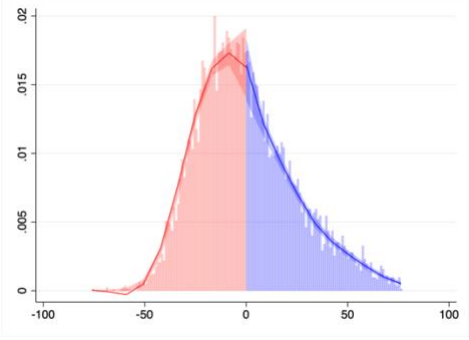
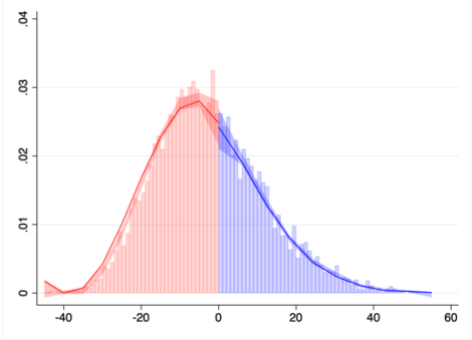
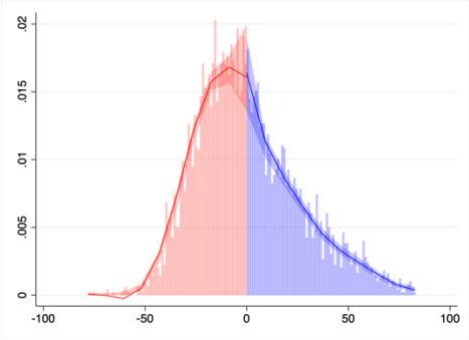
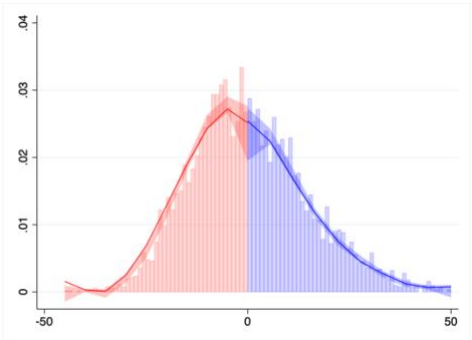
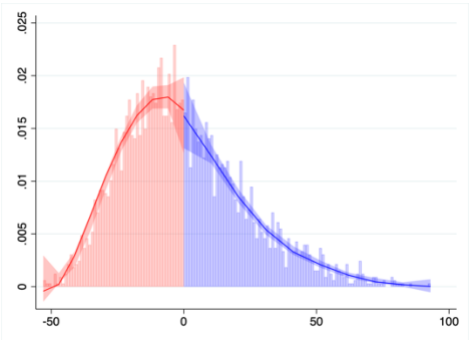
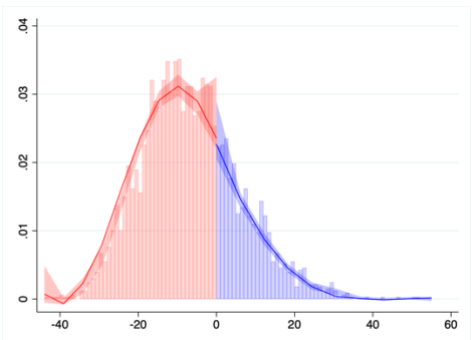
# C. Appendix for Essay 4

## C.1 Additional Analyses

### C.1.1 Manipulation

Figure C.1.1 - 1: Manipulation Testing of Forcing Variables

| | Systolic Blood Pressure | Diastolic Blood Pressure |
|---|---|---|
| **Pooled** |  |  |
| | N=5837, BW=25.35 mmHg, p-val=.781 | N=7540, BW=24 mmHg, p-val=.576 |
| **NIDS** |  |  |
| | N=3494, BW=25.97 mmHg, p-val=.935 | N=4537, BW=24 mmHg, p-val=.525 |
| **HAALSI** |  |  |
| | N=2848, BW=33.53 mmHg, p-val=.827 | N=3003, BW=24 mmHg, p-val=.096 |

Note: Red and blue fitted line represent point estimates constructed polynomial estimates of order 3 using a triangular kernel function; red and blue shaded area around fitted line represents bias-corrected confidence intervals; red and blue bars are histograms; N indicates effective number of observations within bandwidths; BW indicates bandwidth size to the right and left side; bandwidths are chosen using mean squared error criterion function; p-val indicates the p-value of the manipulation testing; more details on the manipulation tests can be found in (Cattaneo, Jansson, and Ma 2018)

## C.1.2 Balance

Table C.1.2 - 1: RD estimates of the "effect" of referral letter for high SBP on pre-treatment negative controls in pooled sample

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| VARIABLES | Age | Female | Education (years) | W1 High BP ever diagnosed | W1 BP under treatment |
| Conventional | 0.18 | 0.02 | -0.18 | 0.01 | 0.04 |
| | (0.95) | (0.04) | (0.38) | (0.04) | (0.04) |
| Bias-corrected | -0.16 | 0.01 | -0.25 | 0.00 | 0.03 |
| | (0.95) | (0.04) | (0.38) | (0.04) | (0.04) |
| Robust | -0.16 | 0.01 | -0.25 | 0.00 | 0.03 |
| | (1.08) | (0.05) | (0.46) | (0.05) | (0.04) |
| Bandwidth | 18.59 | 18.31 | 15.83 | 14.35 | 15.51 |
| Within-bandwiths N | 2811 | 2811 | 2360 | 2232 | 2360 |
| Left-side estimate | 63.33 | 0.541 | 2.842 | 0.395 | 0.281 |

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
All estimates are calculated using local linear regression with triangular weights and a survey fixed effect on respondents falling into Mean Squared Error (MSE) optimal bandwidths.

Table C.1.2 - 2: RD estimates of the "effect" of referral letter for high DBP on pre-treatment negative controls in pooled sample

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| VARIABLES | Age | Female | Education (years) | W1 High BP ever diagnosed | W1 BP under treatment |
| Conventional | 0.46 | -0.08 | -0.00 | 0.05 | 0.02 |
| | (0.92) | (0.05) | (0.39) | (0.04) | (0.03) |
| Bias-corrected | 0.64 | -0.09* | -0.09 | 0.06 | 0.03 |
| | (0.92) | (0.05) | (0.39) | (0.04) | (0.03) |
| Robust | 0.64 | -0.09 | -0.09 | 0.06 | 0.03 |
| | (1.08) | (0.06) | (0.45) | (0.05) | (0.04) |
| Bandwidth | 9.117 | 7.848 | 12.80 | 9.723 | 12.25 |
| Within-bandwiths N | 1955 | 1527 | 2580 | 1955 | 2580 |
| Left-side estimate | 54.95 | 0.662 | 4.734 | 0.357 | 0.238 |

See Note Table C.1.2 - 1; Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table C.1.2 - 3: RD estimates of the "effect" of referral letter for high SBP on pre-treatment negative controls in HAALSI sample

| VARIABLES | (1) Age | (2) Female | (3) Education (years) | (4) W1 High BP ever diagnosed | (5) W1 BP under treatment |
|---|---|---|---|---|---|
| Conventional | 0.22 | 0.06 | -0.43 | 0.05 | 0.06 |
| | (1.53) | (0.05) | (0.49) | (0.06) | (0.06) |
| Bias-corrected | 0.39 | 0.07 | -0.49 | 0.06 | 0.07 |
| | (1.53) | (0.05) | (0.49) | (0.06) | (0.06) |
| Robust | 0.39 | 0.07 | -0.49 | 0.06 | 0.07 |
| | (1.84) | (0.06) | (0.59) | (0.07) | (0.07) |
| Bandwidth | 14.17 | 19.52 | 18.49 | 13.48 | 13.75 |
| Within-bandwiths N | 1163 | 1487 | 1430 | 1084 | 1084 |
| Left-side estimate | 63.36 | 0.532 | 2.831 | 0.364 | 0.247 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.2 - 4: RD estimates of the "effect" of referral letter for high DBP on pre-treatment negative controls in HAALSI sample

| VARIABLES | (1) Age | (2) Female | (3) Education (years) | (4) W1 High BP ever diagnosed | (5) W1 BP under treatment |
|---|---|---|---|---|---|
| Conventional | -0.27 | -0.03 | 0.86 | 0.02 | -0.03 |
| | (2.04) | (0.13) | (1.18) | (0.11) | (0.10) |
| Bias-corrected | -0.21 | -0.02 | 0.84 | 0.02 | -0.05 |
| | (2.04) | (0.13) | (1.18) | (0.11) | (0.10) |
| Robust | -0.21 | -0.02 | 0.84 | 0.02 | -0.05 |
| | (2.44) | (0.16) | (1.43) | (0.13) | (0.12) |
| Bandwidth | 8.318 | 5.460 | 7.039 | 7.770 | 7.556 |
| Within-bandwiths N | 503 | 309 | 433 | 433 | 433 |
| Left-side estimate | 55.27 | 0.641 | 4.406 | 0.426 | 0.319 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.2 - 5: RD estimates of the "effect" of referral letter for high SBP on pre-treatment negative controls in NIDS sample

| VARIABLES | (1) Age | (2) Female | (3) Education (years) | (4) W1 High BP ever diagnosed | (5) W1 BP under treatment |
|---|---|---|---|---|---|
| Conventional | 0.18 | -0.05 | 0.19 | -0.06 | -0.01 |
| | (1.43) | (0.06) | (0.50) | (0.07) | (0.06) |
| Bias-corrected | 0.05 | -0.07 | 0.26 | -0.09 | -0.03 |
| | (1.43) | (0.06) | (0.50) | (0.07) | (0.06) |
| Robust | 0.05 | -0.07 | 0.26 | -0.09 | -0.03 |
| | (1.71) | (0.07) | (0.59) | (0.08) | (0.07) |
| Bandwidth | 16.07 | 17.33 | 20.24 | 10.47 | 12.68 |
| Within-bandwiths N | 1234 | 1313 | 1528 | 764 | 918 |
| Left-side estimate | 55.22 | 0.577 | 5.329 | 0.289 | 0.224 |

See Note Table C.1.2 - 1; Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table C.1.2 - 6: RD estimates of the "effect" of referral letter for high DBP on pre-treatment negative controls in NIDS sample

| VARIABLES | (1) Age | (2) Female | (3) Education (years) | (4) W1 High BP ever diagnosed | (5) W1 BP under treatment |
|---|---|---|---|---|---|
| Conventional | 0.86 | -0.09 | -0.45 | 0.06 | 0.06 |
| | (1.00) | (0.06) | (0.47) | (0.04) | (0.04) |
| Bias-corrected | 1.16 | -0.11* | -0.59 | 0.08* | 0.08** |
| | (1.00) | (0.06) | (0.47) | (0.04) | (0.04) |
| Robust | 1.16 | -0.11 | -0.59 | 0.08 | 0.08* |
| | (1.15) | (0.07) | (0.54) | (0.05) | (0.05) |
| Bandwidth | 9.991 | 7.400 | 10.85 | 8.436 | 8.306 |
| Within-bandwiths N | 1388 | 1094 | 1522 | 1251 | 1251 |
| Left-side estimate | 50.40 | 0.750 | 6.610 | 0.140 | 0.0953 |

