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Richer, wiser and in better health? The socioeconomic gradient in hypertension prevalence, unawareness and control in South Africa

Abstract

The socioeconomic gradient in chronic conditions is clear in the poorest and wealthiest of countries, but extant evidence on this relationship in low- and middle-income countries is inconclusive. We use data gathered between 2008-2012 from a nationally representative sample of over 10,000 South African adults, and objective health measures to analyse the differential effects of education, income and other factors on the prevalence of hypertension, individuals' awareness and control of hypertensive status. Prevalence of hypertension is high at 38% among women and 34% among men. 59% of hypertensive individuals are unaware of their status. We find prevalence and unawareness of hypertension are a public health concern across all income groups in South Africa. Higher income is however associated with effective control amongst men. Completing secondary education is associated with 7 mmHg lower blood pressure only in a small sub-group of women but is associated with 22 percentage point higher likelihood of effective hypertension control amongst women. We conclude that poorer and less educated individuals are particularly at high risk of cardiovascular disease in South Africa

Keywords: South Africa, hypertension, socioeconomic gradient, unawareness, control

1 Introduction

Hypertension is a significant public health challenge in low-and middle-income countries (LMICs). Elevated blood pressure (BP) is the largest single contributor to global mortality and burden of disease (Lim et al., 2012) and a leading risk factor for cardiovascular disease (CVD). It is linked to 62% of strokes and 49% of coronary heart disease cases in LMICs (Gaziano et al., 2010). Unfortunately, diagnosis and control of hypertension is suboptimal in most LMICs, and many patients are not aware of their condition and do not receive treatment (World Health Organisation, 2014). Hypertension is comparably easy and cheap to diagnose and treat in primary care facilities, and management of hypertension is one of the most cost-effective interventions in LMICs, particularly if targeted towards the population groups most at risk (Horton et al., 2017).

We know that communicable disease prevalence is concentrated amongst the disadvantaged in LMICs (Bates et al., 2004; Spence et al., 1993), but robust evidence on the within-country socioeconomic gradients for chronic conditions is sparse and contested (Cesare et al., 2013). There may be a positive gradient between socioeconomic status (SES) and certain chronic diseases and contributing risk factors in LMICs (Zhao et al., 2013; Gaziano et al., 2010; Case et al., 2004), although there is also evidence that such conditions are concentrated among the disadvantaged as they are in high-income countries (Hosseinpoor et al., 2012; Murphy et al., 2013; Lloyd-Sherlock et al., 2014), or that there is no socioeconomic gradient (Lei et al., 2012; Witoelar et al., 2009; Vellakkal et al., 2013).

Our study investigates the socioeconomic gradient in hypertension prevalence, awareness, and control in South Africa. In addition, we evaluate the differential associations between hypertension and other factors such as age, race and area of residence.

Several factors might explain the ambiguous relationship between SES and hypertension. First, it might be due to measurement error in relevant variables. Second, there may indeed be a weak or no association between SES and hypertension, at least in some populations. Third, the results may mask differences in sub-populations driven by latent unobservable preferences that are a priori unknown to the researcher and thus difficult to classify. South Africa has undergone a social transformation which has led to complicated changes in individual preferences and social norms, which may influence health outcomes. Therefore the relationship between SES and hypertension may be heterogeneous across sub-populations that are difficult to delineate with respect to observable factors such as race.

Previous studies have analysed the differential effects of SES on hypertension. Case et al. (2004) find that wealthier individuals were indeed more likely to be on hypertensive medication and aware of their status. Observed hypertension also had no statistically significant negative association with income. The authors suggested that one explanation for this puzzling result is that hypertension was concentrated amongst the wealthier individuals, supported by the finding that obesity rose monotonically with income in the sample. The authors highlight that their study may have suffered from sample selection bias as only 30% of their sample participated in the medical examination where clinical measures of hypertension were recorded. Zhao et al. (2013) found higher hypertension prevalence among the wealthy. They also found that upon receiving an exogenous information shock of hypertension diagnosis, wealthier individuals reduced fat intake more than other income groups. This suggests that diagnosis, and awareness, may ameliorate the positive income gradient of hypertension prevalence. Lloyd-Sherlock et al. (2014) find higher wealth quintiles were associated with awareness and hypertension control.

WHO's SAGE study (Lloyd-Sherlock et al., 2014) found that higher education was associated with lower hypertension prevalence amongst older adults in South Africa, but not with better awareness of having hypertension. They also found a positive association between higher levels of education and hypertension control. Chow et al. (2013) analysed nearly 400,000 individuals from 17 countries and found that better education was associated with greater awareness only in low- but not middle- or high-income countries. Greater education was associated with greater treatment and control in low income countries. Case et al. (2004) used data from 200 households drawn from Khayelitsha township in South Africa. They find no predictive effect of education on hypertension control. Zhao et al. (2013) tested the existence of a positive gradient between education, income, hypertensive status and dietary adjustments in China. They find years of schooling to be negatively associated with being hypertensive.

The remainder of this paper is organised as follows. Section 2 describes the data. In this section we also provide summary statistics and discuss the extent of hypertension prevalence and unawareness in our sample. Section 3 describes the empirical methods we apply. Section 4 presents our findings and Section 5 concludes.

2 Data

The data for our study come from South Africa's National Income Dynamics Survey (NIDS). NIDS is a panel survey with four waves at present, in 2008, 2010, 2012 and 2014 (SALDRU, 2015). It is a nationally representative two-stage random cluster sample that uses South Africa's 53 district councils as a master sample from which 400 primary sampling units were randomly selected, see Leibbrandt et al. (2009) for details.

In each wave, a face-to-face interview was conducted and all consenting respondents received a medical examination by trained survey staff. Measured indicators included height, weight, waist circumference, systolic and diastolic blood pressure (SBP and DBP) and pulse. In the interview, respondents self-reported health conditions including hypertension, diabetes, stroke, other heart related conditions, asthma, tuberculosis and cancer. The hypertension question is framed as follows: ”Have you ever been told by a doctor, nurse or health care professional that you have high blood pressure?” If the respondent reported having ever been diagnosed with high blood pressure (BP), then he or she is asked whether they still have high BP and whether they are currently taking medication for high BP. BP screening involved two successive readings taken by trained study staff in each wave of the survey. The readings were taken in the left arm after a 5 minute rest period using an automated BP monitor (Omron M7 BP, multi-size cuff, factory calibrated). We average the two BP readings to determine an individual's SBP and DBP. Following medical practice we define elevated BP as SBP greater than or equal to 140 or DBP greater than or equal to 90, but estimate alternative specifications with different thresholds. We classify respondents who self-reported being on hypertensive medication as being hypertensive even if their measurements are within normal range. We may mis-classify individuals as unaware if they were not truthful in their survey response and reported being normotensive although they knew they were not.

Over 80% of the sample in waves 1 and 3 had valid results from the medical examinations giving us a sample of 12,493 adults in 2008 and 16,391 adults in 2012 aged 18 years or over. We do not use data from 2010 (wave 2) because there was both high attrition and poor response rate(67%). In 2012 there was negative attrition, with field workers successfully recovering a large share of the baseline sample, to off-set the 2010-2012 attrition and achieve an overall increase in the number of baseline participants re-interviewed in 2012 vs. 2010. Compared to 2008 there was 17% attrition in 2010 and 16% overall attrition in 2012. Descriptive statistics of all variables used in the estimations are presented in Table 1. The average age of our sample is 40 years and 40% are male across the two waves we use. About 46% have completed secondary education and 26% have some form of higher education. The average annual household income is around ZAR 66,000 (US$4,677). Over 50% of our sample has an increased or substantially increased waist circumference. But there are large differences between genders (see figures in Appendix). More than 60% of women in all income groups have an elevated waist circumference (and over 30% are obese). In comparison, fewer men have elevated waist circumferences (or obesity). There is no clear education gradient in either risk factor. Amongst women of all races obesity or elevated waist circumference levels are high, while amongst men there is a gradient with the largest proportion amongst Whites. Sartorius et al. (2015) analysed the determinants of obesity using the same data and find formal urban residence, being of white ethnicity and in the highest income quintile (amongst men) and African ethnicity and in the high-or middle income quintile (amongst women) were associated with higher odds of being obese.

