BMJ Open

Hypertension incidence among middle-aged and older adults: Findings from a 5-year prospective study in rural South Africa, 2010-2015

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2021-049621
Article Type:	Original research
Date Submitted by the Author:	09-Feb-2021
Complete List of Authors:	Houle , Brian ; Australian National University, School of Demography; University of the Witwatersrand Faculty of Health Sciences Gaziano, Thomas A.; Harvard University Angotti, Nicole; University of the Witwatersrand Faculty of Health Sciences; American University, Department of Sociology Mojola, Sanyu A; Princeton University, Department of Sociology Kabudula, Chodziwadziwa; University of the Witwatersrand School of Public Health, MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt), Tollman, Stephen; University of the Witwatersrand; Umea University Gómez-Olivé, F. Xavier; University of the Witwatersrand School of Public Health, MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt); Harvard University, Center for Population and Development Studies
Keywords:	Hypertension < CARDIOLOGY, PUBLIC HEALTH, HIV & AIDS < INFECTIOUS DISEASES, EPIDEMIOLOGY

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Hypertension incidence among middle-aged and older adults: Findings from a 5-year prospective study in rural South Africa, 2010-2015

Brian Houle,[1,2,3] Thomas Gaziano,[4,5] Nicole Angotti,[2,3,6] Sanyu A Mojola,[7] Chodziwadziwa W Kabudula,[2,8] Stephen M Tollman,[2,8,9] F Xavier Gómez-Olivé[2,8,10]

1 School of Demography, The Australian National University, Canberra, ACT, Australia

2 MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt), School of Public Health, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa

3 Institute of Behavioral Science, University of Colorado Boulder, Boulder, Colorado, USA

4 Division of Cardiovascular Medicine, Brigham and Women's Hospital, Boston, MA, USA

5 Harvard Medical School, Harvard University, Boston, MA, USA

6 Department of Sociology and Center on Health, Risk and Society, American University, Washington, DC, USA

7 Department of Sociology and Woodrow Wilson School of Public and International Affairs, and Office of Population Research, Princeton University, Princeton, NJ, USA

8 INDEPTH Network, Accra, Ghana

9 Centre for Global Health Research, Umeå University, Umeå, Sweden

10 Harvard Center for Population and Development Studies, Harvard University, Cambridge, MA, USA

Correspondence to: Brian Houle; brian.houle@anu.edu.au

Word count: 3,045

ABSTRACT

Objectives: There have been urgent calls for longitudinal cohort studies in sub-Saharan Africa to understand the epidemiology of cardiovascular disease as a basis for intervention. We estimated incident hypertension and associated sociodemographic, health and behavioural risk factors in a population aged 40 and older over a 5-year period.

Design: We assessed the association between incident hypertension and sociodemographic, health and behavioural factors using Poisson regression. We adjusted for nonresponse in 2015 using inverse probability sampling weights from a logistic regression including sex and age at baseline.

Setting: Rural South Africa.

Participants: We used a population-based cohort of normotensive adults in 2010 who were ages 40 and older at retest in 2015.

Results: Of 676 individuals completing baseline and 5-year follow-up, there were 193 incident cases of hypertension. The overall hypertension incidence rate was 8.374/100 person-years. In multivariable analyses, those that became hypertensive were more likely to have a high waist circumference (incidence rate ratio (IRR): 1.557 95% CI: 1.074-2.259) and be employed (IRR: 1.579 95% CI 1.071-2.329) at baseline. Being HIV-positive (regardless of antiretroviral therapy status) at baseline was inversely associated with incident hypertension.

Conclusions: Over a 5-year period, 29% of respondents developed hypertension. As the burden of hypertension continues to increase in sub-Saharan Africa, this study provides evidence of modifiable risk factors in a poor, rural South African setting to inform public health prevention strategies and programs. Continued longitudinal follow-up is needed to understand the complex interplay of noncommunicable and infectious diseases and their underlying and modifiable risk factors.

Keywords: Hypertension; incidence; South Africa; rural population; cohort

Strengths and limitations of this study

- In response to the urgent call for longitudinal sub-Saharan African studies, we provide longitudinal evidence on hypertension incidence from a population-based cohort in rural South Africa.
- Our results that being HIV-positive was inversely related to increased BP may be sensitive to survivorship bias if those who died due to HIV/AIDS over the five-year period were also more likely to develop hypertension.
- A longer period of follow-up is needed to assess the effects of HIV and ART on hypertension and related cardiometabolic conditions.

INTRODUCTION

Hypertension is one of the most important noncommunicable disease (NCD) risk factors and the largest contributor to the global burden of disease, with high blood pressure accounting for 7% of global disability-adjusted life years.[1] The burden of hypertension is greatest in low and middle-income countries (LMIC),[2] and has increased rapidly in sub-Saharan Africa.[3–7] A study of people aged 50 years and over from six countries found markedly high prevalence in South Africa (77.9%).[8]

Rapid demographic and epidemiological changes in LMICs, such as population aging, are expected to dramatically increase hypertension prevalence. Results from a modelling study found that without any changes in the age-specific prevalence of hypertension, the hypertensive population in South Africa is expected to grow by 105% by 2050.[9] These dramatic changes on the epidemiology of hypertension are further complicated by a lack of awareness by those with a hypertensive condition, with serious consequences of a low proportion of hypertensive individuals being on treatment.[10–12] In South Africa, an estimated 38-64% of hypertensives were aware of their status and 7.8-22.8% effectively controlled.[8 13]

Longitudinal data from sub-Saharan Africa are needed to examine changes on population-specific hypertension risk factors over time,[14] particularly given differences in socio-cultural environments and related health factors (e.g., diet, concurrent infectious diseases), and differentials in rural versus urban risk factor level.[15] This is particularly important as increased availability of antiretroviral therapy (ART) has reduced HIV/AIDS mortality[16 17] and the subsequent aging of people living with HIV.[18] The aging population will be at higher risk of developing hypertension, and the effect of HIV and ART may also increase the incidence of hypertension.[19–22] In South Africa, an emerging dual burden of disease, along with urban-rural differences due to the legacy of the apartheid era also highlight the importance of understanding location-specific hypertension risk factors over time.[23] However, there is currently a limited number of longitudinal studies examining risk factors for incident hypertension in the region.[24–27]

We use a population-based cohort of adults in rural South Africa who were normotensive in 2010-11 and were 40 years or older in 2014-15 to estimate hypertension incidence and identify sociodemographic, health and behavioural risk factors over a five-year period.