See Note Table C.1.2 - 1; Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

## C.1.3 Power Estimations

Figure C.1.3 - 1: Power Calculations

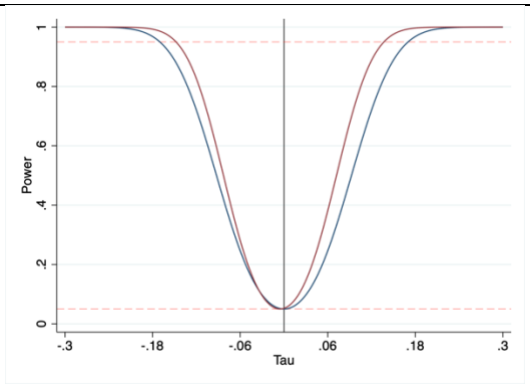
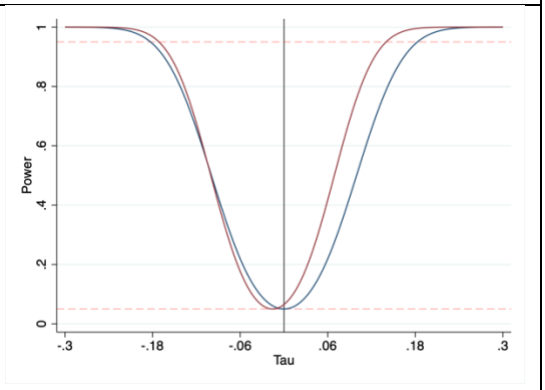
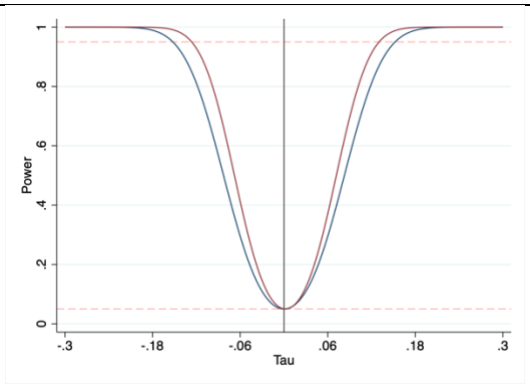
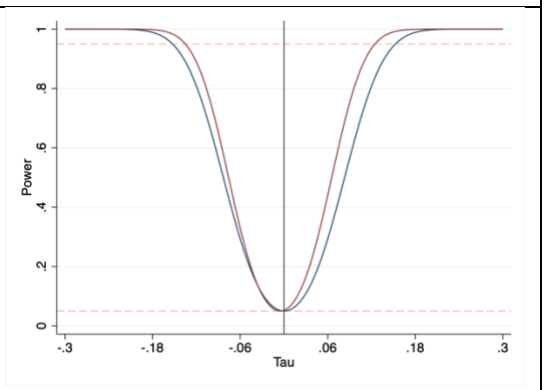
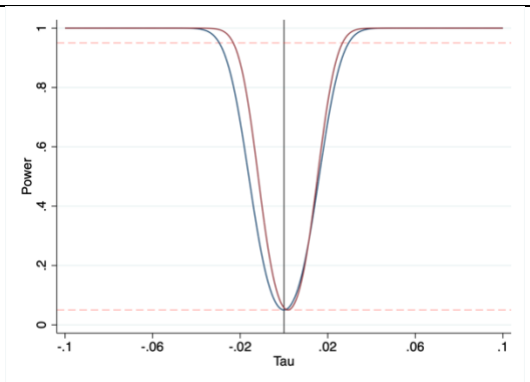
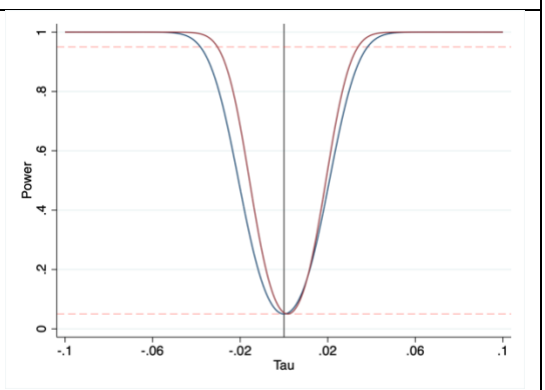
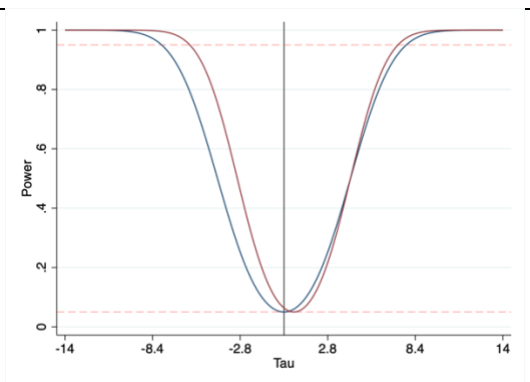
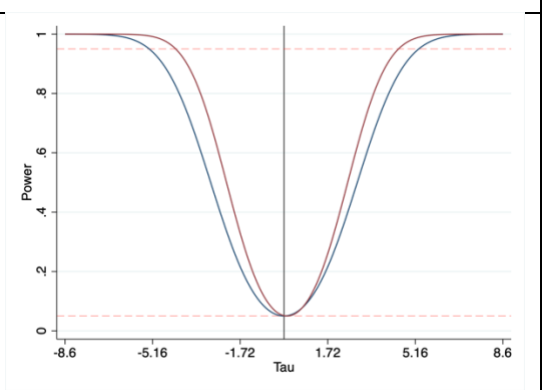
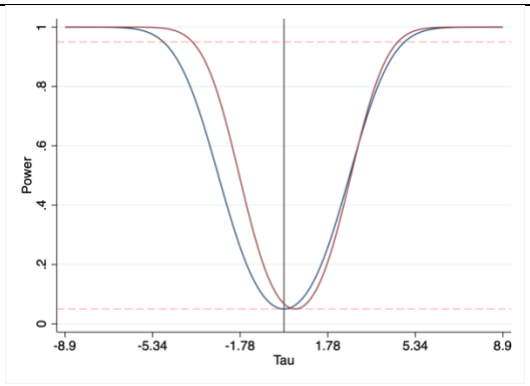
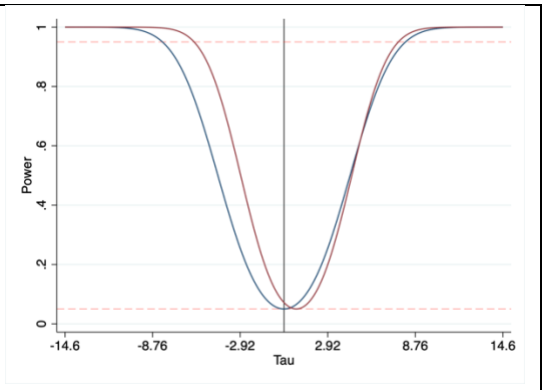
| | SBP | DBP |
|---|---|---|
| Diagnosed |  |  |
| Treated |  |  |
| Hypertensive |  |  |
| Change in avg. SBP |  |  |

Figure C.1.3 - 1 ctd.: Power Calculations

| | | |
|---|---|---|
| Change in avg. DBP |  |  |
| | Robust bias corrected Conventional | |

Note: Power calculations using conventional and local polynomial methods and alpha of 5% significance. Tau is the size of the treatment effect under the alternative at which the power function is evaluated.

### C.1.4 Regression Discontinuity Estimates

Table C.1.4 - 1: RD estimates of the effect of a referral letter for high SBP in the pooled sample

| VARIABLES | (1) W2 High BP ever diagnosed | (2) W2 BP under treatment | (3) Hypertensive at W2 | (4) Change in systolic BP | (5) Change in diastolic BP |
|---|---|---|---|---|---|
| Conventional | 0.04 | 0.04 | 0.01 | -2.76 | -1.94* |
| | (0.04) | (0.04) | (0.01) | (1.85) | (1.16) |
| Bias-corrected | 0.04 | 0.04 | 0.01 | -3.34* | -2.32** |
| | (0.04) | (0.04) | (0.01) | (1.85) | (1.16) |
| Robust | 0.04 | 0.04 | 0.01 | -3.34 | -2.32* |
| | (0.05) | (0.04) | (0.01) | (2.17) | (1.36) |
| Bandwidth | 17.25 | 19.79 | 12.18 | 11.93 | 12.42 |
| Within-bandwiths | | | | | |
| N | 2670 | 2944 | 1928 | 1771 | 1928 |
| Left-side estimate | 0.417 | 0.328 | 0.993 | -5.947 | 0.192 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.4 - 2: RD estimates of the effect of a referral letter for high DBP in the pooled sample

| VARIABLES | (1) W2 High BP ever diagnosed | (2) W2 BP under treatment | (3) Hypertensive at W2 | (4) Change in systolic BP | (5) Change in diastolic BP |
|---|---|---|---|---|---|
| Conventional | 0.04 | 0.00 | 0.00 | 0.19 | 1.31 |
| | (0.04) | (0.04) | (0.01) | (1.89) | (1.21) |
| Bias-corrected | 0.06 | 0.00 | 0.00 | 0.30 | 1.43 |
| | (0.04) | (0.04) | (0.01) | (1.89) | (1.21) |
| Robust | 0.06 | 0.00 | 0.00 | 0.30 | 1.43 |
| | (0.05) | (0.04) | (0.01) | (2.25) | (1.47) |
| Bandwidth | 8.669 | 11.65 | 8.734 | 10.91 | 8.273 |
| Within-bandwiths | | | | | |
| N | 1754 | 2380 | 1754 | 2172 | 1754 |
| Left-side estimate | 0.328 | 0.263 | 0.993 | -4.479 | -4.632 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.4 - 3: RD estimates of the effect of a referral letter for high SBP on main outcomes in the pooled sample when altering the bandwidth by 20% increments around the original bandwidth size