Insert Table 1 here ***

In Table 2 we present age standardized prevalence of total and uncontrolled hypertension. Total hypertension includes all individuals who either had measured elevated values or reported being on medication; uncontrolled hypertension includes all individuals who had measured elevated values irrespective of whether they were on medication. The overall prevalence of hypertension was 36% in 2008, 38% among women and 34% among men. The extent of uncontrolled hypertension was almost the same amongst women and men in 2008, 32% and 31% respectively. By 2012, prevalence of overall and uncontrolled hypertension had decreased slightly.

****Insert Table 2 and 3 here **************

In the first part of our analysis, we model the socioeconomic gradient in hypertension prevalence using measured SBP as a continuous outcome measure. Though DBP is also an important measure of hypertension, SBP has been shown to be a significantly accurate measure of cardiovascular risk (Kannel, 2000). In addition, studies have shown that isolated elevated DBP does not possess the same high risk of major cardiovascular incidents as elevated SBP (Fang et al., 1995). Respondents were informed of their medical results with a written report sheet.

For the second part of our analysis, the socioeconomic gradient in awareness, we use only the 2008 (wave 1) data. This is because our interest is in baseline unawareness prior to respondents being informed of their status as part of the survey. We compared self-reported and measured BP to create a binary outcome of unawareness of being hypertensive. We use the standard definition of unawareness taken from the public health literature which classifies an individual as unaware if conditional on being diagnosed as hypertensive during the medical examination, an individual self-reports being normotensive currently, nor having ever been diagnosed with high BP in the past. Table 3 provides descriptive statistics for hypertension unawareness. In

2008 only 16% of the sample self-reported having hypertension, while 36% were diagnosed with clinical hypertension in the examination. Our sample shows very low levels of awareness with 59% of individuals diagnosed with hypertension not self-reporting as such.

Finally, we use both the 2008 and 2012 waves to analyse the socioeconomic gradient in effective hypertension control. We model hypertension control amongst those who are hypertensive and self-report being aware of being hypertensive regardless of whether they are on medication or not. Controlled hypertension represents a normal BP reading amongst these individuals, while uncontrolled hypertension is represented by measured elevated values above the cut-off of SBP greater than or equal to 140 or DBP greater than or equal to 90.

Insert Figure 1 here ***

Unadjusted figures show fewer women with secondary education are hypertensive (Figure 1(a)). Control of hypertension rises with education amongst women. There is a positive income gradient in measured hypertension and effective control amongst men but not amongst women (Figure 1(b)). There is no clear education gradient for men. There is little difference in unawareness (gap between self-reported and measured hypertension) across income or education groups for either gender, indicating that according to the descriptive statistics undiagnosed hypertension is a problem across all socioeconomic groups. The remainder of this paper focuses on validating the robustness of these findings- in our empirical models once we allow for a range of factors that might mediate the relationship between education, income and hypertension prevalence, unawareness and control.

3 Empirical Methods

We analyse the socioeconomic gradient in hypertension prevalence with a Finite Mixture Model (FMM), the gradient in hypertension unawareness with a Censored Bivariate Probit Model (CBPM) and the gradient in hypertension control using pooled probit models.

3.1 Estimating the socioeconomic gradient in hypertension prevalence

The transition from apartheid has had a dramatic influence on South African society. While race remains a dominant feature of the social landscape, the rise of an emerging black middle class, rapid urbanisation and increases in one-person households have disrupted social norms and preferences. We conjecture that these heterogeneities matter for our research question, because unobserved social norms and individual preferences have a large bearing on the relationship between SES status and hypertension via channels such as work strain, lifestyle choices, health-seeking behaviour and treatment adherence. These avenues of influence are not fully captured by traditional household survey variables. If the population is made up of distinct subgroups, analysis based on standard regression techniques may be misleading. A FMM allows for subgroups with distinctly different associations between SES and hypertension, without requiring that the subgroups are delineated according to observable factors. It is therefore ideally suited to study the complex patterns prevalent in the post-apartheid South African society, and it will allow us to identify subgroups and their characteristics so as to better target health policies. We describe our approach below.

SBP is a continuous variable in our sample. Our basic specification is given by:

$$E(SBP_i|EDU_i, LINC_i, Z_i, X_i) = \alpha EDU_i + \tau LINC_i + \gamma Z_i + \beta X_i \quad (1)$$

where EDU_i is educational attainment, $LINC_i$ is annual household income expressed in natural logarithm. In our analyses we treat education and income as exogenous. We believe that this assumption is not unreasonable given the largely asymptomatic nature of hypertension and the fact diagnosis and treatment is widely available in the public sector, free of charge. Given it's asymptomatic nature even at very high levels it is unlikely to influence education or income. In addition, since we are analysing adults, we expect education to have been largely completed at younger ages and remain fixed over time. Other studies analysing hypertension have made similar assumptions, see for example Chatterji et al. (2012); Johnston et al. (2009); Zhao et al. (2013). Z_i represents a vector of individual specific characteristics - age, race, being married, being a smoker, alcohol consumption; X_i represents a vector of household level characteristics - number of children and number of adults in the household, urban or rural location of households, a wave dummy variable and province dummies. We estimate separate models for men and women using pooled data from the 2008 and 2012 waves. Equation (1) is our basic model specification. In our second and preferred specification we also include waist circumference as a proxy for visceral body fat. Elevated waist circumference has been shown to be predictive of excess visceral fat and clinical studies have demonstrated visceral adiposity results in an increased risk for cardiovascular disease, even more so than high BMI (Guagnano et al., 2001; Desprs, 2012; Janssen et al., 2002).

We first estimate (1) with Ordinary Least Squares (OLS) regression. However, if there are distinct subgroups, the OLS estimate of α, τ and γ represents the average effect of SES across subgroups. To identify the subgroups we therefore estimate (1) using a FMM which allows the subgroups to be drawn from normal distributions. The FMM represents the heterogeneity in our sample using a small number of latent classes. Each class typically represents a "type" or a "group" of individuals.

The population is assumed to be divided into C distinct subgroups in proportions $\pi_1 \ldots \pi_C$, where $\sum_{j=1}^{C} \pi_j = 1$. The general C-group FMM model is given by:

$$f(SBP_i|.) = \sum_{j=1}^{C} \pi_j f_j(SBP_i|.) \tag{2}$$

where $f_j(SBP_i|.)$ is the jth density and $j = 1 \ldots C$. In the case of SBP we apply a mixture of normal distributions for which the component distributions are defined by:

$$f_j(SBP_i|.) = \frac{1}{\sigma_j\sqrt{2\pi}} exp\left(-\frac{1}{2\sigma_j^2}(SBP_i - \alpha EDU_i + \tau LINC_i - \gamma_j \mathbf{Z}_i - \beta_j \mathbf{X}_i)^2\right) \quad (3)$$

The FMMs are estimated using sampling weights and robust standard errors allowing for clustering at the individual level. FMM offers a flexible and parsimonious way to model the data even if a natural interpretation for the different latent classes does not arise (Deb and Trivedi, 2002; Deb et al., 2011). The parameters from the FMM can be used to calculate the posterior probability of being in each of the classes using Bayes Theorem. The membership probabilities for each latent class are estimated conditional on outcome and all the covariates in the model, resulting in probabilities that vary across observations. This enables us to analyse the characteristics that determine membership in each class. The posterior probabilities can be calculated as:

$$Pr(SBP_i \in k|., SBP_i) = \frac{f_k(SBP_i|.)}{\sum_{j=1}^{C} \pi_j f_j(SBP_i|.)}, \quad \forall k = 1, 2....C \quad (4)$$

3.2 Estimating the socioeconomic gradient in unawareness of hypertensive status

The difficulty with analysing individuals' awareness of hypertension status is that we only observe awareness for those who are currently hypertensive. We do not observe the non-hypertensive who potentially may fall into the category of being unaware if they were to develop high BP. To overcome the sample selection problem we estimate a Censored Bivariate Probit Model (CBPM) (Van de Ven and van Praag, 1981), following Johnston et al. (2009) who used this model to analyse misreporting of hypertension in

England. The model consists of two equations; the first estimates the probability that an individual has measured hypertension (as described earlier we define our binary indicator as $SBP \geq 140$ and $DBP \geq 90$); the second estimates the probability of being unaware.

$$
\begin{aligned}
&y_{i1} = \beta Z_i + \epsilon_{1i} \\
&y_{2i} = \lambda X_i + \epsilon_{2i} \\
\\
&Where: \\
&\epsilon_{1i} \sim N(0,1) \\
&\epsilon_{2i} \sim N(0,1) \\
&corr(\epsilon_{1i}, \epsilon_{2i}) = \rho
\end{aligned}
\tag{5}
$$

In the above system of equations $y_{1i} = 1$ if $SBP \geq 140$ or $DBP \geq 90$ and $y_{2i} = 1$ if $y_{1i} = 1$ and the individual self-reports being normotensive. X_i and Z_i represent vectors of socioeconomic characteristics and ϵ_{1i} and ϵ_{2i} are assumed to be bivariate normally distributed with co-variance equal to ρ. The inequality $\rho \neq 0$ accounts for unobservable characteristics that jointly determine being hypertensive and being unaware. If $\rho = 0$ then we could estimate the model with a standard probit specification ignoring the selection problem. In our results we report the values for ρ and Wald Chi squared tests for $\rho = 0$.