METHODS

We use data from two survey studies conducted in 2010-11 and 2014-2015 in the Agincourt Health and socio-Demographic Surveillance System (HDSS) study area in rural northeast South Africa.[28] Since 1992, the Medical Research Council (MRC)/Wits Rural Public Health and Health Transitions Unit has been conducting an annual census update of the population living in the study site, including information on vital events (births, deaths, migrations) and household and individual socio-demographic information. In 2010-11, the baseline study (Ha Nakekela) included a sex-age stratified random sample of 7,662 men and women aged 15 and older who were permanent residents from the 2009 HDSS census.[29] A follow-up study from November 2014 to November 2015 (The Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa (HAALSI)) included a random sample of 6,281 men and women aged 40 years and older who were permanent residents from the 2013 HDSS census,[30] including those in the baseline study who fulfilled the inclusion criteria. Both studies included information on sociodemographic factors and self-reported health and conditions, anthropometric and blood pressure measurements, and point of care blood tests for glucose and lipids, and dried blood spots (DBS) for HIV status.

Outcome measure

Blood pressure (BP) and hypertension. BP was measured three times using a Boso BP instrument in 2010 and an Omron M6W automated cuff in 2015. Validation studies of similar blood pressure monitoring devices indicate that they can provide accurate measurements.[31–33] We used the average of the second and third measurements consistent with national surveillance guidance.[34] Hypertension was defined as a systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg or if the respondent self-reported taking hypertensive medication.

2010 risk factors

Anthropometry and high waist circumference. Height, weight, and waist circumference were measured using a flexible stadiometer (Seca). High waist circumference was defined as >102cm for men and >88cm for women. Obesity was classified as a body mass index (BMI; kg/m^2) ≥30.

Random blood glucose and diabetes. Point of care instruments were used to measure glucose (Caresens POP blood glucose meter). Diabetes was defined as a random blood glucose level of ≥11.1 mmol/L or if the respondent self-reported medication use for diabetes.

High triglycerides. A Cardiocheck instrument was used to measure lipid levels. High triglycerides was defined as ≥1.7 mmol/l.[35]

HIV status. HIV DBS were tested using screening assay Vironostika Uniform 11 (Biomeriuex, France); with positive results retested using the SD Bioline HIV ELISA test

(SD; Standard Diagnostics Inc., Korea). If the two tests were inconsistent, we conducted a third assay (Elecys, Roche, USA) that determined the final result.

Socio-demographics and behaviours. Respondents were asked about smoking and alcohol history, physical activity, and if they were using ART. Information on years of completed education, employment (currently working for pay), union (informal or formal) and socioeconomic status (based on tertiles of an asset index[36]) were extracted from the most recent surveillance census.

Cause of death: For those who died between the baseline and follow-up study and for whom a death was identified from census updates, a verbal autopsy (VA) was conducted using a standardized VA instrument. For each identified death, a specially trained team conducted a VA interview with the closest living care taker to record signs and symptoms experienced before the death. We categorized cause of death using InterVA-4[37] – assigning a single cause for the largest likelihood for each death.

Analysis

We calculated hypertension incidence for those aged 40 years and older at the time of the second survey over five years overall, and by sex, age, and other socio-demographic factors. We calculated age-adjusted incidence using the Agincourt 2009 census population. We used Poisson regression to examine the association of hypertension status with socio-demographic, health and behavioural factors from the baseline study. To adjust for nonresponse in the follow-up study, we developed inverse probability sampling weights (IPSW) based on a logistic regression including sex and age at August 2010. We multiplied the IPSW for nonresponse by the inverse probability weights from the 2010 sample selection to derive our final weights for analysis. For our fully adjusted multivariable models, we fit separate models with and without HIV/ART status given a reduced sample of 2010 respondents with measured HIV status (particularly for the eligible sample estimates, see next paragraph).

We used two approaches to estimating exposure time for our incidence estimates. For the first approach, we included only those individuals who participated in both surveys. For incident cases, we defined exposure time as the midpoint between the dates of the first and second survey assessments. For the second approach, we included all eligible individuals from the first survey who were able to be tracked from census data. For those who out-migrated or died before the start of the second study, we allowed them to contribute exposure time between their blood pressure measurement in the first study and time at death or out-migration. For those who were not found or refused to participate in the second survey, we allowed exposure time between the first study's measurement and the start of the second study. As the second approach includes additional exposure time but no new incident cases, it provides a lower bound for our estimate of hypertension incidence. Individuals who aged to 40 during the follow-up time only contributed to exposure when they had reached 40 years or older. We used Stata 15 for all statistical analyses.[38]

We also tested the sensitivity of our results. We tested models using either BMI or waist-to-hip ratio instead of waist circumference. We also tested a model of hypertension based on only BP thresholds to assess if there were differences in the associations between predictors and incident BP only. Finally, we tested a competing-risk model for those eligible individuals who either died, migrated, or completed the follow-up study to test for bias in our risk factor associations. We modelled incident hypertension as the main event and death due to any cause as a competing event (censoring those who out-migrated) using the Fine-Grey model.[39]

Patient and public involvement

Neither study participants nor public were involved in study design or conduct of the study. The HDSS Learning, Information dissemination and Networking with Community (LINC) office manages community liaison with the HDSS study communities and their leaders. Annual feedback of findings from the HDSS and projects are provided to open village meetings with participation commonly from local service providers.