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| VARIABLES | 60% W2 High BP ever diagnosed | 80% W2 High BP ever diagnosed | 100% W2 High BP ever diagnosed | 120% W2 High BP ever diagnosed | 140% W2 High BP ever diagnosed | 60% W2 BP under treatment | 80% W2 BP under treatment | 100% W2 BP under treatment | 120% W2 BP under treatment | 140% W2 BP under treatment |
| Conventional | 0.02 | 0.03 | 0.04 | 0.04 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| | (0.05) | (0.04) | (0.04) | (0.04) | (0.03) | (0.04) | (0.04) | (0.04) | (0.03) | (0.03) |
| Bias-corrected | 0.00 | 0.02 | 0.01 | 0.03 | 0.03 | 0.04 | 0.03 | 0.04 | 0.04 | 0.04 |
| | (0.05) | (0.04) | (0.04) | (0.04) | (0.03) | (0.04) | (0.04) | (0.04) | (0.03) | (0.03) |
| Robust | 0.00 | 0.02 | 0.01 | 0.03 | 0.03 | 0.04 | 0.03 | 0.04 | 0.04 | 0.04 |
| | (0.08) | (0.06) | (0.06) | (0.05) | (0.05) | (0.07) | (0.06) | (0.05) | (0.05) | (0.04) |
| Bandwidth | 10.35 | 13.80 | 17.25 | 20.71 | 24.16 | 11.87 | 15.83 | 19.79 | 23.75 | 27.71 |
| Within-bandwiths N | 1628 | 2078 | 2670 | 3072 | 3604 | 1771 | 2360 | 2944 | 3507 | 3928 |
| Left-side estimate | 0.411 | 0.417 | 0.417 | 0.416 | 0.414 | 0.328 | 0.329 | 0.328 | 0.325 | 0.324 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.4 - 3 ctd.: RD estimates of the effect of a referral letter for high SBP on main outcomes in the pooled sample when altering the bandwidth by 20% increments around the original bandwidth size

| | (11) | (12) | (13) | (14) | (15) |
|---|---|---|---|---|---|
| | 60% | 80% | 100% | 120% | 140% |
| | Hypertensive at | Hypertensive at | Hypertensive at | Hypertensive at | Hypertensive at |
| VARIABLES | W2 | W2 | W2 | W2 | W2 |
| Conventional | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| Bias-corrected | -0.00 | -0.00 | 0.00 | 0.00 | 0.01 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| Robust | -0.00 | -0.00 | 0.00 | 0.00 | 0.01 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| Bandwidth | 7.305 | 9.741 | 12.18 | 14.61 | 17.05 |
| Within-bandwiths | | | | | |
| N | 1155 | 1462 | 1928 | 2232 | 2670 |
| Left-side estimate | 0.999 | 0.994 | 0.993 | 0.992 | 0.991 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.4 - 3 ctd.: RD estimates of the effect of a referral letter for high SBP on main outcomes in the pooled sample when altering the bandwidth by 20% increments around the original bandwidth size

| | (16) | (17) | (18) | (19) | (20) | (21) | (22) | (23) | (24) | (25) |
|---|---|---|---|---|---|---|---|---|---|---|
| VARIABLES | 60% Difference in systolic BP | 80% Difference in systolic BP | 100% Difference in systolic BP | 120% Difference in systolic BP | 140% Difference in systolic BP | 60% Difference in diastolic BP | 80% Difference in diastolic BP | 100% Difference in diastolic BP | 120% Difference in diastolic BP | 140% Difference in diastolic BP |
| Conventional | -2.84 | -2.89 | -2.76 | -2.37 | -1.98 | -2.27 | -2.15 | -1.94* | -1.70 | -1.48 |
| | (2.43) | (2.06) | (1.85) | (1.69) | (1.57) | (1.57) | (1.32) | (1.16) | (1.05) | (0.97) |
| Bias-corrected | -1.76 | -2.77 | -3.03 | -3.45** | -3.50** | -1.32 | -2.36* | -2.48** | -2.46** | -2.31** |
| | (2.43) | (2.06) | (1.85) | (1.69) | (1.57) | (1.57) | (1.32) | (1.16) | (1.05) | (0.97) |
| Robust | -1.76 | -2.77 | -3.03 | -3.45 | -3.50 | -1.32 | -2.36 | -2.48 | -2.46 | -2.31 |
| | (4.03) | (3.24) | (2.81) | (2.50) | (2.30) | (2.63) | (2.13) | (1.81) | (1.62) | (1.47) |
| Bandwidth | 7.160 | 9.546 | 11.93 | 14.32 | 16.71 | 7.454 | 9.939 | 12.42 | 14.91 | 17.39 |
| Within-bandwiths N | 1155 | 1462 | 1771 | 2232 | 2532 | 1155 | 1462 | 1928 | 2232 | 2670 |
| Left-side estimate | -5.647 | -5.741 | -5.947 | -6.437 | -6.846 | 1.109 | 0.626 | 0.192 | -0.144 | -0.350 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.4 - 4: RD estimates of the effect of a referral letter for high DBP on main outcomes in the pooled sample when altering the bandwidth by 20% increments around the original bandwidth size

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| VARIABLES | 60% W2 High BP ever diagnosed | 80% W2 High BP ever diagnosed | 100% W2 High BP ever diagnosed | 120% W2 High BP ever diagnosed | 140% W2 High BP ever diagnosed | 60% W2 BP under treatment | 80% W2 BP under treatment | 100% W2 BP under treatment | 120% W2 BP under treatment | 140% W2 BP under treatment |
| Conventional | 0.02 | 0.04 | 0.04 | 0.03 | 0.01 | 0.02 | 0.02 | 0.00 | -0.00 | 0.00 |
| | (0.06) | (0.05) | (0.04) | (0.04) | (0.04) | (0.05) | (0.04) | (0.04) | (0.03) | (0.03) |
| Bias-corrected | -0.05 | -0.02 | 0.03 | 0.07 | 0.07* | -0.05 | 0.01 | 0.04 | 0.02 | 0.01 |
| | (0.06) | (0.05) | (0.04) | (0.04) | (0.04) | (0.05) | (0.04) | (0.04) | (0.03) | (0.03) |
| Robust | -0.05 | -0.02 | 0.03 | 0.07 | 0.07 | -0.05 | 0.01 | 0.04 | 0.02 | 0.01 |
| | (0.10) | (0.08) | (0.07) | (0.06) | (0.05) | (0.08) | (0.06) | (0.05) | (0.05) | (0.04) |
| Bandwidth | 5.201 | 6.935 | 8.669 | 10.40 | 12.14 | 6.990 | 9.320 | 11.65 | 13.98 | 16.31 |
| Within-bandwiths N | 1082 | 1309 | 1754 | 2172 | 2580 | 1309 | 1955 | 2380 | 2769 | 3257 |
| Left-side estimate | 0.355 | 0.327 | 0.328 | 0.341 | 0.350 | 0.258 | 0.252 | 0.263 | 0.265 | 0.264 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.4 - 4 ctd.: RD estimates of the effect of a referral letter for high DBP on main outcomes in the pooled sample when altering the bandwidth by 20% increments around the original bandwidth size

| | (11) | (12) | (13) | (14) | (15) |
|---|---|---|---|---|---|
| | 60% | 80% | 100% | 120% | 140% |
| | Hypertensive at | Hypertensive at | Hypertensive at | Hypertensive at | Hypertensive at |
| VARIABLES | W2 | W2 | W2 | W2 | W2 |
| Conventional | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| Bias-corrected | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| Robust | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 |
| | (0.02) | (0.02) | (0.01) | (0.01) | (0.01) |
| Bandwidth | 5.240 | 6.987 | 8.734 | 10.48 | 12.23 |
| Within-bandwiths | | | | | |
| N | 1082 | 1309 | 1754 | 2172 | 2580 |
| Left-side estimate | 0.993 | 0.991 | 0.993 | 0.993 | 0.994 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.4 - 4 ctd.: RD estimates of the effect of a referral letter for high DBP on main outcomes in the pooled sample when altering the bandwidth by 20% increments around the original bandwidth size

| | (16) | (17) | (18) | (19) | (20) | (21) | (22) | (23) | (24) | (25) |
|---|---|---|---|---|---|---|---|---|---|---|
| VARIABLES | 60% Difference in systolic BP | 80% Difference in systolic BP | 100% Difference in systolic BP | 120% Difference in systolic BP | 140% Difference in systolic BP | 60% Difference in diastolic BP | 80% Difference in diastolic BP | 100% Difference in diastolic BP | 120% Difference in diastolic BP | 140% Difference in diastolic BP |
| Conventional | 0.34 | 0.41 | 0.19 | 0.13 | 0.15 | 1.95 | 1.56 | 1.31 | 1.17 | 1.07 |
| | (2.40) | (2.08) | (1.89) | (1.75) | (1.66) | (1.70) | (1.37) | (1.21) | (1.12) | (1.05) |
| Bias-corrected | -1.38 | -0.14 | 0.33 | 0.40 | 0.42 | 1.12 | 2.31* | 2.16* | 1.78 | 1.54 |
| | (2.40) | (2.08) | (1.89) | (1.75) | (1.66) | (1.70) | (1.37) | (1.21) | (1.12) | (1.05) |
| Robust | -1.38 | -0.14 | 0.33 | 0.40 | 0.42 | 1.12 | 2.31 | 2.16 | 1.78 | 1.54 |
| | (4.01) | (3.22) | (2.79) | (2.51) | (2.34) | (3.31) | (2.32) | (1.93) | (1.71) | (1.53) |
| Bandwidth | 6.545 | 8.726 | 10.91 | 13.09 | 15.27 | 4.964 | 6.618 | 8.273 | 9.928 | 11.58 |
| Within-bandwiths N | 1309 | 1754 | 2172 | 2769 | 3087 | 904 | 1309 | 1754 | 1955 | 2380 |
| Left-side estimate | -3.181 | -3.769 | -4.479 | -4.897 | -5.117 | -5.128 | -4.821 | -4.632 | -4.709 | -4.911 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.4 - 5: RD estimates of the effect of a referral letter on main outcomes in the pooled sample using uniform kernel function

| | Referral letter for high SBP | | | | | Referral letter for high DBP | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| VARIABLES | W2 High BP ever diagnosed | W2 BP under treatment | Hypertensive at W2 | Change in systolic BP | Change in diastolic BP | W2 High BP ever diagnosed | W2 BP under treatment | Hypertensive at W2 | Change in systolic BP | Change in diastolic BP |
| Conventional | 0.06 | 0.04 | 0.01 | -2.88 | -1.81* | 0.06 | 0.05 | 0.00 | -0.31 | 1.56 |
| | (0.04) | (0.04) | (0.01) | (1.79) | (1.08) | (0.04) | (0.04) | (0.01) | (1.87) | (1.40) |
| Bias-corrected | 0.05 | 0.05 | 0.01 | -3.56** | -2.15** | 0.06 | 0.05 | 0.00 | -0.67 | 1.78 |
| | (0.04) | (0.04) | (0.01) | (1.79) | (1.08) | (0.04) | (0.04) | (0.01) | (1.87) | (1.40) |
| Robust | 0.05 | 0.05 | 0.01 | -3.56* | -2.15* | 0.06 | 0.05 | 0.00 | -0.67 | 1.78 |
| | (0.04) | (0.04) | (0.01) | (2.02) | (1.23) | (0.05) | (0.05) | (0.01) | (2.12) | (1.61) |
| Bandwidth | 15.55 | 13.42 | 9.122 | 10.47 | 11.65 | 7.334 | 7.356 | 5.885 | 9.726 | 5.642 |
| Within-bandwiths N | 2360 | 2078 | 1462 | 1628 | 1771 | 1527 | 1527 | 1082 | 1955 | 1082 |
| Left-side estimate | 0.412 | 0.333 | 0.990 | -5.945 | -0.272 | 0.318 | 0.232 | 0.992 | -5.378 | -5.010 |

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

All estimates are calculated using local linear regression with triangular weights and a survey fixed effect on respondents falling into Mean Squared Error (MSE) optimal bandwidths.