The CBPM requires valid exclusion restrictions for identification. We need a variable that determines the probability of having high BP but does not directly affect the probability of being unaware conditional on other control variables. We employ two variables, measured heart rate and waist circumference. Elevated heart rate and large waist circumference have been shown to be associated with the development of hypertension (Reule and Drawz, 2012; Palatini et al., 2006; Palatini, 2011; Guagnano et al., 2001), but not of awareness of having BP. At any given BMI level, an elevated waist circumference is predictive of an increased level of abdominal fat (Desprs, 2012). Independently from BMI, waist circumference contributes to the prediction of abdominal subcutaneous and visceral fat. Both are major risk factors for developing hypertension and other cardiovascular conditions (Janssen et al., 2002).

We find that both variables are indeed highly statistically significant in our selection equation and thus satisfy the first condition for a valid exclusion restriction. The second condition cannot be directly tested, but is likely to hold for heart rate which cannot be directly observed or influenced by individuals. However, it is possible that a higher heart rate and larger waist measurements are associated with greater awareness of hypertensive status, possibly because individuals sought healthcare for conditions caused by either - such as diabetes or cardiac conditions or due to health related behaviours. Our data allows us to explicitly control for this possibility by including in our unawareness equation (in addition to BMI) type of healthcare provider consulted within the last 12 months, self-reported diabetes, several lifestyle variables and severity of hypertension (measured SBP). We estimate three specifications; the first controls for basic socioeconomic factors, the second adds education, the third adds lifestyle variables and employment status.

3.3 Estimating the socioeconomic gradient in hypertension control

We analyse the socioeconomic gradient in hypertension control amongst those who are aware of being hypertensive using pooled probit models of the 2008 and 2012 waves. We estimate separate models for men and women. Our dependent variable is a binary indicator that takes the value 0 if a hypertensive individual who is aware of being hypertensive has an elevated BP reading and 1 if the individual has a normotensive reading. We once again estimate three specifications; the first includes income and controls for urban vs rural residence, gender, age, race, healthcare utilization, BMI and household composition. The second adds education to the model, the third adds lifestyle variables and employment status. All specifications are estimated using sample weights and include wave and province dummies and standard errors were clustered at the individual level.

This paper uses secondary data, access to which can be requested from the University of Cape Town, no ethical approval was required.

4 Results

4.1 Socioeconomic gradient in hypertension prevalence

We present results from the FMM and OLS regressions on hypertension prevalence in Table 4. For both genders we estimated 2-component mixtures; 3-component models failed to converge after many iterations, suggesting the third component was attempting to fit a very small number of observations or outliers. We then present results from two additional specifications of the FMM model in Table 5. Finally we present determinants of the posterior probability of belonging to one of the latent classes in Table 6.

Insert Table 4 here

OLS results show that women who have completed secondary education have on average 3mmHg lower SBP than those with primary education. We find no statistically significant association between education and SBP amongst men and for women, having some secondary education. There is no statistically significant association between SBP and income for either men or women.

The FMM for men identified two latent classes (components) in proportions 0.31 and 0.69. In both components the effects of education are small in magnitude and not statistically significant. In Component 1, the smaller of the two latent classes, we see no statistically significant income effect, but in Component (2) we find a statistically significant positive ($p<0.05$) effect, but it is very small in magnitude. On average, men in Component 2 have a 1.1mmHg increase in SBP for a one log-point increase in income; this approximates to a 0.11mmHg increase in BP for a 10% increase in income. For women, we also identify two latent classes in proportions of 0.69 and 0.31. However, there is no significant income gradient in SBP in either component. We do however find a quite large education effect in the smaller Component 2. Completing secondary education (compared to primary school or less) is associated with 7mmHg lower SBP.

4.1.1 Robustness checks

We estimated an additional specification to test the robustness of our findings when controlling for waist circumference as an indicator of visceral fat (Table 5). “Normal”, "Increased" and "Substantially increased" waist circumference were defined as $waist \leq 79cm$, $80cm \leq waist \leq 88cm$ and $waist \geq 89cm$ for women, and $waist \leq 93cm$, $94cm \leq waist \leq 102cm$ and $waist \geq 103cm$ for men, respectively. Our results for income and education remain unchanged. For men and women and both components a "substantially increased" waist circumference has a significant and large effect in raising SBP. Previous studies confirm this finding, see for example Zhao et al. (2013); Case et al. (2004); Johnston et al. (2009), although most used BMI as a proxy for body fat. In further alternative specifications we included a "depression symptoms index" created from 10 questions on mental and emotional health status to test if the effect is mediated via stress. Our findings remain unchanged. Additionally, we tested alternate definitions of income including log of equivalised and per capita household income, as well as inflation adjusted real household income. We also estimated probit models on a binary outcome of being hypertensive defined as either $SBP \geq 140$ or $DBP \geq 90$. Again, our findings remain unchanged.

Insert Table 5 here

4.1.2 Membership in latent classes

We examine the determinants of membership in each of the two latent classes for our preferred specification. For men, several variables predict membership of the larger Component 2 (see Table 6), including younger age, White or Asian/Indian race, and lower waist circumference. The average age in this group is 36 years and mean SBP is close to normal at 120mmHg (as compared to 47 years and 158mmHg in Component 1).

For women, the beneficial impact of education on hypertension is seen in the smaller Component 2, and membership is predicted by older age, Black race, and lower income (Table 6). The mean age in this group is 50 years and mean SBP is 160mmHg (compared to 38 years and 118mmHg in Component 1). The WHO's SAGE study in elders also found that higher education was associated with lower hypertension prevalence (Lloyd-Sherlock et al., 2014). However, this study does not estimate models separately for men and women making it difficult to make direct comparisons.

Insert Table 6 here

4.2 Socioeconomic gradient in unawareness of hypertensive status

We now present results from the censored bivariate probit models (CBPMs) for unawareness of hypertensive status. Based on evidence mainly from high-income countries we expect a negative relationship between SES and awareness, i.e. that higher education and income levels are more aware of their status. Findings are presented as marginal effects (Table 7). All three specifications appear to be well identified, the instruments are statistically significant ($p<0.05$ in all models) and the correlation (ρ) between the two equations are positive and statistically significant. Model (1) presents the effect of income on unawareness controlling for basic socio-demographic factors, model (2) adds education, while model (3) adds lifestyle variables and employment status. All models include healthcare utilization, self-reported diabetes and measured SBP.

Insert Table 7 here

We discuss results from our preferred specification (3). Contrary to evidence from England (Johnston et al., 2009) and low-income countries (Chow et al., 2013), we find no statistically significant association between education and being unaware of hypertensive status. Our finding is confirmed by WHO's SAGE study which found that in South Africa secondary education is not significantly associated with better awareness in 3820 adults above the age of 50 (Lloyd-Sherlock et al., 2014). Chow et al. (2013) also found that better education was associated with greater awareness only in low- but not middle- or high-income countries.

We also find no significant association between income and awareness of hypertensive status. This finding is robust to different functional forms for income, including quintiles of household income, log of per capita and equivalised household income. Our results imply that unawareness of hypertension is a problem across all income levels in South Africa.

In keeping with previous studies in both LMICs and high income settings (see for example Lloyd-Sherlock et al. (2014); Johnston et al. (2009); Chow et al. (2013)) we find that men are 11 percentage points more likely to be unaware of having hypertension compared to women. We find no difference in unawareness by age or race. Individuals at higher risk of hypertension are less likely to be unaware; a one unit increase in BMI reduces the probability of unawareness by around 1 percentage point (even when controlling for lifestyle variables - smoking, alcohol consumption and exercise, which themselves are not statistically significant in the model), a result confirmed by other studies who have analysed data on BMI or obesity (Johnston et al., 2009; Lloyd-Sherlock et al., 2014). Being aware of having diabetes, a condition closely linked to hypertension, results in 28 percentage point lower probability of unawareness of hypertension.