RESULTS

Figure 1 shows the participant flowchart. A total of 977 individuals were eligible for analysis from the first study and 676 (69%) also completed the second study. Table 1 presents sample characteristics from the baseline study comparing those who completed the second study and those who did not. Women, those with a high waist circumference, those in older ages and in a union with lower completed education were more likely to participate in the second study.

There were 193 incident cases of hypertension since baseline. The overall hypertension incidence rate was 8.374 per 100 person-years for those completing both studies (men 9.097; women 8.159; Table 2). The overall age adjusted hypertension incidence rate for those completing both studies was 8.372 per 100 person-years (men 8.955; women 8.50). Rates were lower when including the full eligible sample (Online supplemental table 1). By age, men in their 40s and 50s had higher incidence compared to same aged women, while women showed higher rates than men from ages 60-plus (Figure 2).

Table 2 shows incident rates and ratios for those completing both studies by baseline socio-demographic, health, and behavioural factors. Older age individuals were associated with higher incident hypertension risk compared to those ages 40-49. Those with high waist circumference and elevated triglycerides had a higher risk of incident hypertension. Respondents engaging in high physical activity levels had a lower risk of incident hypertension compared to those with low physical activity levels. Those HIV-positive and not on ART at baseline had a 55% lower risk of developing hypertension over the 5 years of follow-up, while those on ART also had lower hypertensive risk than those HIV-negative at baseline. Results for the full eligible sample are presented in online supplemental table 1.

Table 3 shows the multivariable-adjusted results from the full Poisson regression excluding HIV status for those completing both studies (see online supplemental table 2 for the full eligible sample results). Older ages, being employed (IRR: 1.579 95% CI: 1.071-2.329), and having a high waist circumference (IRR: 1.557 95% CI: 1.074-2.259) were associated with higher risk of incident hypertension in 2015. Those engaging in high levels of physical activity had an approximately 43% lower risk of incident hypertension, although the 95% CI overlapped with the null value of 1 (95% CI: 0.319-1.018)

Table 4 shows the same multivariable-adjusted Poisson model as Table 3 including HIV status, with similar results to those risk factors from the model without HIV status. The results for high waist circumference were in the same direction but the 95% CI overlapped with the null value of 1, likely due to the reduced sample size. Those who were HIV-positive and not on ART had an approximately 52% lower risk of incident hypertension compared to those HIV-negative at baseline (95% CI 0.301-0.778), while those HIV-positive and on ART showed similar associations to those not on ART.

Results of the sensitivity analyses of alternate anthropometry measures showed similar associations for BMI as for waist circumference (online supplemental table 3). There were not enough cases of high waist-to-hip ratio to include in the models. A model examining an outcome based only on BP thresholds also showed similar associations to the original models (online supplemental table 4). For the competing risk model, high rates of missingness on HIV/ART status precluded including that indicator. Results omitting HIV/ART status at baseline are presented in online supplemental table 5, showing similar results to the full eligible sample (online supplemental table 2). Cause of death information according to broad cause groups is presented in online supplemental table 6.

DISCUSSION

In 1998, South Africa had approximately 6.3 million adults with hypertension.[40] Now it is estimated to be close to 12 million, nearly doubling despite population growth of about 34% over the same time period, with prevalence increasing from 24% to over 40% in some populations.[41] Based on our finding of 8.37 per 100 person-years, roughly 1.4 million adults over the age of 40 will develop hypertension over the next five years. Given an increase of nearly 50% in the risk of ischemic heart disease and stroke death for each 10 mmHg increase,[42] the results suggest a significant increase in the number of people required for additional treatment and premature mortality if not adequately controlled.

We found that 29% of older adults in our study developed hypertension over a five-year period. Our results were similar to another study from South Africa following individuals ages 30-plus who started with optimal blood pressure over five years (2005-2010). They found a relatively similar incidence of 24%[27] given the slightly younger age range.

We showed that men have higher hypertension incidence rates in mid-life, while women had higher rates in older ages. This is likely due at least in part to the smaller sample size of men in our study. A potentially similar pattern was shown in a study in South Africa (2004-2016) of patients initiating ART at 10 public sector clinics (9 urban, 1 rural) and including a wider age range (ages 18-50-plus).[24] They found that men had higher hypertension incidence rates at ages 18-39, while women had higher rates at ages 40-49 and 50-plus. Our finding may also be due in part to greater employment for middle-aged men[43] and higher survival[17 44] or obesity[45 46] among older women.

In multivariable-adjusted models, we found that being employed and having a high waist circumference at baseline were risk factors for incident hypertension. In another study in South Africa, they also found that high waist circumference was a key risk factor, along with alcohol intake.[27] While we showed no association with alcohol use, our sample also had low self-reported use of alcohol, with 80% reporting not drinking in the past month, which may be due in part to response bias.[47] Given the limited employment opportunities in our setting,[28] a higher risk of hypertension amongst employed individuals may represent those more likely to be exposed to workplace-related stress and other behavioural factors such as diet[48 49] that may differ from those not employed.