Table C.1.4 - 6: RD estimates of the effect of a referral letter for high SBP in NIDS

| VARIABLES | (1) W2 High BP ever diagnosed | (2) W2 BP under treatment | (3) Hypertensive at W2 | (4) Change in systolic BP | (5) Change in diastolic BP |
|---|---|---|---|---|---|
| Conventional | 0.05 | 0.05 | 0.01 | -2.60 | -2.00 |
| | (0.06) | (0.05) | (0.01) | (2.87) | (1.89) |
| Bias-corrected | 0.06 | 0.06 | 0.01 | -3.35 | -2.54 |
| | (0.06) | (0.05) | (0.01) | (2.87) | (1.89) |
| Robust | 0.06 | 0.06 | 0.01 | -3.35 | -2.54 |
| | (0.07) | (0.06) | (0.02) | (3.40) | (2.23) |
| Bandwidth | 15.97 | 14.59 | 13.92 | 13.52 | 14.63 |
| Within-bandwiths | | | | | |
| N | 1137 | 1069 | 994 | 994 | 1069 |
| Left-side estimate | -0.251 | 0.0562 | 0.986 | -1.993 | 4.251 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.4 - 7: RD estimates of the effect of a referral letter for high DBP in NIDS

| VARIABLES | (1) W2 High BP ever diagnosed | (2) W2 BP under treatment | (3) Hypertensive at W2 | (4) Change in systolic BP | (5) Change in diastolic BP |
|---|---|---|---|---|---|
| Conventional | 0.03 | -0.00 | -0.00 | 1.22 | 1.60 |
| | (0.05) | (0.04) | (0.01) | (2.35) | (1.49) |
| Bias-corrected | 0.05 | 0.00 | -0.00 | 1.85 | 1.79 |
| | (0.05) | (0.04) | (0.01) | (2.35) | (1.49) |
| Robust | 0.05 | 0.00 | -0.00 | 1.85 | 1.79 |
| | (0.06) | (0.05) | (0.01) | (2.75) | (1.81) |
| Bandwidth | 8.021 | 11.08 | 8.328 | 10.56 | 7.501 |
| Within-bandwiths | | | | | |
| N | 1251 | 1642 | 1251 | 1522 | 1094 |
| Left-side estimate | 0.167 | -0.579 | -1.007 | -5.540 | -5.505 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.4 - 8: RD estimates of the effect of a referral letter for high SBP in HAALSI

| VARIABLES | (1) W2 High BP ever diagnosed | (2) W2 BP under treatment | (3) Hypertensive at W2 | (4) Change in systolic BP | (5) Change in diastolic BP |
|---|---|---|---|---|---|
| Conventional | 0.02 | 0.04 | 0.01 | -2.78 | -1.87 |
| | (0.06) | (0.05) | (0.00) | (2.21) | (1.25) |
| Bias-corrected | 0.01 | 0.05 | 0.01* | -3.37 | -2.23* |
| | (0.06) | (0.05) | (0.00) | (2.21) | (1.25) |
| Robust | 0.01 | 0.05 | 0.01 | -3.37 | -2.23 |
| | (0.07) | (0.06) | (0.01) | (2.63) | (1.49) |
| Bandwidth | 15.53 | 18.15 | 12.09 | 12.01 | 11.60 |
| Within-bandwiths | | | | | |
| N | 1223 | 1430 | 1010 | 1010 | 932 |
| Left-side estimate | 0.434 | 0.341 | 0.995 | -5.307 | 0.554 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.4 - 9: RD estimates of the effect of a referral letter for high DBP in HAALSI

| VARIABLES | (1) W2 High BP ever diagnosed | (2) W2 BP under treatment | (3) Hypertensive at W2 | (4) Change in systolic BP | (5) Change in diastolic BP |
|---|---|---|---|---|---|
| Conventional | 0.07 | 0.04 | 0.02 | -4.74 | 1.46 |
| | (0.13) | (0.10) | (0.01) | (4.91) | (3.07) |
| Bias-corrected | 0.04 | 0.04 | 0.02 | -6.08 | 1.85 |
| | (0.13) | (0.10) | (0.01) | (4.91) | (3.07) |
| Robust | 0.04 | 0.04 | 0.02 | -6.08 | 1.85 |
| | (0.16) | (0.12) | (0.02) | (5.92) | (3.83) |
| Bandwidth | 5.416 | 8.006 | 11.43 | 5.006 | 5.296 |
| Within-bandwiths | | | | | |
| N | 309 | 503 | 738 | 309 | 309 |
| Left-side estimate | 0.373 | 0.277 | 0.985 | 0.0746 | -5.573 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.4 - 10: RD estimates of the effect of a referral letter for high SBP and high DBP on being aware of ever having had BP measurement by health professional in HAALSI

| VARIABLES | (1) W2 BP ever measured | (2) W2 BP ever measured |
|---|---|---|
| Conventional | 0.02 | 0.17* |
| | (0.05) | (0.10) |
| Bias-corrected | 0.03 | 0.17* |
| | (0.05) | (0.10) |
| Robust | 0.03 | 0.17 |
| | (0.06) | (0.12) |
| Bandwidth | 12.22 | 5.095 |
| Within-bandwiths N | 1010 | 309 |
| Left-side estimate | 0.791 | 0.763 |

See Note Table C.1.2 - 1; Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; Column (1) SBP as forcing variable; Column (2) DBP as forcing variable

Table C.1.4 - 11: RD estimates of the effect of a referral letter for high SBP and high DBP on dying before follow-up in pooled sample

| VARIABLES | (1) Died by wave 2 | (2) Died by wave 2 |
|---|---|---|
| Conventional | -0.02 | 0.00 |
| | (0.02) | (0.03) |
| Bias-corrected | -0.03 | -0.00 |
| | (0.02) | (0.03) |
| Robust | -0.03 | -0.00 |
| | (0.03) | (0.04) |
| Bandwidth | 17.84 | 8.184 |
| Within-bandwiths N | 3016 | 1924 |
| Left-side estimate | 0.130 | 0.134 |

See Note Table C.1.2 - 1; Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; Column (1) SBP as forcing variable; Column (2) DBP as forcing variable

Table C.1.4 - 12: RD estimates of the effect of a referral letter for high SBP with covariate adjustment for self-rated health in the pooled sample when altering the bandwidth by 20% increments around the original bandwidth size

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| VARIABLES | 60% W2 High BP ever diagnosed | 80% W2 High BP ever diagnosed | 100% W2 High BP ever diagnosed | 120% W2 High BP ever diagnosed | 140% W2 High BP ever diagnosed | 60% W2 BP under treatment | 80% W2 BP under treatment | 100% W2 BP under treatment | 120% W2 BP under treatment | 140% W2 BP under treatment |
| RD | 0.03 | 0.03 | 0.04 | 0.03 | 0.03 | 0.06 | 0.05 | 0.04 | 0.03 | 0.03 |
| | (0.05) | (0.04) | (0.04) | (0.04) | (0.03) | (0.05) | (0.04) | (0.04) | (0.03) | (0.03) |
| Rated Health | -0.17*** | -0.17*** | -0.17*** | -0.17*** | -0.17*** | -0.13*** | -0.14*** | -0.14*** | -0.15*** | -0.15*** |
| | (0.03) | (0.03) | (0.02) | (0.02) | (0.02) | (0.03) | (0.02) | (0.02) | (0.02) | (0.02) |
| RD * Rated Health | 0.00 | 0.00 | 0.01 | 0.02 | 0.02 | -0.02 | -0.01 | 0.00 | 0.01 | 0.01 |
| | (0.05) | (0.04) | (0.04) | (0.04) | (0.03) | (0.04) | (0.04) | (0.03) | (0.03) | (0.03) |
| R-squared | 0.08 | 0.07 | 0.07 | 0.07 | 0.08 | 0.05 | 0.05 | 0.05 | 0.05 | 0.06 |
| Bandwidth | 10.59 | 14.12 | 17.64 | 21.17 | 24.70 | 12.27 | 16.36 | 20.45 | 24.54 | 28.63 |
| Within-bandwiths N | 1626 | 2229 | 2667 | 3217 | 3596 | 1925 | 2529 | 3065 | 3596 | 4016 |
| Mean Age | 60 | 60 | 59 | 59 | 59 | 60 | 59 | 59 | 59 | 58 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.4 - 12 ctd.: RD estimates of the effect of a referral letter for high SBP with covariate adjustment for self-rated health in the pooled sample when altering the bandwidth by 20% increments around the original bandwidth size

| | (11) | (12) | (13) | (14) | (15) |
|---|---|---|---|---|---|
| | 60% | 80% | 100% | 120% | 140% |
| | Hypertensive at | Hypertensive at | Hypertensive at | Hypertensive at | Hypertensive at |
| VARIABLES | W2 | W2 | W2 | W2 | W2 |
| RD | -0.01 | -0.00 | 0.00 | 0.00 | 0.00 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| Rated Health | -0.01 | -0.01 | -0.01 | -0.01 | -0.01 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.00) |
| RD * Rated Health | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| R-squared | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Bandwidth | 7.276 | 9.702 | 12.13 | 14.55 | 16.98 |
| Within-bandwiths | | | | | |
| N | 1153 | 1460 | 1925 | 2229 | 2529 |
| Mean Age | 60 | 60 | 60 | 60 | 59 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.4 - 12 ctd.: RD estimates of the effect of a referral letter for high SBP with covariate adjustment for self-rated health in the pooled sample when altering the bandwidth by 20% increments around the original bandwidth size

| | (16) | (17) | (18) | (19) | (20) | (21) | (22) | (23) | (24) | (25) |
|---|---|---|---|---|---|---|---|---|---|---|
| VARIABLES | 60% Change in systolic BP | 80% Change in systolic BP | 100% Change in systolic BP | 120% Change in systolic BP | 140% Change in systolic BP | 60% Change in diastolic BP | 80% Change in diastolic BP | 100% Change in diastolic BP | 120% Change in diastolic BP | 140% Change in diastolic BP |
| RD | -3.80 | -3.34 | -2.96 | -2.69 | -2.27 | -3.99** | -3.49** | -3.19*** | -3.02*** | -2.76*** |
| | (2.52) | (2.19) | (1.99) | (1.76) | (1.66) | (1.55) | (1.36) | (1.18) | (1.10) | (1.01) |
| Rated Health | -1.49 | -0.87 | -0.66 | -0.87 | -0.91 | -0.54 | -0.11 | -0.06 | -0.19 | -0.20 |
| | (1.62) | (1.40) | (1.24) | (1.08) | (1.00) | (1.00) | (0.86) | (0.74) | (0.67) | (0.61) |
| RD * Rated Health | 1.43 | 0.68 | 0.33 | 0.51 | 0.49 | 2.42* | 1.85 | 1.75 | 1.87* | 1.82* |
| | (2.32) | (2.07) | (1.90) | (1.70) | (1.61) | (1.44) | (1.29) | (1.13) | (1.06) | (0.98) |
| R-squared | 0.04 | 0.04 | 0.04 | 0.05 | 0.06 | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 |
| Bandwidth | 7.152 | 9.536 | 11.92 | 14.30 | 16.69 | 7.403 | 9.871 | 12.34 | 14.81 | 17.27 |
| Within-bandwiths N | 1153 | 1460 | 1768 | 2229 | 2529 | 1153 | 1460 | 1925 | 2229 | 2667 |
| Mean Age | 60 | 60 | 60 | 60 | 59 | 60 | 60 | 60 | 60 | 59 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.4 - 13: RD estimates of the effect of a referral letter for high DBP with covariate adjustment for self-rated health in the pooled sample when altering the bandwidth by 20% increments around the original bandwidth size