We find that health care utilization has a large impact on the probability of being unaware. Having had no healthcare visit in the past 12 months is associated with 40 percentage points higher propensity of being unaware, compared to participants that visited a public healthcare provider. Sohn (2015) found that visiting a health facility is an effective way of increasing awareness among hypertensive patients in Indonesia. Patients attending private facilities are 14 percentage points more likely to be unaware than patients attending public facilities. This is a surprising result, and suggests that private patients are less likely to be routinely screened for elevated blood pressure. Similar findings have been shown by Van Wyk et al. (2011) in the case of tuberculosis diagnosis in South Africa.

4.2.1 Robustness checks

We first tested whether controlling for stress affects our non-significant results on SES by controlling for the "depression symptoms index". We also included several other chronic conditions that might influence the probability of unawareness, including having had a stroke, tuberculosis (which has a high prevalence in South Africa), asthma and an indicator for any other chronic condition. We further evaluated whether findings are sensitive to the cut-offs used to define high BP by estimating models using $SBP \geq 150; DBP \geq 95$ and $SBP \geq 160; DBP \geq 100$. While international guidelines typically use $SBP \geq 140$ and $DBP \geq 90$, local healthcare providers may use higher cut-offs. We further evaluated our instrument waist circumference; if individuals are knowledgeable about the medical risks of visceral and subcutaneous abdominal fat then waist circumference may directly influence unawareness. This is less likely to be the case for heart rate which individuals cannot readily observe. We therefore estimated models with heart rate as only instrument and waist circumference as a covariate. Lastly, we ran our models separately for men and women. In all of the above alternative specifications our main finding remains unchanged: there is no socioeconomic gradient in awareness.

4.3 Socioeconomic gradient in hypertension control

Table 8 presents the models for hypertension control amongst men and women. Our results are similar across the three specifications. We focus the discussion on our full specification (3) and (6). Education has a large positive association with the likelihood of hypertension control amongst women (6). Having completed secondary education is associated with 22.3 percentage point higher likelihood of controlled BP compared to those with primary education or less. We however do not find a statistically significant association between education and hypertension control amongst men (3). The finding of a positive association is consistent with the SAGE study in South Africa (Lloyd-Sherlock et al., 2014). Case et al. (2004) did not find education to be predictive of hypertension control in their Khayelitsha township sample in South Africa.

Insert Table 8 here

We find income has a positive and quite large association with hypertension control amongst men. One log-point increase in income is associated with 10.7 percentage point higher probability of controlled hypertension. But this is not the case for women where we see weak and small associations. Our findings are robust to alternate functional forms of income. The positive income gradient in hypertension control (across genders) is consistent with the findings of Lloyd-Sherlock et al. (2014) and Zhao et al. (2013). We also find that employment status is not associated with hypertension control in men but is associated with a 9.9 percentage point lower likelihood amongst women.

For men, we find no meaningful association between race, urban/rural residence, household composition, having diabetes, and healthcare utilisation in the last 12 months. We do however find that compared to those who did not drink at all, moderate drinking was associated with a 14 percentage point lower probability of controlling BP.

Amongst our sample of women a one unit increase in BMI is associated with a 5 percentage point lower probability of hypertension control. Higher age was associated with a small (3 percentage point) and weak (10% significance) reduction in likelihood of having controlled hypertension. While we find no association between 3 or more alcoholic drinks per week and probability of hypertension control for men and a large negative association for women, we are concerned that these results are driven by small sample sizes in this group and therefore should be interpreted with caution. The same applies to the co-efficients on Asian/Indian race where the sample sizes are small.

4.3.1 Robustness checks

Our results for the socioeconomic gradient in hypertension control are robust to the inclusion of the "depression symptoms index", waist circumference described earlier and categorised as "'Normal"', "'Increased"' or "'Substantially increased"' and the inclusion of other self reported health conditions - including having had a stroke, tuberculosis, asthma and an indicator for any other chronic condition.

5 Conclusion

This study investigates the existence and direction of a socioeconomic gradient in hypertension prevalence, unawareness and control in South Africa, using a national income survey with detailed socioeconomic information and measured hypertension status. We allow for heterogeneity in the gradient across subgroups of the population by using a finite mixture model. The advantage of this approach is that it allows us to take account of South Africa's complex patterns of social norms and individual preferences that defy traditional delineations according to race or other easily observable factors. We test the hypothesis that advantaged individuals are more likely to be aware of having a chronic health condition, adjusting for censoring of hypertension awareness using a censored bivariate probit model. Finally, we analysed the socioeconomic gradient in effective hypertension control.

We recognise that our study suffers from potential limitations. BP readings typically vary from one day to the next, and there is the possibility that readings are affected by white coat syndrome or other influences. However, we expect that these influences are randomly distributed across participants of our study, and therefore do not systematically bias estimates. It is possible that statistics on unawareness and control that are derived from survey responses are affected by intentional or unintentional misreporting of health conditions that respondents are actually aware of.

Our analysis explicitly tests the hypothesis of a positive socioeconomic gradient for hypertension in South Africa that was originally put forward by Case et al. (2004). We find a very small positive income gradient that is unlikely to represent a meaningful result amongst South African men who are likely to be younger and of White or Asian race. In the case of women there is no evidence of an income gradient, but a positive gradient with respect to secondary education in a small sub-group of women. Zhao et al. (2013) show that in the absence of perfect information, the extent to which individuals invest in health depends on the accuracy with which they are able to observe their level of existing health capital. Our analysis of unawareness shows that it is a major problem in South Africa with 56% of hypertensive individuals remaining unaware. We further find no evidence of a socioeconomic gradient in unawareness, which implies that it is a public health problem across all socioeconomic groups. This differs from the finding of Lloyd-Sherlock et al. (2014) but their data only allowed them to consider the 50 plus cohort. We find high levels of uncontrolled hypertension (30%) and find a large positive education gradient in hypertension control amongst women and a smaller but meaningful positive income gradient among men, suggesting that the socioeconomic gradient may play more of a role in hypertension control.

While it may be seen as a positive conclusion that there is little evidence of socioeconomic bias in hypertension prevalence and unawareness, of great concern are the high levels of uncontrolled hypertension and effective control being concentrated amongst richer and more educated individuals. The message may rather be that there is little evidence that either the public or the private system is performing adequately in the most important part of the hypertension management cascade. Given that hypertension has a high prevalence in South Africa, it is clear that hypertension prevention, awareness and control require more prominence.

References

Bates, I., Fenton, C., Gruber, J., Lalloo, D., Lara, A. M., Squire, S. B., Theobald, S., Thomson, R., Tolhurst, R., 2004. Vulnerability to malaria, tuberculosis, and hiv/aids infection and disease. part 1: determinants operating at individual and household level. The Lancet Infectious Diseases 4 (5), 267 – 277.

Case, A., Le Roux, I., Menendez, A., 2004. Medical compliance and income-health gradients. American Economic Review 94 (2), 331–335.

Cesare, M. D., Khang, Y.-H., Asaria, P., Blakely, T., Cowan, M. J., Farzadfar, F., Guerrero, R., Ikeda, N., Kyobutungi, C., Msyamboza, K. P., Oum, S., Lynch, J. W., Marmot, M. G., Ezzati, M., 2013. Inequalities in non-communicable diseases and effective responses. The Lancet 381 (9866), 585 – 597.

Chatterji, P., Joo, H., Lahiri, K., 2012. Beware of being unaware: Racial/ethnic disparities in chronic illness in the usa. Health Economics 21 (9), 1040–1060.

Chow, C. K., Teo, K. K., Rangarajan, S., Islam, S., Gupta, R., et al., 2013. Prevalence, awareness, treatment, and control of hypertension in rural and urban communities in high-, middle-, and low-income countries. JAMA 310 (9), 959–68.

Deb, P., Gallo, W. T., Ayyagari, P., Fletcher, J. M., Sindelar, J. L., March 2011. The effect of job loss on overweight and drinking. Journal of Health Economics 30 (2), 317–327.