We found that being HIV-positive at baseline was associated with a lower risk of incident hypertension. This also aligns with an earlier study in South Africa that showed that being HIV-positive was inversely related to increased BP.[27] However, our results may be sensitive to survivorship bias if those who died due to HIV/AIDS over the five-year period were also more likely to develop hypertension. Of the 71 individuals for which mortality information is available, about 28% died due to HIV/AIDS or TB. If a substantial portion of those individuals developed hypertension this may affect our estimates of the association between HIV/ART status and risk of incident hypertension. Further, as we lacked information on HIV/ART status for many individuals in the eligible sample who did not complete the follow-up study, this may affect our estimates if those individuals were more likely to be HIV-positive.[50] A longer period of follow-up is needed to assess the effects of HIV and ART on hypertension and related cardiometabolic conditions. Longitudinal studies restricted to HIV-positive individuals have shown high hypertension incident rates over relatively short periods of follow-up and similar risk factors to the HIV-negative population.[25 26]

Our longitudinal findings are particularly important given the complex health transition occurring in South Africa, with a concomitant burden of infectious and noncommunicable diseases.[17 23 29 45] A study from the same community as our study demonstrated a high and increasing burden of stroke morbidity and mortality.[51] While our findings are consistent with hypertension-related risk factors found in other regions, population-specific studies such as ours are important to contextualize the epidemiological findings from elsewhere and inform local prevention and treatment strategies.[14] They also provide an opportunity to understand the interaction between cardiometabolic and infectious diseases such as HIV. A longer period of follow-up, which will be possible as future waves of the study are completed, will permit a greater understanding of the interplay between hypertension, HIV, and treatment of both and related conditions.

We acknowledge our study limitations. While our study is one of the few population-based, longitudinal cohorts on hypertension incidence in Africa, the study comes from a defined region in rural northeast South Africa. Additional studies are needed in other settings, particularly given differences in exposures and differential risk factors in rural and urban contexts. We include a wide range of potential risk factors based on existing studies. Other factors, however, such as migration history, would be important to consider given the high levels of circular labour migration in this setting and potential links of rural to urban migration to increased blood pressure.[52–55] Further, food insecurity is highly prevalent in this setting[56] and may lead to differential hypertension risk due to dietary differences. Given the high level of missingness on HIV/ART status amongst the eligible population who did not complete the follow-up study, we were unable to assess the effect of HIV/ART in a competing risk framework. Our measure of ART status is also based on self-report and may be subject to response bias, as well as factors related to HIV awareness such as engagement with health services.[57]

Over a period of five years, 29% of individuals developed hypertension in a population-based cohort of individuals ages 40 and older given an incidence rate of 8.374 per 100 person-years. Abdominal obesity was one of the most consistent risk factors. Being employed was also a predictor of incident hypertension. As South Africa continues to undergo a complex health and epidemiological transition, continued longitudinal follow-up is needed to understand the complex interplay of noncommunicable and infectious diseases, along with their underlying and modifiable risk factors. In response to the urgent call for longitudinal sub-Saharan African studies, an increasing evidence base can help inform and target public health strategies to reduce preventable morbidity and mortality.

Acknowledgements

The authors thank the study participants and all those involved in the successful field operations in Ha Nakekela, HAALSI and the Agincourt HDSS.

Contributions: BH wrote the first draft and designed and completed the statistical analyses. FXG, BH, TG and SMT conceptualized the work. FXG, NA, CWK, and SMT designed and implemented the baseline study. TG, FXG, CWK, and SMT designed and implemented the follow-up study. TG, NA, SAM, CWK, SMT, and FXG revised the manuscript for important intellectual content and contributed to interpretation of the data. All authors read and approved the final manuscript.

Funding: The Ha Nakekela study was supported by the National Institutes of Health [R24 AG032112-05] and the William and Flora Hewlett Foundation 2009-4060 African Population Research and Training Program. Data analysis for this study was funded by the US National Institute on Aging [R01 AG049634] and the University of Colorado, Innovative Seed Grant HIV after 40 in rural South Africa [not applicable].

HAALSI was supported by the U.S. National Institute on Aging [P01AG041710; 1R01AG051144-01; 3U54HG006938-03S1].

The MRC/Wits Rural Public Health and Health Transitions Research Unit and Agincourt Health and Socio-Demographic Surveillance System, a node of the South African Population Research Infrastructure Network (SAPRIN), is supported by the Department of Science and Innovation [not applicable], the University of the Witwatersrand [not applicable], and the

Medical Research Council, South Africa [not applicable], and previously the Wellcome Trust, UK (Grants 058893/Z/99/A; 069683/Z/02/Z; 085477/Z/08/Z; 085477/B/08/Z).

Competing interests: None declared.

Ethics approval: Ethical clearance for both surveys and the HDSS were obtained from the University of the Witwatersrand Human Research Ethics Committee (Medical) [M10458 and M141159] and the Mpumalanga Provincial Research and Ethics Committee. The baseline study also received ethical approval from the Institutional Review Board of the University of Colorado – Boulder [11-0549] and the follow-up study from the Harvard TH Chan School of Public Health, Office of Human Research Administration [C13-1608-02]. Written consent to participate was obtained for all participants in the baseline study. Each respondent in the follow-up study also provided written, informed consent (or by a proxy, when needed).

Data sharing: The datasets generated and/or analysed for the follow-up study are available at the Harvard Center for Population and Development Studies (HCPDS) program website: www.haalsi.org. The data supporting the findings of this study are available from the corresponding author on reasonable request.