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|
| VARIABLES | 60% W2 High BP ever diagnosed | 80% W2 High BP ever diagnosed | 100% W2 High BP ever diagnosed | 120% W2 High BP ever diagnosed | 140% W2 High BP ever diagnosed | 60% W2 BP under treatment | 80% W2 BP under treatment | 100% W2 BP under treatment | 120% W2 BP under treatment | 140% W2 BP under treatment |
| RD | -0.10 | -0.05 | -0.03 | -0.03 | -0.04 | -0.04 | -0.02 | -0.02 | -0.02 | -0.02 |
| | (0.06) | (0.05) | (0.05) | (0.04) | (0.04) | (0.05) | (0.04) | (0.04) | (0.04) | (0.03) |
| Rated Health | -0.19*** | -0.17*** | -0.15*** | -0.13*** | -0.13*** | -0.15*** | -0.13*** | -0.12*** | -0.12*** | -0.12*** |
| | (0.04) | (0.03) | (0.03) | (0.03) | (0.02) | (0.03) | (0.03) | (0.02) | (0.02) | (0.02) |
| RD * Rated Health | 0.15*** | 0.11** | 0.09* | 0.07* | 0.06 | 0.07 | 0.04 | 0.03 | 0.02 | 0.02 |
| | (0.06) | (0.05) | (0.05) | (0.04) | (0.04) | (0.05) | (0.04) | (0.04) | (0.04) | (0.03) |
| R-squared | 0.05 | 0.05 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Bandwidth | 5.397 | 7.196 | 8.995 | 10.79 | 12.59 | 7.490 | 9.987 | 12.48 | 14.98 | 17.48 |
| Within-bandwiths N | 1081 | 1524 | 1751 | 2168 | 2576 | 1524 | 1951 | 2576 | 2933 | 3415 |
| Mean Age | 52 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 54 | 54 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.4 - 13 ctd.: RD estimates of the effect of a referral letter for high DBP with covariate adjustment for self-rated health in the pooled sample when altering the bandwidth by 20% increments around the original bandwidth size

| | (11) | (12) | (13) | (14) | (15) |
|---|---|---|---|---|---|
| | 60% | 80% | 100% | 120% | 140% |
| | Hypertensive at | Hypertensive at | Hypertensive at | Hypertensive at | Hypertensive at |
| VARIABLES | W2 | W2 | W2 | W2 | W2 |
| RD | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| Rated Health | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| RD * Rated Health | -0.01 | -0.01 | -0.01 | -0.01 | -0.00 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| R-squared | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Bandwidth | 5.228 | 6.970 | 8.713 | 10.46 | 12.20 |
| Within-bandwiths | | | | | |
| N | 1081 | 1308 | 1751 | 2168 | 2576 |
| Mean Age | 52 | 53 | 53 | 53 | 53 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.4 - 13 ctd.: RD estimates of the effect of a referral letter for high DBP with covariate adjustment for self-rated health in the pooled sample when altering the bandwidth by 20% increments around the original bandwidth size

| | (16) | (17) | (18) | (19) | (20) | (21) | (22) | (23) | (24) | (25) |
|---|---|---|---|---|---|---|---|---|---|---|
| VARIABLES | 60% Change in systolic BP | 80% Change in systolic BP | 100% Change in systolic BP | 120% Change in systolic BP | 140% Change in systolic BP | 60% Change in diastolic BP | 80% Change in diastolic BP | 100% Change in diastolic BP | 120% Change in diastolic BP | 140% Change in diastolic BP |
| RD | 1.47 | 1.95 | 1.82 | 1.57 | 1.58 | 3.83* | 3.41** | 3.18** | 2.92** | 2.71** |
| | (2.96) | (2.37) | (2.09) | (1.92) | (1.80) | (1.96) | (1.53) | (1.30) | (1.24) | (1.13) |
| Rated Health | 1.33 | 1.25 | 0.92 | 0.68 | 0.59 | 2.12* | 1.72* | 1.47* | 1.19 | 0.98 |
| | (1.88) | (1.48) | (1.26) | (1.11) | (1.00) | (1.24) | (0.97) | (0.80) | (0.74) | (0.65) |
| RD * Rated Health | -1.75 | -2.21 | -2.10 | -2.06 | -2.10 | -2.39 | -2.45* | -2.57** | -2.43** | -2.31** |
| | (2.68) | (2.25) | (2.02) | (1.87) | (1.76) | (1.72) | (1.42) | (1.24) | (1.19) | (1.10) |
| R-squared | 0.03 | 0.04 | 0.04 | 0.04 | 0.05 | 0.02 | 0.03 | 0.04 | 0.04 | 0.05 |
| Bandwidth | 5.674 | 7.566 | 9.457 | 11.35 | 13.24 | 4.896 | 6.528 | 8.159 | 9.791 | 11.42 |
| Within-bandwiths N | 1081 | 1524 | 1951 | 2376 | 2765 | 903 | 1308 | 1751 | 1951 | 2376 |
| Mean Age | 52 | 53 | 53 | 53 | 54 | 52 | 53 | 53 | 53 | 53 |

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

See Note Table C.1.2 - 1

Table C.1.4 - 14: RD estimates of the effect of a referral letter for high SBP with covariate adjustment for self-rated health and depressive symptom in the pooled sample when altering the bandwidth by 20% increments around the original bandwidth size

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|---|---|---|---|---|

| VARIABLES | W2 High BP ever diagnosed | W2 High BP ever diagnosed | W2 High BP ever diagnosed | W2 High BP ever diagnosed | W2 High BP ever diagnosed | W2 BP under treatment | W2 BP under treatment | W2 BP under treatment | W2 BP under treatment | W2 BP under treatment |
|---|---|---|---|---|---|---|---|---|---|---|
| RD | 0.02 | 0.03 | 0.03 | 0.03 | 0.02 | 0.04 | 0.03 | 0.02 | 0.01 | 0.01 |
| | (0.06) | (0.05) | (0.04) | (0.04) | (0.04) | (0.05) | (0.04) | (0.04) | (0.04) | (0.03) |
| Rated Health | -0.17*** | -0.17*** | -0.16*** | -0.16*** | -0.16*** | -0.13*** | -0.14*** | -0.14*** | -0.15*** | -0.15*** |
| | (0.03) | (0.03) | (0.02) | (0.02) | (0.02) | (0.03) | (0.02) | (0.02) | (0.02) | (0.02) |
| RD * Rated Health | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | -0.01 | 0.00 | 0.01 | 0.02 | 0.02 |
| | (0.05) | (0.04) | (0.04) | (0.04) | (0.03) | (0.04) | (0.04) | (0.03) | (0.03) | (0.03) |
| D. Symptom | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| | (0.03) | (0.03) | (0.02) | (0.02) | (0.02) | (0.03) | (0.02) | (0.02) | (0.02) | (0.02) |
| RD * D. Symptom | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 0.05 | 0.05 | 0.05 | 0.05* | 0.05* |
| | (0.05) | (0.04) | (0.04) | (0.04) | (0.03) | (0.04) | (0.04) | (0.03) | (0.03) | (0.03) |
| R-squared | 0.08 | 0.08 | 0.07 | 0.07 | 0.08 | 0.05 | 0.05 | 0.05 | 0.06 | 0.06 |
| Bandwidth | 10.61 | 14.15 | 17.69 | 21.23 | 24.77 | 12.67 | 16.89 | 21.11 | 25.33 | 29.55 |
| Within-bandwiths N | 1626 | 2229 | 2667 | 3217 | 3596 | 1925 | 2529 | 3217 | 3705 | 4112 |
| Mean Age | 60 | 60 | 59 | 59 | 59 | 60 | 59 | 59 | 58 | 58 |

See Note Table C.1.2 - 1; Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table C.1.4 - 14 ctd.: RD estimates of the effect of a referral letter for high SBP with covariate adjustment for self-rated health and depressive symptom in the pooled sample when altering the bandwidth by 20% increments around the original bandwidth size

| | (11) | (12) | (13) | (14) | (15) |
|---|---|---|---|---|---|

| VARIABLES | Hypertensive at W2 | Hypertensive at W2 | Hypertensive at W2 | Hypertensive at W2 | Hypertensive at W2 |
|---|---|---|---|---|---|
| RD | -0.01 | -0.01 | -0.00 | -0.00 | -0.00 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| Rated Health | -0.01 | -0.01 | -0.01 | -0.01 | -0.01 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.00) |
| RD * Rated Health | 0.02* | 0.01 | 0.01 | 0.01 | 0.01 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| D. Symptom | -0.01 | -0.00 | -0.00 | -0.00 | -0.00 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.00) |
| RD * D. Symptom | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| R-squared | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Bandwidth | 7.225 | 9.634 | 12.04 | 14.45 | 16.86 |
| Within-bandwiths | | | | | |
| N | 1153 | 1460 | 1925 | 2229 | 2529 |
| Mean Age | 60 | 60 | 60 | 60 | 59 |

See Note Table C.1.2 - 1; Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table C.1.4 - 14 ctd.: RD estimates of the effect of a referral letter for high SBP with covariate adjustment for self-rated health and depressive symptom in the pooled sample when altering the bandwidth by 20% increments around the original bandwidth size

| VARIABLES | (16) Change in systolic BP | (17) Change in systolic BP | (18) Change in systolic BP | (19) Change in systolic BP | (20) Change in systolic BP | (21) Change in diastolic BP | (22) Change in diastolic BP | (23) Change in diastolic BP | (24) Change in diastolic BP | (25) Change in diastolic BP |
|---|---|---|---|---|---|---|---|---|---|---|
| RD | -4.93* | -4.04* | -3.32 | -2.78 | -2.25 | -4.81*** | -4.11*** | -3.64*** | -3.34*** | -3.04*** |
| | (2.72) | (2.38) | (2.16) | (1.92) | (1.81) | (1.67) | (1.47) | (1.29) | (1.20) | (1.11) |
| Rated Health | -1.58 | -0.89 | -0.63 | -0.80 | -0.82 | -0.65 | -0.20 | -0.12 | -0.23 | -0.23 |
| | (1.63) | (1.40) | (1.25) | (1.09) | (1.00) | (1.00) | (0.87) | (0.74) | (0.68) | (0.61) |
| RD * Rated Health | 1.75 | 0.90 | 0.47 | 0.59 | 0.52 | 2.63* | 2.02 | 1.88 | 1.98* | 1.91* |
| | (2.34) | (2.09) | (1.92) | (1.72) | (1.62) | (1.45) | (1.30) | (1.14) | (1.08) | (0.99) |
| D. Symptom | -1.10 | -0.34 | 0.26 | 0.58 | 0.72 | -1.13 | -0.88 | -0.52 | -0.33 | -0.26 |
| | (1.58) | (1.36) | (1.21) | (1.06) | (0.98) | (0.97) | (0.84) | (0.72) | (0.66) | (0.59) |
| RD * D. Symptom | 2.54 | 1.66 | 0.88 | 0.30 | 0.05 | 1.80 | 1.38 | 0.99 | 0.71 | 0.61 |
| | (2.29) | (2.04) | (1.87) | (1.68) | (1.59) | (1.41) | (1.27) | (1.12) | (1.05) | (0.97) |
| R-squared | 0.04 | 0.04 | 0.05 | 0.05 | 0.06 | 0.05 | 0.04 | 0.04 | 0.04 | 0.05 |
| Bandwidth | 7.189 | 9.586 | 11.98 | 14.38 | 16.77 | 7.398 | 9.864 | 12.33 | 14.80 | 17.26 |
| Within-bandwiths N | 1153 | 1460 | 1768 | 2229 | 2529 | 1153 | 1460 | 1925 | 2229 | 2667 |
| Mean Age | 60 | 60 | 60 | 60 | 59 | 60 | 60 | 60 | 60 | 59 |