Deb, P., Trivedi, P. K., July 2002. The structure of demand for health care: latent class versus two-part models. Journal of Health Economics 21 (4), 601–625.

Desprs, J.-P., 2012. Body fat distribution and risk of cardiovascular disease: An update. Circulation 126 (10), 1301–1313.

Fang, J., Madhavan, S., Cohen, H., Alderman, M. H., 1995. Isolated diastolic hypertension: A favorable finding among young and middle-aged hypertensive subjects. Hypertension 26 (3), 377–382.

Gaziano, T. A., Bitton, A., Anand, S., Abrahams-Gessel, S., Murphy, A., 2010. Growing epidemic of coronary heart disease in low- and middle-income countries. Curr Probl Cardiol 35 (2), 72–115.

Guagnano, M. T., Ballone, E., Colagrande, V., Della Vecchia, R., Manigrasso, M. R., Merlitti, D., Riccioni, G., Sensi, S., 2001. Large waist circumference and risk of hypertension. Int J Obes Relat Metab Disord 25 (9), 1360–4.

Horton, S., Gelband, H., Jamison, D., Levin, C., Nugent, R., Watkins, D., 08 2017. Ranking 93 health interventions for low- and middle-income countries by cost-effectiveness. PLOS ONE 12 (8), 1–12.

Hosseinpoor, A. R., Bergen, N., Mendis, S., Harper, S., Verdes, E., Kunst, A., Chatterji, S., 2012. Socioeconomic inequality in the prevalence of noncommunicable diseases in low- and middle-income countries: Results from the world health survey. BMC Public Health 12 (1), 1–13.

Janssen, I., Heymsfield, S. B., Allison, D. B., Kotler, D. P., Ross, R., 2002. Body mass index and waist circumference independently contribute to the prediction of nonabdominal, abdominal subcutaneous, and visceral fat. The American Journal of Clinical Nutrition 75 (4), 683–688.

Johnston, D. W., Propper, C., Shields, M. A., 2009. Comparing subjective and objective measures of health: Evidence from hypertension for the income/health gradient. Journal of Health Economics 28 (3), 540–552, 453YJ Times Cited:39 Cited References Count:41.

Kannel, W., 2000. Elevated systolic blood pressure as a cardiovascular risk factor. American Journal of Cardiology, 251–255.

Lei, X., Yin, N., Zhao, Y., 2012. Socioeconomic status and chronic diseases: The case of hypertension in china. China Economic Review 23 (1), 105–121.

Leibbrandt, M., Woolard, I., de Villiers, L., 2009. Methodology: Report on nids wave 1. Tech. rep., Southern African Labour & Development Research Unit.

Lim, S. S., Vos, T., Flaxman, A. D., Danaei, G., Shibuya, K., Adair-Rohani, H., et al., 2012. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the global burden of disease study 2010. Lancet 380 (9859), 2224–60.

Lloyd-Sherlock, P., Beard, J., Minicuci, N., Ebrahim, S., Chatterji, S., 2014. Hypertension among older adults in low- and middle-income countries: prevalence, awareness and control. International Journal of Epidemiology 43 (1), 116–128.

Murphy, G. A., Asiki, G., Ekoru, K., Nsubuga, R. N., Nakiyingi-Miiro, J., Young, E. H., Seeley, J., Sandhu, M. S., Kamali, A., 2013. Sociodemographic distribution of non-communicable disease risk factors in rural uganda: a cross-sectional study. International Journal of Epidemiology 42 (6), 1740–1753.

Palatini, P., 2011. Role of elevated heart rate in the development of cardiovascular disease in hypertension. Hypertension 58 (5), 745–50.

Palatini, P., Dorigatti, F., Zaetta, V., Mormino, P., Mazzer, A., Bortolazzi, A., D'Este, D., Pegoraro, F., Milani, L., Mos, L., 2006. Heart rate as a predictor of development of sustained hypertension in subjects screened for stage 1 hypertension: the harvest study. Journal of Hypertension 24 (9), 1873–1880.

Reule, S., Drawz, P. E., 2012. Heart rate and blood pressure: any possible implications for management of hypertension? Curr Hypertens Rep 14 (6), 478–84.

SALDRU, 2015. National income dynamics study 2012, wave 3. Tech. rep., Southern Africa Labour and Development Research Unit.

Sartorius, B., Veerman, L. J., Manyema, M., Chola, L., Hofman, K., 06 2015. Determinants of obesity and associated population attributability, south africa: Empirical evidence from a national panel survey, 2008-2012. PLOS ONE 10 (6), 1–20.

Sohn, K., 2015. Sick but unaware: Hypertension in indonesia. Biodemography and Social Biology 61 (3), 298–318.

Spence, D. P., Hotchkiss, J., Williams, C. S., Davies, P. D., 1993. Tuberculosis and poverty. BMJ 307 (6907), 759–761.

Van de Ven, W. P. M. M., van Praag, B., 1981. The demand for deductibles in private health insurance: A probit model with sample selection. Journal of Econometrics 17 (2), 229–252.

Van Wyk, S. S., Enarson, D. A., Beyers, N., Lombard, C., Hesseling, A. C., 2011. Consulting private health care providers aggravates treatment delay in urban south african tuberculosis patients. International Journal of Tuberculosis and Lung Disease 15 (8), 1069–76.

Vellakkal, S., Subramanian, S. V., Millett, C., Basu, S., Stuckler, D., Ebrahim, S., 07 2013. Socioeconomic inequalities in non-communicable diseases prevalence in india: Disparities between self-reported diagnoses and standardized measures. PLoS ONE 8 (7), 1–12.

Witoelar, F., Strauss, J., Sikoki, B., 2009. Socioeconomic success and health in later life: Evidence from the indonesia family life survey.

World Health Organisation, a., 2014. Global status report on noncommunicable diseases 2014. Tech. rep., World Health Organisation,.

Zhao, M., Konishi, Y., Paul, G., 2013. Does information on health statys lead to a healthier lifestyle? evidence from china on the effect of hypertension diagnosis on food consumption. Journal of Health Economics, 367–385.

Tables

Table 1: Sample means of covariates included in the models

	Sample means	
	FMM (2008 and 2012)	CBPM 2008
Annual household income	66392.1	54934.1
Age	39.9	40.4
Male	39.7%	39.8%
Primary school or less	28.8%	33.1%
Some secondary school	45.6%	43.4%
Completed secondary school	25.6%	23.4%
Black	80.8%	79.8%
Mixed	14.1%	13.8%
Asian/Indian	1.1 %	1.2%
White	5.4%	5.2%
Married	29.4%	31.3%
Not economically active	40.8%	36.8%
Unemployed not looking for work	4.2%	6.7%
Unemployed looking for work	14.9%	13.4%
Employed	40.1%	43.2%
Number of children 5 years and under in HH	0.68	0.64
Number of children 6 to 15 years in HH	1.14	1.1
Number of adults over 15 years in HH	3.38	3.24
No healthcare consultation in last 12 mths	56.3%	50.9%
Consulted public provider in last 12 months	29.5%	32.8%
Consulted private provider in last 12 months	14.2%	16.3%
BMI	26.65	26.24
Normal waist circumference	46.0%	49.3%
Increased waist circumference	16.2%	16.0%
Substantially increased waist circumference	37.8%	34.8%
Rural formal	10.5%	11.6%
Tribal Authority Area	40.6%	40.8%
Urban formal	41.9%	41.3%
Urban informal	7.0%	6.3%
Current smoker	20.8%	22.9%
Non-drinker	77.3%	74.2%
Drinks less than 3 times per week	22.5%	22.3%
Drinks 3 or more times per week	3.4%	3.5%
Average pulse		76.12
Diagnosed with diabetes		4.4 %
N	25,796	10,509

Table 2: Age standardized prevalence of total and uncontrolled hypertension

	Total hypertension		Uncontrolled hypertension	
	2008	2012	2008	2012
Overall	0.36	0.35	0.31	0.30
Men	0.34	0.34	0.31	0.28
African	0.34	0.34	0.31	0.30
Mixed	0.40	0.41	0.37	0.36
Asian	0.29	0.38	0.25	0.31
White	0.31	0.29	0.27	0.25
Women	0.38	0.35	0.32	0.30
African	0.38	0.35	0.32	0.28
Mixed	0.42	0.42	0.35	0.35
Asian/Indian	0.31	0.33	0.27	0.27
White	0.30	0.31	0.25	0.22