REFERENCES

1. Lim, S. S., T. Vos, A. D. Flaxman, G. Danaei, K. Shibuya, H. Adair-Rohani, M. A. AlMazroa, M. Amann, H. R. Anderson, and K. G. Andrews. 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. *The Lancet* 2013;380:2224-2260.
2. Ibrahim, M. M., and A. Damasceno. Hypertension in developing countries. *The Lancet* 2012;380:611-619.
3. Bosu, W. K., S. T. Reilly, J. M. K. Aheto, and E. Zucchelli. Hypertension in older adults in Africa: A systematic review and meta-analysis. *PloS One* 2019;14:e0214934.
4. Guwatudde, D., J. Nankya-Mutyoba, R. Kalyesubula, C. Laurence, C. Adebamowo, I. Ajayi, F. Bajunirwe, M. Njelekela, F. S. Chiwanga, T. Reid, J. Volmink, H. O. Adami, M. D. Holmes, and S. Dalal. The burden of hypertension in sub-Saharan Africa: a four-country cross sectional study. *BMC Public Health* 2015;15:1211.
5. Kaze, A. D., A. E. Schutte, S. Erqou, A. P. Kengne, and J. B. Echouffo-Tcheugui. Prevalence of hypertension in older people in Africa. *Journal of Hypertension* 2017;35:1345-1352.
6. Sarki, A. M., C. U. Nduka, S. Stranges, N. B. Kandala, and O. A. Uthman. Prevalence of Hypertension in Low- and Middle-Income Countries: A Systematic Review and Meta-Analysis. *Medicine* 2015;94:e1959.
7. Twagirumukiza, M., D. De Bacquer, J. G. Kips, G. de Backer, R. V. Stichele, and L. M. Van Bortel. Current and projected prevalence of arterial hypertension in sub-Saharan Africa by sex, age and habitat: an estimate from population studies. *J Hypertens* 2011;29:1243-1252.
8. Lloyd-Sherlock, P., J. Beard, N. Minicuci, S. Ebrahim, and S. Chatterji. Hypertension among older adults in low- and middle-income countries: prevalence, awareness and control. *International Journal of Epidemiology* 2014;43:116-128.
9. Sudharsanan, N., and P. Geldsetzer. Impact of Coming Demographic Changes on the Number of Adults in Need of Care for Hypertension in Brazil, China, India, Indonesia, Mexico, and South Africa. *Hypertension* 2019;73:770-776.
10. Addo, J., L. Smeeth, and D. A. Leon. Hypertension in sub-saharan Africa: a systematic review. *Hypertension* 2007;50:1012-1018.
11. Gómez-Olivé, F. X., S. A. Ali, F. Made, C. Kyobutungi, E. Nonterah, L. Micklesfield, M. Alberts, and R. Boua. Stark Regional and Sex Differences in the Prevalence and Awareness of Hypertension: An H3Africa AWI-Gen Study Across 6 Sites in Sub-Saharan Africa. *Global Heart* 2017
12. Ataklte, F., S. Erqou, S. Kaptoge, B. Taye, J. B. Echouffo-Tcheugui, and A. P. Kengne. Burden of undiagnosed hypertension in sub-saharan Africa: a systematic review and meta-analysis. *Hypertension* 2015;65:291-298.
13. Jardim, T. V., S. Reiger, S. Abrahams-Gessel, F. X. Gomez-Olive, R. G. Wagner, A. Wade, T. W. Bärnighausen, J. Salomon, S. Tollman, and T. A. Gaziano. Hypertension management in a population of older adults in rural South Africa. *Journal of Hypertension* 2017;35:1283-1289.
14. Kengne, A. P., L. M. Ntyintyane, and B. M. Mayosi. A systematic overview of prospective cohort studies of cardiovascular disease in sub-Saharan Africa. *Cardiovascular Journal of Africa* 2012;23:103-112.

15. Holmes, M. D., S. Dalal, J. Volmink, C. A. Adebamowo, M. Njelekela, W. W. Fawzi, W. C. Willett, and H. O. Adami. Non-communicable diseases in sub-Saharan Africa: the case for cohort studies. *PLoS Med* 2010;7:e1000244.
16. Herbst, A. J., G. S. Cooke, T. Bärnighausen, A. KanyKany, F. Tanser, and M. Newell. Adult mortality and antiretroviral treatment roll-out in rural KwaZulu-Natal, South Africa. *Bulletin of the World Health Organization* 2009;87:754-762.
17. Kabudula, C. W., B. Houle, M. A. Collinson, K. Kahn, F. X. Gómez-Olivé, S. J. Clark, and S. Tollman. Progression of the epidemiological transition in a rural South African setting: findings from population surveillance in Agincourt, 1993-2013. *BMC Public Health* 2017;17:424.
18. Vollmer, S., K. Harttgen, T. Alfven, J. Padayachy, P. Ghys, and T. Bärnighausen. The HIV epidemic in sub-Saharan Africa is aging: Evidence from the Demographic and Health Surveys in sub-Saharan Africa. *AIDS Behav* 2016;21:101-113.
19. Anand, A. R., G. Rachel, and D. Parthasarathy. HIV proteins and endothelial dysfunction: Implications in cardiovascular disease. *Front Cardiovasc Med* 2018;5:185.
20. Grinspoon, S., and A. Carr. Cardiovascular risk and body-fat abnormalities in HIV-infected adults. *New England Journal of Medicine* 2005;352:48-62.
21. Dillon, D. G. Association of HIV and ART with cardiometabolic traits in sub-Saharan Africa: a systematic review and meta-analysis. *International Journal of Epidemiology* 2013;42:1754-1771.
22. Rigaud, A.-S., and B. Forette. Hypertension in older adults. *Journal of Gerontology* 2001;56A:M217-M225.
23. Mayosi, B. M., A. J. Flisher, U. G. Lalloo, F. Sitas, S. M. Tollman, and D. Bradshaw. The burden of non-communicable diseases in South Africa. *Lancet* 2009;374:934-947.
24. Brennan, A. T., L. Jamieson, N. J. Crowther, M. P. Fox, J. A. George, K. M. Berry, A. Stokes, M. Maskew, I. Sanne, and L. Long. Prevalence, incidence, predictors, treatment, and control of hypertension among HIV-positive adults on antiretroviral treatment in public sector treatment programs in South Africa. *PloS One* 2018;13:e0204020.
25. Okello, S., M. Kanyesigye, W. R. Muyindike, B. H. Annex, P. W. Hunt, S. Haneuse, and M. J. Siedner. Incidence and predictors of hypertension in adults with HIV-initiating antiretroviral therapy in south-western Uganda. *J Hypertens* 2015;33:2039-2045.
26. Rodríguez-Arbolí, E., K. Mwamelo, A. V. Kalinjuma, H. Furrer, C. Hatz, M. Tanner, M. Battegay, E. Letang, and S. G. KIULARCO. Incidence and risk factors for hypertension among HIV patients in rural Tanzania - A prospective cohort study. *PLoS One* 2017;12:e0172089.
27. Schutte, A. E., R. Schutte, H. W. Huisman, J. M. van Rooyen, C. M. Fourie, N. T. Malan, L. Malan, C. M. Mels, W. Smith, S. J. Moss, G. W. Towers, H. S. Kruger, E. Wentzel-Viljoen, H. H. Vorster, and A. Kruger. Are behavioural risk factors to be blamed for the conversion from optimal blood pressure to hypertensive status in Black South Africans? A 5-year prospective study. *International Journal of Epidemiology* 2012;41:1114-1123.
28. Kahn, K., M. A. Collinson, F. X. Gomez-Olive, O. Mokoena, R. Twine, P. Mee, S. A. Afolabi, B. D. Clark, C. W. Kabudula, A. Khosa, S. Khoza, M. G. Shabangu, B. Silaule, J. B. Tibane, R. G. Wagner, M. L. Garenne, S. J. Clark, and S. M. Tollman. Profile: Agincourt Health and Socio-demographic Surveillance System. *Int J Epidemiol* 2012;41:988-1001.