See Note Table C.1.2 - 1; Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table C.1.4 - 15: RD estimates of the effect of a referral letter for high DBP with covariate adjustment for self-rated health and depressive symptom in the pooled sample when altering the bandwidth by 20% increments around the original bandwidth size

| VARIABLES | (1) W2 High BP ever diagnosed | (2) W2 High BP ever diagnosed | (3) W2 High BP ever diagnosed | (4) W2 High BP ever diagnosed | (5) W2 High BP ever diagnosed | (6) W2 BP under treatment | (7) W2 BP under treatment | (8) W2 BP under treatment | (9) W2 BP under treatment | (10) W2 BP under treatment |
|---|---|---|---|---|---|---|---|---|---|---|
| RD | -0.12* | -0.07 | -0.05 | -0.05 | -0.06 | -0.07 | -0.04 | -0.04 | -0.03 | -0.03 |
| | (0.07) | (0.06) | (0.05) | (0.05) | (0.04) | (0.05) | (0.05) | (0.04) | (0.04) | (0.04) |
| Rated Health | -0.19*** | -0.17*** | -0.14*** | -0.13*** | -0.13*** | -0.16*** | -0.13*** | -0.12*** | -0.12*** | -0.12*** |
| | (0.04) | (0.03) | (0.03) | (0.03) | (0.02) | (0.03) | (0.03) | (0.02) | (0.02) | (0.02) |
| RD * Rated Health | 0.16*** | 0.12** | 0.09** | 0.08* | 0.07* | 0.08* | 0.05 | 0.03 | 0.03 | 0.02 |
| | (0.06) | (0.05) | (0.05) | (0.04) | (0.04) | (0.05) | (0.04) | (0.04) | (0.04) | (0.03) |
| D. Symptom | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.00 | 0.00 | -0.00 | 0.00 | 0.00 |
| | (0.04) | (0.03) | (0.03) | (0.02) | (0.02) | (0.03) | (0.02) | (0.02) | (0.02) | (0.02) |
| RD * D. Symptom | 0.05 | 0.05 | 0.04 | 0.04 | 0.04 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 |
| | (0.05) | (0.05) | (0.04) | (0.04) | (0.04) | (0.04) | (0.04) | (0.03) | (0.03) | (0.03) |
| R-squared | 0.06 | 0.05 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Bandwidth | 5.277 | 7.036 | 8.795 | 10.55 | 12.31 | 7.301 | 9.734 | 12.17 | 14.60 | 17.03 |
| Within-bandwiths N | 1081 | 1524 | 1751 | 2168 | 2576 | 1524 | 1951 | 2576 | 2933 | 3415 |
| Mean Age | 52 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 54 | 54 |

See Note Table C.1.2 - 1; Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table C.1.4 - 15 ctd.: RD estimates of the effect of a referral letter for high DBP with covariate adjustment for self-rated health and depressive symptom in the pooled sample when altering the bandwidth by 20% increments around the original bandwidth size

| VARIABLES | (11) Hypertensive at W2 | (12) Hypertensive at W2 | (13) Hypertensive at W2 | (14) Hypertensive at W2 | (15) Hypertensive at W2 |
|---|---|---|---|---|---|
| RD | 0.00 | 0.00 | -0.00 | -0.00 | -0.00 |
| | (0.02) | (0.01) | (0.01) | (0.01) | (0.01) |
| Rated Health | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| RD * Rated Health | -0.01 | -0.01 | -0.01 | -0.00 | -0.00 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| D. Symptom | -0.01 | -0.01 | -0.01 | -0.01 | -0.01 |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| RD * D. Symptom | 0.02* | 0.02* | 0.02** | 0.02** | 0.02** |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| R-squared | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Bandwidth | 5.233 | 6.977 | 8.721 | 10.47 | 12.21 |
| Within-bandwiths N | 1081 | 1308 | 1751 | 2168 | 2576 |
| Mean Age | 52 | 53 | 53 | 53 | 53 |

See Note Table C.1.2 - 1; Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Table C.1.4 - 15 ctd.: RD estimates of the effect of a referral letter for high DBP with covariate adjustment for self-rated health and depressive symptom in the pooled sample when altering the bandwidth by 20% increments around the original bandwidth size

| VARIABLES | (16) Change in systolic BP | (17) Change in systolic BP | (18) Change in systolic BP | (19) Change in systolic BP | (20) Change in systolic BP | (21) Change in diastolic BP | (22) Change in diastolic BP | (23) Change in diastolic BP | (24) Change in diastolic BP | (25) Change in diastolic BP |
|---|---|---|---|---|---|---|---|---|---|---|
| RD | -1.47 | -0.78 | -0.46 | -0.26 | 0.05 | 2.59 | 2.15 | 2.00 | 1.83 | 1.70 |
| | (3.16) | (2.57) | (2.29) | (2.10) | (1.98) | (2.10) | (1.65) | (1.41) | (1.35) | (1.24) |
| Rated Health | 1.19 | 1.10 | 0.79 | 0.62 | 0.55 | 2.02 | 1.65* | 1.42* | 1.15 | 0.93 |
| | (1.88) | (1.49) | (1.27) | (1.12) | (1.01) | (1.25) | (0.97) | (0.81) | (0.75) | (0.66) |
| RD * Rated Health | -0.99 | -1.50 | -1.48 | -1.59 | -1.71 | -2.06 | -2.11 | -2.25* | -2.14* | -2.04* |
| | (2.68) | (2.26) | (2.04) | (1.88) | (1.78) | (1.73) | (1.42) | (1.24) | (1.20) | (1.11) |
| D. Symptom | -1.03 | -1.03 | -0.66 | -0.34 | -0.13 | -0.69 | -0.52 | -0.38 | -0.29 | -0.29 |
| | (1.71) | (1.37) | (1.17) | (1.04) | (0.95) | (1.13) | (0.89) | (0.74) | (0.69) | (0.62) |
| RD * D. Symptom | 6.52*** | 5.87*** | 4.78** | 3.88** | 3.27** | 2.69* | 2.72** | 2.53** | 2.31** | 2.15** |
| | (2.49) | (2.10) | (1.89) | (1.76) | (1.66) | (1.59) | (1.32) | (1.16) | (1.12) | (1.03) |
| R-squared | 0.04 | 0.04 | 0.04 | 0.05 | 0.05 | 0.03 | 0.03 | 0.04 | 0.05 | 0.06 |
| Bandwidth | 5.767 | 7.690 | 9.612 | 11.53 | 13.46 | 4.888 | 6.518 | 8.147 | 9.777 | 11.41 |
| Within-bandwiths | | | | | | | | | | |
| N | 1081 | 1524 | 1951 | 2376 | 2765 | 903 | 1308 | 1751 | 1951 | 2376 |
| Mean Age | 52 | 53 | 53 | 53 | 54 | 52 | 53 | 53 | 53 | 53 |

See Note Table C.1.2 - 1; Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

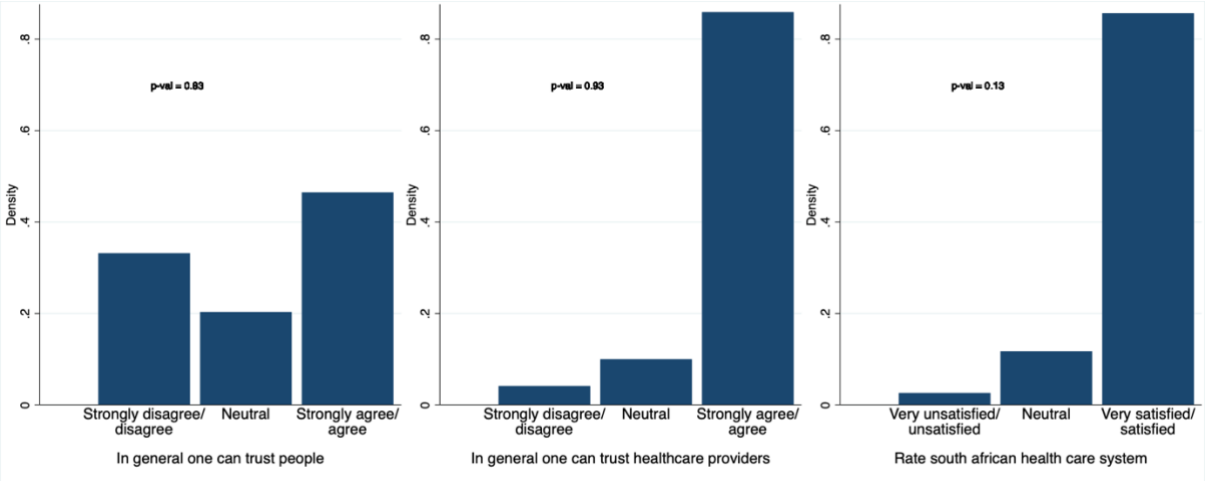
## C.1.5 Descriptive Analysis

Table C.1.5 - 1: Comparison of means for health system indicators by self-rated health using t-test

| | Poor to moderate/ fair health | Good to excellent health | p-val |
|---|---|---|---|
| Confirmed DM/anemia/dyslipidemia | 70 | 63 | 0.000 |
| CVD or TB diagnosis | 46 | 29 | 0.000 |
| Diagnosed DM | 46 | 50 | 0.554 |
| Depressive Symptom | 47 | 31 | 0.000 |
| Distance to clinic | 1301 | 1396 | 0.015 |

Note: *Confirmed DM/anemia/dyslipidemia* is share of respondents with DM, anemia, or dyslipidemia based on HAALSI-based biomarker collection. *CVD or TB diagnosis* is share of respondents self-reporting to being aware of having received at least one diagnosis for diabetes, dyslipidemia, heart problems, stroke, tuberculosis, or asthma. *Diagnosed DM* is share of respondents with DM as defined by biomarker and self-reported diagnosis in HAALSI. *Depressive Symptom* is share of respondents having depressive symptoms based on CESD-8 scale in HAALSI and CESD-10 in NIDS. *Distance to clinic* is mean distance to nearest health clinic measured in meters using GPS data in HAALSI.