Table 3: Self-reported and measured hypertension, summary statistics 2008

	2008
Proportion self-reporting hypertension as an illness	0.16
Proportion unaware: self-reporting having never been diagnosed with high blood pressure, but measured SBP>=140 or DBP>=90	0.59
Missed opportunities: Proportion being unaware that had healthcare consultation in the last 12 months	0.42

Table 4: OLS and Finite mixture model for systolic blood pressure

	(1)	(2)	(3)		(4)	
	OLS men	OLS women	FMM - Men		FMM - Women	
			component1	component2	component1	component2
Log of household income	0.288	-0.406	-1.574	1.100***	-0.078	-0.466
	(0.379)	(0.323)	(1.004)	(0.403)	(0.367)	(0.854)
Some secondary school	0.865	-1.656	2.170	0.362	-1.113	-2.704
	(0.930)	(0.859)	(2.434)	(0.950)	(1.029)	(2.283)
Completed secondary school	1.111	-3.744***	4.211	-0.228	-1.780	-7.333***
	(1.151)	(0.981)	(3.388)	(1.078)	(1.130)	(2.352)
Age	0.423***	0.619***	1.209***	0.247**	0.359***	1.401**
	(0.109)	(0.094)	(0.325)	(0.118)	(0.133)	(0.578)
Age squared	0.001	0.001	-0.002	-0.000	0.000	-0.003
	(0.001)	(0.001)	(0.003)	(0.001)	(0.002)	(0.005)
Mixed	-0.419	1.737	-1.638	0.209	0.683	2.059
	(1.387)	(1.297)	(3.460)	(1.379)	(1.244)	(2.885)
Asian/Indian	-1.220	-0.670	-6.658	2.984	1.378	-6.575
	(2.111)	(2.057)	(6.289)	(2.721)	(3.139)	(3.631)
White	-3.940***	-2.996	-10.728***	1.005	-1.529	-4.276
	(1.397)	(1.756)	(3.568)	(1.506)	(2.388)	(5.861)
Married	-1.191	1.294	-2.869	-0.847	0.672	2.149
	(0.898)	(0.693)	(2.439)	(0.906)	(0.667)	(1.528)
No healthcare consultation in last 12 mths	0.921	0.140	3.294	0.611	1.469**	-1.292
	(0.747)	(0.601)	(2.040)	(0.872)	(0.614)	(1.777)
Consulted private provider in last 12 months	0.502	-1.934**	3.576	-0.383	-1.352	-1.316
	(1.076)	(0.870)	(2.572)	(1.202)	(0.848)	(1.976)
Number of children 5 years and under in HH	-0.488	-0.576**	-1.014	-0.174	-0.745***	-0.048
	(0.350)	(0.255)	(0.956)	(0.359)	(0.254)	(0.659)
Number of children 6 to 15 years in HH	-0.181	-0.194	-0.146	-0.058	-0.231	-0.098
	(0.257)	(0.204)	(0.806)	(0.291)	(0.348)	(1.068)
Number of adults over 15 years in HH	-0.145	0.058	0.720	-0.513***	-0.087	0.143
	(0.172)	(0.157)	(0.412)	(0.198)	(0.184)	(0.409)
Tribal Authority Area	-1.692	-2.599***	-5.850**	-0.331	-2.393**	-1.918
	(0.991)	(0.944)	(2.756)	(1.002)	(1.098)	(2.118)
Urban formal	0.383	-0.603	0.267	-0.119	-1.912	0.022
	(1.039)	(0.948)	(2.621)	(1.062)	(1.174)	(2.730)
Urban informal	-1.904	-0.381	-8.800**	0.383	-2.228	2.214
	(1.292)	(1.284)	(3.450)	(1.476)	(1.641)	(5.388)
Current smoker	-1.165	1.136	-1.145	-1.145	1.283	1.987
	(0.693)	(1.284)	(1.715)	(0.696)	(1.495)	(2.525)
Drinks less than 3 times per week	2.003***	0.520	1.390	2.045***	1.296	-0.585
	(0.664)	(0.827)	(1.828)	(0.665)	(1.003)	(1.803)
Drinks 3 or more times per week	0.446	-1.802	1.080	0.572	2.036	-8.685**
	(1.327)	(1.927)	(3.018)	(1.458)	(2.151)	(4.349)
π			0.31	0.69	0.69	0.31
Observations	10418	15896	10418		15896	

Robust standard errors in parentheses. Models also include survey year and province of residence dummies

Omitted categories:primary school or less, black, not married, consulted public provider in last 12 months, rural formal, non-smoker, non-drinker

π is the probability of being in one of the components. ** p<0.05, *** p<0.01

Table 5: Finite mixture model for systolic blood pressure - main specification

	(1)		(2)	
	FMM-Men		FMM-Women	
	component1	component2	component1	component2
Log of household income	-2.034	0.788**	-0.236	-0.501
	(1.060)	(0.392)	(0.403)	(0.961)
Some secondary school	2.000	-0.168	-1.167	-3.365
	(2.557)	(0.929)	(0.868)	(1.814)
Completed secondary school	3.995	-0.770	-1.516	-7.849***
	(3.474)	(1.061)	(1.011)	(2.233)
Age	1.087***	0.202	0.185	1.070***
	(0.331)	(0.119)	(0.115)	(0.369)
Age squared	-0.001	-0.000	0.002	-0.000
	(0.003)	(0.001)	(0.001)	(0.004)
Mixed	-1.628	-0.455	0.716	2.302
	(3.690)	(1.265)	(1.185)	(2.605)
Asian/Indian	-6.738	1.683	1.042	-4.820
	(7.144)	(2.550)	(3.064)	(3.364)
White	-12.096***	0.143	-0.593	-5.005
	(3.429)	(1.469)	(2.018)	(4.153)
Married	-3.920	-1.539	0.086	1.440
	(2.437)	(0.899)	(0.669)	(1.536)
No healthcare consultation in last 12 mths	3.357	0.654	1.416**	-0.944
	(2.058)	(0.878)	(0.607)	(1.582)
Consulted private provider in last 12 months	3.713	-0.653	-1.340	-1.597
	(2.635)	(1.188)	(0.856)	(2.050)
Number of children 5 years and under in HH	-0.577	-0.178	-0.859***	-0.119
	(0.953)	(0.356)	(0.251)	(0.603)
Number of children 6 to 15 years in HH	-0.197	-0.012	-0.203	-0.324
	(0.813)	(0.288)	(0.246)	(0.636)
Number of adults over 15 years in HH	0.639	-0.497**	-0.067	0.201
	(0.411)	(0.197)	(0.149)	(0.311)
Tribal Authority Area	-6.215**	0.126	-2.505**	-1.256
	(2.839)	(1.000)	(1.118)	(1.952)
Urban formal	0.118	-0.229	-2.242**	0.756
	(2.703)	(1.037)	(1.119)	(2.273)
Urban informal	-9.050**	0.395	-2.475	2.061
	(3.537)	(1.453)	(1.659)	(4.790)
Increased waist circumference	3.078	4.592***	1.926***	1.555
	(2.839)	(1.077)	(0.699)	(1.557)
Substantially increased waist circumference	9.396***	7.948***	5.609***	7.225***
	(2.641)	(1.076)	(0.687)	(1.861)
Current smoker	-0.502	-0.480	1.404	2.121
	(1.700)	(0.688)	(1.553)	(2.349)
Drinks less than 3 times per week	1.156	1.775***	1.314	0.197
	(1.851)	(0.661)	(1.064)	(1.902)
Drinks 3 or more times per week	0.931	0.503	2.739	-5.490
	(2.837)	(1.502)	(2.221)	(4.725)
π	0.30	0.70	0.68	0.32
N	10289		15632	

Robust standard errors in parentheses. Models also include survey year and province of residence dummies

Omitted categories:primary school or less, black, not married, consulted public provider in last 12 months, normal waist circumference, rural formal, non-smoker, non-drinker

π is the probability of being in one of the components. ** p<0.05, *** p<0.01

Table 6: Determinants of the posterior probability of being in Component 2 for systolic blood pressure - Men and Women.