29. Gómez-Olivé, F. X., N. Angotti, B. Houle, K. Klipstein-Grobusch, C. Kabudula, J. Menken, J. Williams, S. Tollman, and S. J. Clark. Prevalence of HIV among those 15 and older in rural South Africa. *AIDS Care* 2013;25:1122-1128.
30. Gómez-Olivé, F. X., L. Montana, R. G. Wagner, C. W. Kabudula, J. K. Rohr, K. Kahn, T. Bärnighausen, M. Collinson, D. Canning, T. Gaziano, J. A. Salomon, C. F. Payne, A. Wade, S. M. Tollman, and L. Berkman. Cohort Profile: Health and Ageing in Africa: a Longitudinal Study of an INDEPTH Community in South Africa (HAALSI). *International Journal of Epidemiology* 2018;47:689-690j.
31. Altunkan, S., K. Öztas, and E. Altunkan. Validation of the Omron 637IT wrist blood pressure measuring device with a position sensor according to the International Protocol in adults and obese adults. *Blood Pressure Monitoring* 2006;11:79-85.
32. Saladini, F., E. Benetti, and P. Palatini. Accuracy of the visomat handy wrist blood pressure measuring device according to the International Protocol. *Blood Press Monit* 2010;15:281-284.
33. Omboni, S., I. Riva, A. Giglio, G. Caldara, A. Groppelli, and G. Parati. Validation of the Omron M5-I, R5-I and HEM-907 automated blood pressure monitors in elderly individuals according to the International Protocol of the European Society of Hypertension. *Blood Pressure Monitoring* 2007;12:233-242.
34. Centers for Disease Control and Prevention (CDC). National Health and Nutrition Examination Survey: 1999-2000 Data Documentation, Codebook, and Frequencies. 2002
35. US Department of Health and Human Services. 2004. *The seventh report of the Joint National Committee on prevention, detection, evaluation, and treatment of high blood pressure*. National Heart, Lung, and Blood Institute (US),
36. Kabudula, C., B. Houle, M. A. Collinson, K. Kahn, S. Tollman, and S. Clark. Assessing changes in household socioeconomic status in rural South Africa, 2001-2013: a distributional analysis using household asset indicators. *Social Indicators Research* 2016;133:1047-1073.
37. Byass, P., D. Chandramohan, S. J. Clark, L. D'Ambruoso, E. Fottrell, W. J. Graham, A. J. Herbst, A. Hodgson, S. Hounton, K. Kahn, A. Krishnan, J. Leitao, F. Odhiambo, O. A. Sankoh, and S. M. Tollman. Strengthening standardised interpretation of verbal autopsy data: the new InterVA-4 tool. *Glob Health Action* 2012;5:1-8.
38. StataCorp. 2017. *Stata Statistical Software: Release 15*. StataCorp, LP, College Station, TX.
39. Fine, J. P., and R. J. Gray. A Proportional Hazards Model for the Subdistribution of a Competing Risk. *Journal of the American Statistical Association* 1999;94:496-509.
40. Steyn, K., T. A. Gaziano, D. Bradshaw, R. Laubscher, and J. Fourie. Hypertension in South African adults: results from the Demographic and Health Survey, 1998. *Journal of Hypertension* 2001;19:1717-1725.
41. Ntuli, S. T., E. Maimela, M. Alberts, S. Choma, and S. Dikotope. Prevalence and associated risk factors of hypertension amongst adults in a rural community of Limpopo Province, South Africa. *Afr J Prim Health Care Fam Med* 2015;7:847.
42. Chobanian, A. V., G. L. Bakris, H. R. Black, W. C. Cushman, L. A. Green, J. L. Izzo Jr, D. W. Jones, B. J. Materson, S. Oparil, and J. T. Wright Jr. The seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure: the JNC 7 report. *JAMA* 2003;289:2560-2571.
43. Blalock, C. L. Labor migration and employment in post-apartheid rural South Africa. *Department of Sociology* 2014;Doctor of Philosophy