Figure C.1.5 - 1: Trust and satisfaction ratings in HAALSI




Note: Graph depicts ratings from HAALSI sample; p-val indicates the p-value from a Pearson's Chi-squared test on differences across self-rated health status

## C.2 Survey Questions

### C.2.1 NIDS

The below presented questions were taken from the NIDS wave 1 adult questionnaire. For the full questionnaire from wave 1 and all other questionnaires, please refer to the National Income Dynamics documentation ("NIDS | South Africa Income Dynamics | National Surveys - | NIDS" n.d.)

| ***INTERVIEWER READ OUT***: We would like to ask you some questions about your background. | | | |
|---|---|---|---|
| **B1** *dob* | What is your date of birth? | **dd** (SD) **mm** **year** | |
| **B2** *gen* | What is your gender? | Male | 1 |
| | | Female | 2 |

| ***INTERVIEWER READ OUT:*** We would like to ask you about your education. | | | |
|---|---|---|---|
| **H1** *edschgrd* | What is the highest grade in school that you have successfully completed?<br>Do not count the final year you were in school if you did not successfully complete the year.<br>**Interviewer: See code sheet for Education Codes**<br>**Codes 16 to 24 are not applicable** | Highest school grade<br>**→If 25, SKIP TO H34** | |
| | | **If other, specify here** | |

| ***INTERVIEWER READ OUT:*** Now we would like to ask you about some particular health conditions. | | | | | | | |
|---|---|---|---|---|---|---|---|
| | J13<br>Have you ever been told by a doctor, nurse or health care professional that you have [...]<br>**(If No move to the next condition)** | | J14<br>In which year were you diagnosed with this condition? | J15<br>Are you currently taking medication for this condition?<br>**(If Yes, move to the next condition)** | | J16<br>Do you still have this condition? | |
| | Yes | No | | Yes | No | Yes | No |
| 1. Tuberculosis / TB *hltb* | 1 | 2 | *hltb_yr* | 1 | 2 | 1 | 2 |
| 2. High blood pressure *hlbp* | 1 | 2 | *hlbp_yr* | 1 | 2 | 1 | 2 |
| 3. Diabetes or high blood sugar *hldia* | 1 | 2 | *hldia_yr* | 1 | 2 | 1 | 2 |
| 4. Stroke *hlstrk* | 1 | 2 | *hlstrk_yr* | 1 | 2 | 1 | 2 |
| 5. Asthma *hlast* | 1 | 2 | *hlast_yr* | 1 | 2 | 1 | 2 |
| 6. Heart Problems *hlhrt* | 1 | 2 | *hlhrt_yr* | | | | |
| 7. Cancer *hlcan* | 1 | 2 | *hlcan_yr* | | | | |

***INTERVIEWER READ OUT:*** We would like to know how your general well-being has been over the past week.

I am going to read a list of some of the ways you may have felt or behaved during the last week. Using the showcard, please indicate how often you have felt this way during the **past week.**
**Interviewer: Circle one number on each line**

| | **During the past week...** | Rarely or none of the time (less than 1 day) | Some or little of the time (1-2 days) | Occasionally or a moderate amount of time (3-4 days) | All of the time (5-7 days) |
|---|---|---|---|---|---|
| **K1** *emobth* | I was bothered by things that usually don't bother me | 1 | 2 | 3 | 4 |
| **K2** *emomnd* | I had trouble keeping my mind on what I was doing | 1 | 2 | 3 | 4 |
| **K3** *emodep* | I felt depressed | 1 | 2 | 3 | 4 |
| **K4** *emoeff* | I felt that everything I did was an effort | 1 | 2 | 3 | 4 |
| **K5** *emohope* | I felt hopeful about the future | 1 | 2 | 3 | 4 |
| **K6** *emofear* | I felt fearful | 1 | 2 | 3 | 4 |
| **K7** *emoslp* | My sleep was restless | 1 | 2 | 3 | 4 |
| **K8** *emohap* | I was happy | 1 | 2 | 3 | 4 |
| **K9** *emolone* | I felt lonely | 1 | 2 | 3 | 4 |
| **K10** *emogo* | I could not "get going" | 1 | 2 | 3 | 4 |

| ***INTERVIEWER READ OUT:*** Now we would like to take your height, weight, waist and blood pressure measurements. | | | |
|---|---|---|---|
| **N1.1** *height_1* | Respondent's Height – Measure 1 | | ___ ___ ___ • ___ centimetres |
|  | **INTERVIEWER CHECK! Is the height measurement less than 130.0cm?** | **Yes → Re-do height measure, you may cross out and correct N1.1 if appropriate** | **1** |
| | | **No** | **2** |
| **N1.2** *height_2* | Respondent's Height – Measure 2 | | ___ ___ ___ • ___ centimetres |
|  | **INTERVIEWER CHECK! Is the difference between N1.1 and N1.2 more than 1cm?** | **Yes** | **1** |
| | | **No → SKIP TO N2.1** | **2** |
| **N1.3** *height_3* | Respondent's Height – Measure 3 | | ___ ___ ___ • ___ centimetres |
| **N2.1** *weight_1* | Respondent's Weight – Measure 1 | | ___ ___ ___ • ___ kilograms |
|  | **INTERVIEWER CHECK! Does the scale display a figure of more than 150?** | **Yes → Reset the scale to kilograms. You may cross out and correct N2.1** | **1** |
| | | **No** | **2** |
| **N2.2** *weight_2* | Respondent's Weight – Measure 2 | | ___ ___ ___ • ___ kilograms |
|  | **INTERVIEWER CHECK! Is the difference between N2.1 and N2.2 more than 1 kg?** | **Yes** | **1** |
| | | **No → SKIP TO N3.1** | **2** |
| **N2.3** *weight_3* | Respondent's Weight – Measure 3 | | ___ ___ ___ • ___ kilograms |
| **N3.1** *waist_1* | Respondent's Waist – Measure 1 | | ___ ___ ___ • ___ centimetres |
| **N3.2** *waist_2* | Respondent's Waist – Measure 2 | | ___ ___ ___ • ___ centimetres |
|  | **INTERVIEWER CHECK! Is the difference between N3.1 and N3.2 more than 2cm?** | **Yes** | **1** |
| | | **No → SKIP TO N4.1** | **2** |
| **N3.3** *waist_3* | Respondent's Waist – Measure 3 | | ___ ___ ___ • ___ centimetres |

| **N4.1** | **Blood pressure – Reading 1** | **N4.2** | **Blood pressure – Reading 2** |
|---|---|---|---|
| 1. SYSTOLIC *bpsys_1* | _____ _____ _____ | 1 SYSTOLIC *bpsys_2* | _____ _____ _____ |
| 2. DIASTOLIC *bpdia_1* | _____ _____ _____ | 2. DIASTOLIC *bpdia_2* | _____ _____ _____ |
| 3. PULSE *bppls_1* | _____ _____ _____ | 3. PULSE *bppls_2* | _____ _____ _____ |

| | | | |
|---|---|---|---|
| **N5** | **INTERVIEWER CHECK! Have you filled out the health information sheet and given it to the respondent?** | Yes | 1 |
| | | No | 2 |

## Section J: Health

| ***INTERVIEWER READ OUT:*** We would like to ask you some questions about your health. | | | |
|---|---|---|---|
| **J1** *hldes* | How would you describe your health at present? Would you say it is excellent, very good, good, fair, or poor? | Excellent | 1 |
| | | Very good | 2 |
| | | Good | 3 |
| | | Fair | 4 |
| | | Poor | 5 |
| | | Don't know | -9 |

## C.2.2 HAALSI

*HAALSI Baseline Questionnaire*

| | | |
|---|---|---|
| CD001 | Now think about the past week and the feelings you have experienced. Please tell me if each of the following was true for you much of the time this past week. Would you say yes or no?<br>Much of the time in the past week, you felt depressed | YES.....1<br>NO .....2 |
| CD002 | Much of the time in the past week, you felt that everything you did was an effort.<br>**Note: This question was mistranslated and must be reverse-coded in the CESD scale. | YES.....1<br>NO .....2 |
| CD003 | Much of the time in the past week, your sleep was restless. | YES.....1<br>NO .....2 |
| CD004 | Much of the time in the past week, you were happy. | YES.....1<br>NO .....2 |
| CD005 | Much of the time in the past week, you felt lonely. | YES.....1<br>NO .....2 |
| CD006 | Much of the time in the past week, you did not enjoy life. | YES.....1<br>NO .....2 |
| CD007 | Much of the time in the past week, you felt sad. | YES.....1<br>NO .....2 |
| CD008 | Much of the time in the past week, you could not get "going". | YES.....1<br>NO .....2 |
| CM001 | The following questions ask about your health associated with a few chronic conditions. | YES.....1<br>NO .....2 |

| | | |
|---|---|---|
| | Has a doctor, nurse, or other healthcare worker ever measured your blood pressure? | |
| CM004 | Have you ever received treatment for high blood pressure prescribed by a doctor, nurse, or other healthcare worker? | YES.....1<br>NO .....2 |
| CM005 | Are you currently on treatment for high blood pressure prescribed by a doctor, nurse, or other healthcare worker? | YES.....1<br>NO .....2 |
| GH001 | Now, I will ask your views about your health. If you are unsure about how to answer a question, please give the best answer you can.<br>In general, how would you rate your health today? | Very good …….....1<br>Good…….....2<br>Moderate…….....3<br>Bad…….……<br>….4<br>Very<br>bad……..5 |
| CM007_females | Have you ever been told by a doctor, nurse, or other healthcare worker that you have raised blood sugar or diabetes outside of pregnancy? | YES.....1<br>NO .....2 |
| CM007_males | Have you ever been told by a doctor, nurse, or other healthcare worker that you have raised blood sugar or diabetes? | YES.....1<br>NO .....2 |
| CM010 | Are you currently receiving any treatment for diabetes prescribed by a doctor, nurse, or other healthcare worker? | YES.....1<br>NO .....2 |
| CM020 | Have you ever been told by a doctor, nurse, or other healthcare worker that you have TB? | YES.....1<br>NO .....2 |
| CM022 | Are you currently receiving TB treatment prescribed by a doctor, nurse or other healthcare worker? | YES.....1<br>NO .....2 |
| CM025 | Have you ever been told by a doctor, nurse, or other healthcare worker that you have had a stroke? | YES.....1<br>NO .....2 |
| CM027 | Are you currently on treatment to prevent a further stroke prescribed by a doctor, nurse or other healthcare worker? | YES.....1<br>NO .....2 |
| CM038 | Have you ever been told by a doctor, nurse, or other healthcare worker that you have had a heart attack? | YES…….....1<br>NO …….....2 |

| | | |
|---|---|---|
| CM041 | Have you ever been told by a doctor, nurse, or other healthcare worker that you have had heart failure? | YES…….....1<br>NO …….....2 |
| CM043 | Are you currently on treatment for heart failure prescribed by a doctor, nurse or other healthcare worker? | YES…….....1<br>NO …….....2 |
| CM029 | Have you ever been told by a doctor, nurse, or other healthcare worker that you have angina (chest pain due to heart disease)? | YES.....1<br>NO .....2 |
| CM031 | Are you currently taking any medications for angina (chest pain due to heart disease) prescribed by a doctor, nurse, or other healthcare worker? | YES.....1<br>NO .....2 |
| CM046 | Have you ever been told by a doctor, nurse, or other healthcare worker that you have high cholesterol? | YES…….....1<br>NO …….....2 |
| CM047 | Have you ever been treated for high cholesterol by a doctor, nurse or other healthcare worker? | YES…….....1<br>NO …….....2 |
| BS002_left | Have you had any recent surgeries or injuries to your left arm that will prevent me from wrapping the cuff around your left upper arm? | YES.....1<br>NO .....2 |
| BS002_left_specify | [IWER: PLEASE DESCRIBE THE PREVENTING CONDITIONS IN THE LEFT ARM. CONDITIONS INCLUDE: OPEN SORES, WOUNDS, GAUZE DRESSINGS OR RASHES, PARTICIPANT HAS NO LEFT ARM.] | |
| BS002_right | Have you had any recent surgeries or injuries to your right arm that will prevent me from wrapping the cuff around your right upper arm? | YES.....1<br>NO .....2 |
| BS002_right_specify | [IWER: PLEASE DESCRIBE THE PREVENTING CONDITIONS IN THE LEFT ARM. CONDITIONS INCLUDE: OPEN SORES, WOUNDS, GAUZE DRESSINGS OR RASHES, PARTICIPANT HAS NO RIGHT ARM.] | |