	(1)		(2)	
	Probability of being in Component 2 - Men		Probability of being in Component 2 - Women	
Log of household income	0.029	(0.020)	-0.052***	(0.017)
Some secondary school	-0.039	(0.043)	0.017	(0.035)
Completed secondary school	-0.019	(0.055)	-0.039	(0.047)
Age	-0.031***	(0.005)	0.062***	(0.004)
Age squared	0.000**	(0.000)	-0.000***	(0.000)
Mixed	-0.127	(0.065)	0.101	(0.056)
Asian/Indian	0.721***	(0.215)	-0.137	(0.127)
White	0.261***	(0.089)	-0.190**	(0.082)
Married	-0.016	(0.041)	0.054	(0.030)
No healthcare consultation in last 12 mths	0.030	(0.037)	-0.099***	(0.027)
Consulted private provider in last 12 months	0.010	(0.052)	-0.015	(0.039)
Number of children 5 years and under in HH	0.046**	(0.021)	0.033**	(0.014)
Number of children 6 to 15 years in HH	0.005	(0.015)	0.018	(0.010)
Number of adults over 15 years in HH	-0.019	(0.011)	0.005	(0.008)
Tribal Authority Area	0.072	(0.057)	-0.056	(0.048)
Urban formal	0.050	(0.054)	0.023	(0.047)
Urban informal	0.050	(0.077)	0.027	(0.064)
Increased waist circumference	-0.125***	(0.047)	0.018	(0.039)
Substantially increased waist circumference	-0.163***	(0.051)	0.041	(0.033)
Current smoker	-0.054	(0.037)	0.025	(0.047)
Drinks less than 3 times per week	-0.054	(0.035)	0.057	(0.040)
Drinks 3 or more times per week	-0.108	(0.063)	-0.111	(0.110)
N	10289		15632	

Robust standard errors in parentheses. Models also include survey year and province of residence dummies

Omitted categories:primary school or less, black, not married, consulted public provider in last 12 months, rural formal, normal waist circumference, non-smoker, non-drinker.

** p<0.05, *** p<0.01

Table 7: Censored bivariate probit selection models of unawareness of being hypertensive - marginal effects

	(1)		(2)		(3)	
	ME	SE	ME	SE	ME	SE
Log of household income	0.009	(0.018)	-0.003	(0.018)	-0.002	(0.019)
Male	0.108***	(0.032)	0.105***	(0.032)	0.116***	(0.032)
Mixed	-0.098	(0.057)	-0.093	(0.056)	-0.102	(0.059)
Asian/Indian	0.008	(0.134)	-0.001	(0.136)	0.004	(0.141)
White	-0.086	(0.074)	-0.112	(0.075)	-0.116	(0.075)
No healthcare consultation in last 12 months	0.390***	(0.061)	0.383***	(0.061)	0.396***	(0.049)
Consulted private provider in last 12 months	0.132***	(0.044)	0.121***	(0.042)	0.131***	(0.042)
Age	-0.005	(0.005)	-0.003	(0.005)	-0.005	(0.005)
Number of children 5 years and under in HH	-0.030	(0.018)	-0.028	(0.018)	-0.022	(0.018)
Number of children 6 to 15 years in HH	-0.006	(0.013)	-0.006	(0.013)	-0.010	(0.012)
Number of adults over 15 years in HH	-0.006	(0.010)	-0.004	(0.010)	-0.003	(0.010)
Average systolic BP	0.002**	(0.001)	0.002**	(0.001)	0.002***	(0.001)
Has diabetes (diagnosed)	-0.270***	(0.070)	-0.269***	(0.067)	-0.282***	(0.065)
BMI	-0.009***	(0.003)	-0.009***	(0.003)	-0.011***	(0.003)
Tribal Authority Area	0.083	(0.048)	0.077	(0.048)	0.082	(0.050)
Urban formal	0.068	(0.047)	0.055	(0.048)	0.066	(0.049)
Urban informal	0.048	(0.068)	0.047	(0.068)	0.037	(0.070)
Some secondary school			0.034	(0.033)	0.029	(0.034)
Completed secondary school			0.096	(0.053)	0.098	(0.052)
Smoker					0.016	(0.045)
Drinks less than 3 times per week					-0.033	(0.044)
Drinks 3 or more times per week					-0.051	(0.076)
Unemployed not looking for work					0.056	(0.073)
Unemployed looking for work					-0.065	(0.052)
Employed					-0.021	(0.033)
Rho	0.63		0.65		0.60	
Wald test (Rho=0) Chi-squared(1)	4.05		4.72		4.24	
p-value	0.04		0.03		0.04	
Test of first stage instrument power Chi-squared(2)	41.09		40.33		41.27	
N	10613		10613		10509	

Robust standard errors in parentheses. Model also includes a quadratic term for age.

Omitted categories:female, black, not married, consulted public provider in last 12 months, not diagnosed with diabetes. rural formal, primary school or less, non-smoker, non-drinker, not economically active.

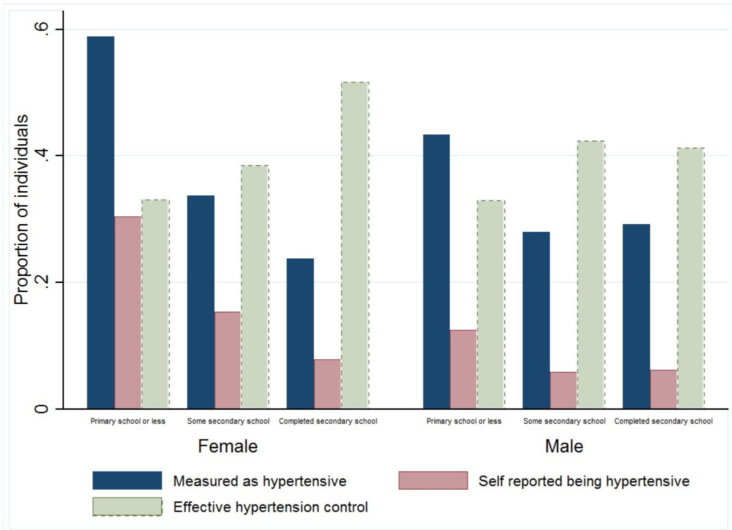
** p<0.05, *** p<0.01

Table 8: Pooled probit models of the socioeconomic gradient in hypertension control - marginal effects