44. Houle, B., S. J. Clark, F. X. Gómez-Olivé, K. Kahn, and S. M. Tollman. The unfolding counter-transition in rural South Africa: mortality and cause of death, 1994-2009. *PLoS One* 2014;9:e100420.
45. Clark, S. J., F. X. Gómez-Olivé, B. Houle, M. Thorogood, K. Klipstein-Grobusch, N. Angotti, C. Kabudula, J. Williams, J. Menken, and S. Tollman. Cardiometabolic disease risk and HIV status in rural South Africa: establishing a baseline. *BMC Public Health* 2015;15:372.
46. Gaziano, T. A., S. Abrahams-Gessel, F. X. Gomez-Olive, A. Wade, N. J. Crowther, S. Alam, J. Manne-Goehler, C. W. Kabudula, R. Wagner, J. Rohr, L. Montana, K. Kahn, T. W. Bärnighausen, L. F. Berkman, and S. Tollman. Cardiometabolic risk in a population of older adults with multiple co-morbidities in rural south africa: the HAALSI (Health and Aging in Africa: longitudinal studies of INDEPTH communities) study. *BMC Public Health* 2017;17:206.
47. Houle, B., N. Angotti, F. X. Gómez-Olivé, and S. J. Clark. Fieldworker effects on substance use reporting in rural South Africa. *International Journal of Alcohol and Drug Research* 2018;7:29-39.
48. Maredza, M., K. J. Hofman, and T. Tollman. A hidden menace: cardiovascular disease in South Africa and the costs of an inadequate policy response: health policy and cardiovascular disease. *SA Heart* 2011;8:48-57.
49. Feeley, A. B. B., K. Kahn, R. Twine, and S. A. Norris. Exploratory survey of informal vendor-sold fast food in rural South Africa. *South African Journal of Clinical Nutrition* 2011;24:199-201.
50. Clark, S. J., and B. Houle. Validation, replication, and sensitivity testing of Heckman-type selection models to adjust estimates of HIV prevalence. *PLoS One* 2014;9:e112563.
51. Maredza, M., M. Y. Bertram, and S. M. Tollman. Disease burden of stroke in rural South Africa: an estimate of incidence, mortality and disability adjusted life years. *BMC Neurol* 2015;15:54.
52. Collinson, M. A., M. J. White, P. Bocquier, S. T. McGarvey, S. A. Afolabi, S. J. Clark, K. Kahn, and S. M. Tollman. Migration and the epidemiological transition: insights from the Agincourt sub-district of northeast South Africa. *Global Health Action* 2014;7:23514.
53. Pheiffer, C. F., S. T. McGarvey, C. Ginsburg, M. Collinson, F. X. Gómez-Olivé, S. Tollman, and M. J. White. Dimensions of internal migration and their relationship to blood pressure in South Africa. *J Biosoc Sci* 20191-16.
54. Poulter, N. R., K. T. Khaw, B. E. Hopwood, M. Mugambi, W. S. Peart, G. Rose, and P. S. Sever. The Kenyan Luo migration study: observations on the initiation of a rise in blood pressure. *BMJ* 1990;300:967-972.
55. Steyn, K., D. Bradshaw, R. Norman, and R. Laubscher. Determinants and treatment of hypertension in South Africans: the first Demographic and Health Survey. *South African Medical Journal* 2008;98:376-380.
56. Hunter, L. M., W. Twine, and L. Patterson. "Locusts are now our beef": adult mortality and household dietary use of local environmental resources in rural South Africa. *Scand J Public Health Suppl* 2007;69:165-174.
57. Manne-Goehler, J., L. Montana, F. X. Gómez-Olivé, J. Rohr, G. Harling, R. G. Wagner, A. Wade, C. W. Kabudula, P. Geldsetzer, K. Kahn, S. Tollman, L. F. Berkman, T. W. Bärnighausen, and T. A. Gaziano. The ART advantage: healthcare utilization for diabetes and hypertension in rural South Africa. *JAIDS Journal of Acquired Immune Deficiency Syndromes* 2017;75:561-567.

FIGURE CAPTIONS

Figure 1. Participant flowchart.

Figure 2. Proportion of participants with incident hypertension, by age and gender, 2015.

Table 1. Sample characteristics at baseline (2010), by study participation in 2015 for eligible individuals (n=977).

	Lost to follow-up (n=301)		Completed 2015 (n=676)			Total (n=977)	
	n	**%**	**n**	**%**	**p-value**	**n**	**%**
Gender							
Male	140	(46.5)	239	(35.4)	0.001	379	(38.8)
Female	161	(53.5)	437	(64.6)		598	(61.2)
Age groups							
35-44	130	(43.2)	227	(33.6)	0.003	357	(36.5)
45-54	71	(23.6)	180	(26.6)		251	(25.7)
55-64	34	(11.3)	126	(18.6)		160	(16.4)
65-74	29	(9.6)	81	(12.0)		110	(11.3)
75+	37	(12.3)	62	(9.2)		99	(10.1)
Education							
None	40	(34.2)	277	(41.0)	0.018	317	(40.0)
Less than secondary	54	(46.2)	327	(48.4)		381	(48.0)
Secondary or more	23	(19.7)	72	(10.7)		95	(12.0)
Union status							
Not in union	166	(55.1)	302	(44.7)	0.002	468	(47.9)
Formal/informal union	135	(44.9)	374	(55.3)		509	(52.1)
SES[a]							
Low	130	(43.2)	253	(37.7)	0.258	383	(39.4)
Middle	86	(28.6)	216	(32.2)		302	(31.1)
High	85	(28.2)	202	(30.1)		287	(29.5)
Employment status							
Not employed	80	(68.4)	498	(74.1)	0.196	578	(73.3)
Employed	37	(31.6)	174	(25.9)		211	(26.7)
Smoking history							
Never	236	(78.4)	548	(81.1)	0.206	784	(80.2)
Prior	18	(6.0)	49	(7.2)		67	(6.9)
Current	47	(15.6)	79	(11.7)		126	(12.9)
Alcohol use							
Not in past 30 days	235	(78.1)	544	(80.5)	0.686	779	(79.7)
Less than weekly	24	(8.0)	47	(7.0)		71	(7.3)
Weekly	42	(14.0)	85	(12.6)		127	(13.0)
Physical activity[b]							
Low	27	(9.4)	40	(6.0)	0.128	67	(7.0)