| | | |
|---|---|---|
| BS003 | In the past 30 minutes, have you eaten any food, smoked a cigarette, or exercised? | YES.....1<br>NO .....2 |
| BS005 | Now I will take the first of three blood pressure readings. While I am measuring your blood pressure, it is very important that you remain still, sitting up straight with your arms relaxed, your feet flat on the ground, and that we not have any conversation. [IWER: INTERVIEWER: ENSURE THE SETTING IS APPROPRIATE AND RESPONDENT IS READY FOR MEASUREMENT (SUFFICIENTLY QUIET, CALM, RELAXED, SITTING STRAIGHT WITH FEET FLAT ON GROUND) FOR BLOOD PRESSURE MEASUREMENT] [IWER: IT IS IMPORTANT AT THIS POINT THAT THE PARTICIPANT REMAINS STILL AND DOES NOT SPEAK. WHEN THE MEASUREMENT FINISHES THE CUFF WILL DEFLATE AND THE MEASUREMENT RESULTS (BLOOD PRESSURE VALUES, PULSE RATE, DATE AND TIME) ARE THEN DISPLAYED. IF YOU NEED TO STOP THE MEASUREMENT, PUSH THE START/STOP BUTTON TO TURN OFF THE POWER.] | |
| BS008 | [IWER: YOU HAVE PLACED MONITOR ON ^BS007 ARM. HAVE YOU CHANGED THE ARM SELECTION SETTING TO INDICATE THE ^BS007 ARM?] | |
| BS009 | [IWER: IT IS IMPORTANT AT THIS POINT THAT THE PARTICIPANT REMAINS STILL AND DOES NOT SPEAK.<br>WHEN THE MEASUREMENT FINISHES THE CUFF WILL DEFLATE AND THE MEASUREMENT RESULTS (BLOOD PRESSURE VALUES, PULSE RATE, DATE AND TIME) ARE THEN DISPLAYED.<br>IF YOU NEED TO STOP THE MEASUREMENT, PUSH THE START/STOP BUTTON TO TURN OFF THE POWER.] | |

| | | |
|---|---|---|
| BS010 | [IWER: INDICATE OUTCOME OF BLOOD PRESSURE READING] | Reading obtained……1<br>Missed reading (equipment failure, interruption, other problem……<br>…..2<br>Refused……<br>……3 |
| BS011 | [IWER: REASON NO BLOOD PRESSURE MEASUREMENT OBTAINED? MARK ALL THAT APPLY.] | Respondent unable/unwilling to understand and follow instructions…….<br>.1<br>Respondent refuses to be measured……<br>..2<br>Withered arms, injury, recent surgery, dressing, rash (on both arms)……<br>…….3<br>Equipment failure……4<br>Other……<br>…….5 |
| BS012 | [IWER: ENTER BLOOD PRESSURE AND PULSE READING] ENTER SYSTOLIC READING: | _____SYS/mmHg |
| BS013 | ENTER DIASTOLIC READING: | _____DIA/mmHg |
| BS014 | ENTER PULSE READING: | _____PULSE/min |
| BS015_intro | [IWER: RE-ENTER BLOOD PRESSURE AND PULSE READING ]<br>RE-ENTER SYSTOLIC READING<br>_____SYS/mmHg<br>RE-ENTER DIASTOLIC READING:<br>_____DIA/mmHg<br>RE-ENTER PULSE READING<br>_____PULSE/min | |

| | | |
|---|---|---|
| BS015 | [IWER: RE-ENTER BLOOD PRESSURE AND PULSE READING] RE-ENTER SYSTOLIC READING: | _____SYS/mmHg |
| BS015_delay | [IWER: WAIT TWO MINUTES UNTIL NEXT MEASUREMENT. USE THIS TIME TO RETRIEVE AND PREPARE THE REST OF YOUR EQUIPMENT SUCH AS THE SCALE, TAPE MEASURE, WALKING COURSE, AND GRIP STRENGTH. ENSURE THE PARTICIPANT REMAINS CALM AND RELAXED DURING THESE TWO MINUTES. ] | |
| BS016 | RE-ENTER DIASTOLIC READING: | |

*HAALSI Midline Questionnaire*

**24. Please rate your satisfaction with South Africa's healthcare system, on a scale from 1 (very unsatisfied) to 5 (very satisfied):**

1 Very unsatisfied
2 Unsatisfied
3 Neutral
4 Satisfied
5 Very satisfied
.r Refused

**26. How much do you agree with the following statements [on scale of 1 (strongly disagree) to 5 (strongly agree)]?**

PART A: In general, one can trust people
Answer Options: 1-5
1 Strongly disagree
2 Disagree
3 Neutral
4 Agree
5 Strongly agree
.r Refused

PART B: In general, one can trust healthcare providers
Answer Options: 1-5
1 Strongly disagree
2 Disagree
3 Neutral

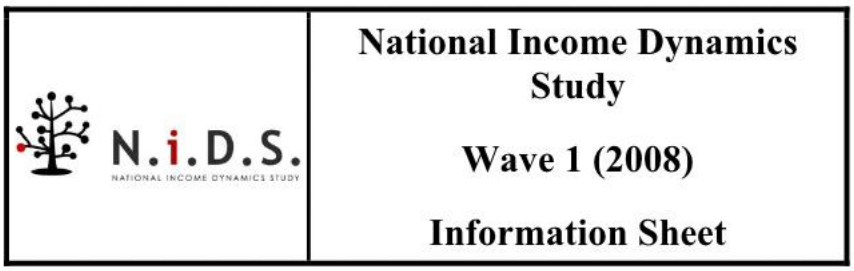
4 Agree

5 Strongly agree

.r Refused

## C.3 Referral Letters

### C.3.1 NIDS



**National Income Dynamics Study**

**Wave 1 (2008)**

**Information Sheet**

**YOUR PHYSICAL MEASUREMENTS**

| | |
|---|---|
| Respondent's Height | _____ _____ _____ centimetres |
| Respondent's Weight | _____ _____ _____ kilograms |
| Respondent's Waist | _____ _____ _____ centimetres |

| **Blood Pressure reading 1** | **Blood Pressure reading 2** |
|---|---|
| SYSTOLIC<br>_____ _____ _____<br>DIASTOLIC<br>_____ _____ _____<br>PULSE<br>_____ _____ _____ | SYSTOLIC<br>_____ _____ _____<br>DIASTOLIC<br>_____ _____ _____<br>PULSE<br>_____ _____ _____ |

| | | |
|---|---|---|
| ☐ | Our readings of your blood pressure are within the normal range (Systolic less than 140 and Diastolic less than 90) | |
| ☐ | Your blood pressure readings are higher than normal. High blood pressure is dangerous because it makes the heart work too hard. High blood pressure increases the risk of heart disease and stroke. High blood pressure can also cause other problems, such as heart failure, kidney disease, and blindness. You can control high blood pressure by taking action. | |
| | ☐ | It is recommended that you should seek medical care within 2 months. (Systolic 140 to 159 or Diastolic 90 to 99) |
| | ☐ | It is recommended that you should seek medical care within 1 month. (Systolic 160 to 179 or Diastolic 100 to 109) |
| | ☐ | It is recommended that you should seek **medical care immediately**. (Systolic more than 179 or Diastolic more than 109) |

Source: Appendix XIII (Sudharsanan et al. 2020)

## C.3.2 HAALSI

HAALSI Referral Letter

P.O. Box 2, Acornhoek 1360, South Africa
Telephone: +27 13 7955076 (Acornhoek) or +27 13 708 0003 (Agincourt)
Fax: +27 13 7955076 (Acornhoek) or +27 13 708 1540 (Agincourt)

**REFERAL TO THE CLINIC**

As part of the survey "Health and Aging in Africa: Longitudinal studies in INDEPTH communities – HI KURILE" that the MRC/Wits Agincourt Research Unit is currently running in the area, we have identified that _____ _____ has a potential problem with his/her:

a) **Blood pressure**

☐

b) **Blood glucose**

☐

c) **Cholesterol**

☐

d) **Haemoglobin**

☐

In case you need to contact us please do it using the following contacts:

| | | |
|---|---|---|
| F. Xavier Gomez-Olive<br>Ph: 013 795 50 76<br>Cell: 073 768 82 55<br>Fax: 013 795 50 76<br>F.Gomez-OliveCasas@wits.ac.za | Ryan Wagner<br>Ph: 013 795 50 76<br>Cell: 071 586 09 06<br>Fax: 013 795 50 76<br>Ryan.Wagner@wits.ac.za | Bernard Silaule<br>Ph: 013 708 14 20<br>Cell: 082 353 86 29<br>Fax: 013 708 15 40<br>Bernard.Silaule@wits.ac.za |

Field worker signature: _____

Date |___|___|/|___|___|___|/|___|___|___|___|

[1]

_____

[1] HAALSI_referralclinicletter_V2_13032015.docx

HAALSI Results Letter:

P.O. Box 2, Acornhoek 1360, South Africa
Telephone: +27 13 7955076 (Acornhoek) or +27 13 7080003 (Agincourt)
Fax: +27 13 7955076 (Acornhoek) or +27 13 7081540 (Agincourt)

As part of the survey “Health and Aging in Africa: Longitudinal studies in INDEPTH communities – HI KURILE” that the MRC/Wits Agincourt Research Unit is currently running in the area, we have run different blood tests to _____ with the following results:

| | | | | |
|---|---|---|---|---|
| Blood pressure | ☐☐☐ | mmHg | ☐☐☐ | mmHg |
| | Systolic | | Diastolic | |
| Height | ☐☐☐ | cm | | |
| Weight | ☐☐.☐ | kg | | |
| Blood glucose | ☐.☐ | mmol/L | | |
| Haemoglobin | ☐☐.☐ | g/dl | | |
| Total cholesterol | ☐☐.☐☐ | mmol/L | | |
| LDL cholesterol | ☐☐.☐☐ | mmol/L | | |
| HDL cholesterol | ☐☐.☐☐ | mmol/L | | |

In case you need to contact us please do it using the following contacts:

| | | |
|---|---|---|
| F. Xavier Gomez-Olive<br>Ph: 013 795 5076<br>Cell: 073 768 8255<br>Fax: 013 795 5076<br>F.Gomez-OliveCasas@wits.ac.za | Ryan Wagner<br>Ph: 013 795 5076<br>Cell: 071 586 0906<br>Fax: 013 795 5076<br>Ryan.wagner@wits.ac.za | Bernard Silaule<br>Ph: 013 708 14 20<br>Cell: 082 353 86 29<br>Fax: 013 708 15 40<br>Bernard.Silaule@wits.ac.za |

Field worker signature: _____

Date |___|___|/|___|___|___|/|___|___|___|___|