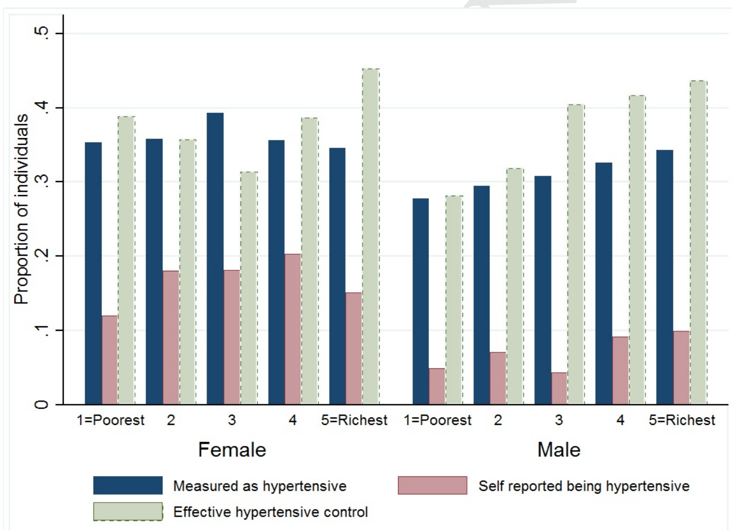
	Men			Women		
	(1)	(2)	(3)	(4)	(5)	(6)
Log of household income	0.068	0.098**	0.107***	0.043	0.018	0.032
	(0.039)	(0.042)	(0.041)	(0.023)	(0.024)	(0.024)
Male						
Mixed	-0.045	-0.020	-0.005	0.051	0.064	0.066
	(0.082)	(0.082)	(0.085)	(0.067)	(0.067)	(0.071)
Asian/Indian	0.243	0.236	0.251	-0.173	-0.193	-0.236***
	(0.181)	(0.182)	(0.171)	(0.107)	(0.100)	(0.082)
White	0.145	0.144	0.207	0.108	0.058	0.054
	(0.120)	(0.119)	(0.119)	(0.097)	(0.097)	(0.098)
No healthcare consultation in last 12 months	0.015	-0.001	-0.013	-0.059	-0.073	-0.065
	(0.079)	(0.078)	(0.081)	(0.041)	(0.040)	(0.040)
Consulted private provider in last 12 months	-0.080	-0.083	-0.085	0.007	-0.018	-0.005
	(0.083)	(0.083)	(0.085)	(0.044)	(0.045)	(0.044)
Age	-0.001	-0.001	-0.004	-0.003**	-0.002	-0.003
	(0.003)	(0.003)	(0.003)	(0.001)	(0.001)	(0.002)
Age squared						
Number of children 5 years and under in HH	0.024	0.028	0.004	-0.001	-0.002	-0.004
	(0.041)	(0.041)	(0.039)	(0.020)	(0.020)	(0.021)
Number of children 6 to 15 years in HH	-0.009	-0.009	-0.013	-0.010	-0.010	-0.012
	(0.025)	(0.025)	(0.025)	(0.013)	(0.013)	(0.013)
Number of adults over 15 years in HH	0.014	0.008	0.005	0.011	0.019	0.018
	(0.018)	(0.019)	(0.019)	(0.012)	(0.013)	(0.012)
Has diabetes (diagnosed)	0.025	0.026	-0.025	-0.005	-0.011	-0.026
	(0.087)	(0.087)	(0.082)	(0.042)	(0.042)	(0.041)
BMI	-0.006	-0.005	-0.006	-0.004	-0.004	-0.005**
	(0.005)	(0.005)	(0.005)	(0.002)	(0.002)	(0.002)
Tribal Authority Area	0.052	0.050	0.002	0.109**	0.096	0.072
	(0.114)	(0.112)	(0.119)	(0.053)	(0.054)	(0.054)
Urban formal	-0.073	-0.073	-0.098	-0.003	-0.031	-0.049
	(0.104)	(0.102)	(0.104)	(0.054)	(0.053)	(0.054)
Urban informal	0.092	0.088	0.015	0.026	0.008	-0.020
	(0.138)	(0.135)	(0.138)	(0.070)	(0.072)	(0.072)
Some secondary school		0.059	0.059		0.053	0.049
		(0.064)	(0.065)		(0.034)	(0.035)
Completed secondary school		-0.077	-0.104		0.200***	0.223***
		(0.098)	(0.093)		(0.062)	(0.063)
Smoker			-0.066			-0.039
			(0.065)			(0.077)
Drinks less than 3 times per week			-0.139**			-0.029
			(0.060)			(0.058)
Drinks 3 or more times per week			0.003			-0.323***
			(0.130)			(0.062)
Unemployed not looking for work			0.116			0.025
			(0.144)			(0.093)
Unemployed looking for work			-0.000			0.032
			(0.113)			(0.074)
Employed			-0.050			-0.099**
			(0.088)			(0.039)
N	883	881	875	2691	2691	2673

Robust standard errors in parentheses. Model also includes a quadratic term for age.
Omitted categories:female, black, not married, consulted public provider in last 12 months, not diagnosed with diabetes. rural formal, primary school or less, non-smoker, non-drinker, not economically active.
** $p<0.05$, *** $p<0.01$

Figures



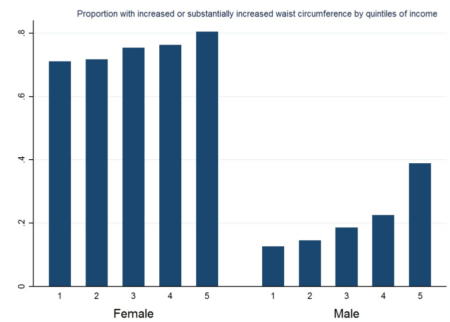
(a) Education gradient



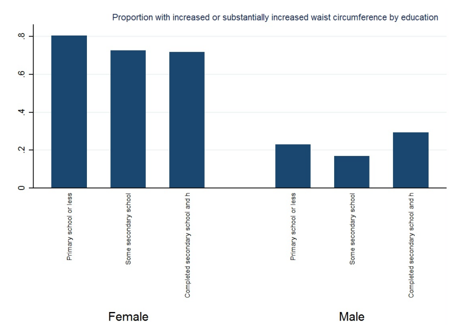
(b) Income gradient

Figure 1: Proportion with measured hypertension, self-reporting hypertensive and effective hypertension control

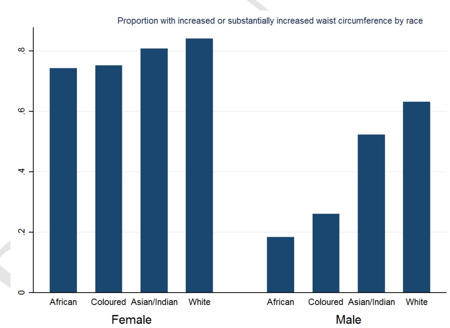
Appendix



(a) Waist circumference and income

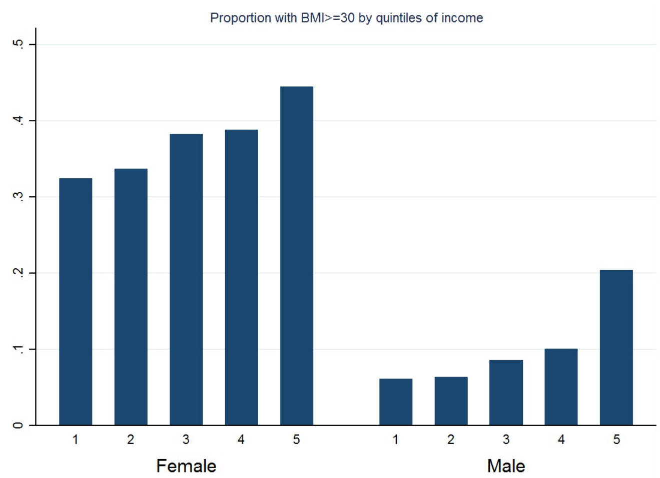


(b) Waist circumference and education

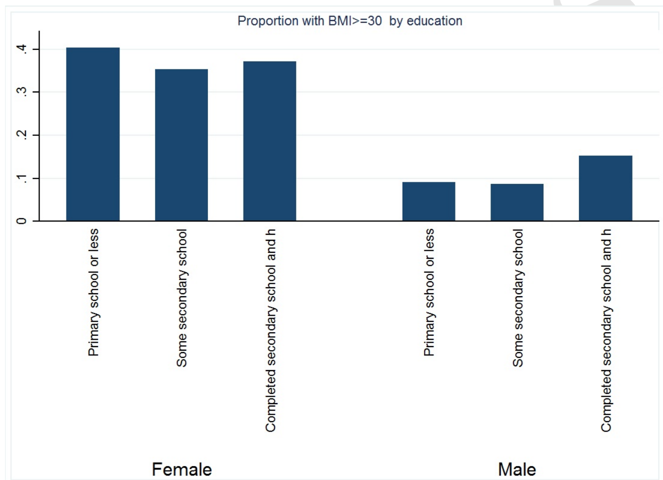


(c) Waist circumference and race

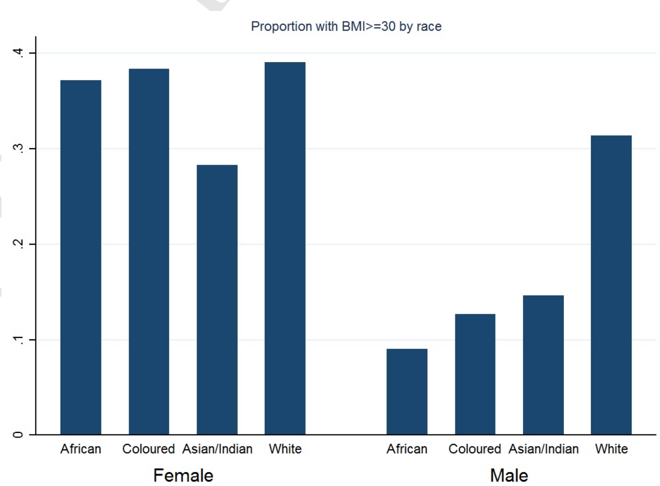
Figure 2: Proportion with ”increased” or ”substantially increased” waist circumference



(a) BMI and income



(b) BMI and education



(c) BMI and race

Figure 3: Proportion with BMI >=30

Research Highlights

- South Africa has a high prevalence of hypertension amongst men and women
- 59% of those who are hypertensive are unaware of their status
- This is no socioeconomic gradient in hypertension prevalence and unawareness
- Higher income is associated with greater effective control amongst men
- Higher education is associated with greater effective control amongst women