Moderate	80	(27.9)	209	(31.3)		289	(30.3)
High	180	(62.7)	419	(62.7)		599	(62.7)
High waist circumference[c]							
No	205	(72.7)	430	(65.8)	0.04	635	(67.9)
Yes	77	(27.3)	223	(34.2)		300	(32.1)
Diabetes[d]							
No	293	(98.0)	655	(97.2)	0.46	948	(97.4)
Yes	6	(2.0)	19	(2.8)		25	(2.6)
High triglycerides[e]							
No	213	(72.7)	479	(73.5)	0.805	692	(73.2)
Yes	80	(27.3)	173	(26.5)		253	(26.8)

HIV/ART is not included given missing values (n=297) for the vast majority of those lost to follow-up.

[a] Based on a household asset index score.

[b] Based on the International Physical Activity Questionnaire (IPAQ).

[c] Greater than 102cm for men and 88cm for women.

[d] Blood glucose greater than or equal to 11.1.

[e] Greater than or equal to 1.7 mmol/l.

Table 2. Hypertension incidence rates and incidence rate ratios per 100 person-years over 5 years of follow-up (2010-2015), by sociodemographic, health and behavioural factors among those completing both time points.

				95% CI			95% CI		
Value	**Events**	**PYRS**	**IR**	**Lower**	**Upper**	**IRR**	**Lower**	**Upper**	**p-value**
Overall	193	2311	8.374	7.242	9.721				
Gender									
Male	74	815	9.097	7.266	11.496	1			
Female	119	1496	8.159	6.832	9.804	0.897	0.67	1.2	0.463
Age groups									
40-49	56	975	5.04	3.837	6.73	1			
50-59	47	556	8.897	6.667	12.077	1.765	1.177	2.647	0.006
60-69	42	399	11.104	8.282	15.14	2.203	1.464	3.315	<0.001
70-79	28	239	11.875	8.285	17.436	2.356	1.486	3.735	<0.001
80+	20	141	16.197	10.647	25.379	3.213	1.931	5.348	<0.001
Education									
None	85	986	9.256	7.491	11.536	1			
Less than secondary	92	1090	8.21	6.645	10.229	0.887	0.655	1.202	0.439
Secondary or more	16	235	5.318	3.112	9.652	0.575	0.319	1.034	0.065
Union status									
Not in union	91	1034	8.613	6.983	10.709	1			
Formal/informal union	102	1277	8.165	6.685	10.051	0.948	0.706	1.273	0.722
SES[a]									
Low	68	867	8.064	6.328	10.397	1			
Middle	64	736	8.715	6.798	11.305	1.081	0.759	1.539	0.667
High	60	689	8.389	6.449	11.056	1.04	0.723	1.497	0.831
Employment status									
Not employed	144	1701	8.336	7.048	9.911	1			
Employed	48	595	8.511	6.375	11.557	1.021	0.726	1.435	0.905
Smoking history									
Never	163	1861	8.644	7.392	10.155	1			
Prior	11	171	6.356	3.501	12.447	0.735	0.391	1.381	0.339
Current	19	279	6.715	4.293	10.956	0.777	0.478	1.262	0.308
Alcohol use									
Not in past 30 days	153	1852	8.416	7.167	9.931	1			
Less than weekly	10	167	5.459	2.879	11.284	0.649	0.331	1.272	0.208
Weekly	30	292	9.789	6.708	14.649	1.163	0.766	1.765	0.478
Physical activity[b]									

Low	20	122	15.468	9.85	24.91	1			
Moderate	71	687	10.641	8.402	13.61	0.688	0.412	1.149	0.153
High	100	1471	6.98	5.718	8.59	0.451	0.275	0.742	0.002
High waist circumference[c]									
No	104	1512	6.519	5.326	8.046	1			
Yes	78	735	10.571	8.483	13.283	1.621	1.197	2.196	0.002
Diabetes[d]									
No	186	2240	8.298	7.156	9.662	1			
Yes	6	64	10.06	4.451	26.006	1.212	0.529	2.778	0.649
High triglycerides[e]									
No	122	1660	7.262	6.049	8.775	1			
Yes	59	575	10.59	8.177	13.88	1.458	1.057	2.012	0.022
HIV and ART status									
Negative	155	1514	10.452	8.909	12.318	1			
Positive, not on ART	25	486	4.749	3.15	7.439	0.454	0.289	0.713	0.001
Positive, on ART	6	178	3.553	1.52	10.122	0.34	0.142	0.811	0.015

[a] Based on a household asset index score.
[b] Based on the International Physical Activity Questionnaire (IPAQ).
[c] Greater than 102cm for men and 88cm for women.
[d] Blood glucose greater than or equal to 11.1.
[e] Greater than or equal to 1.7 mmol/l.

Table 3. Multivariable Poisson regression of incident hypertension on sociodemographic, health and behavioural risk factors among those completing both time points (n=616).

		95% CI		
	IRR	Lower	Upper	p-value
Gender				
Male	1			
Female	0.818	0.512	1.305	0.399
Age groups				
40-49	1			
50-59	1.831	1.193	2.811	0.006
60-69	2.4	1.463	3.938	<0.001
70-79	2.607	1.451	4.684	<0.001
80+	2.561	1.196	5.488	<0.001
Education				
None	1			
Less than secondary	1.061	0.732	1.537	0.755
Secondary or more	0.741	0.372	1.478	0.395
Union status				
Not in union	1			
Formal/informal union	1.023	0.724	1.445	0.899
SES[a]				
Low	1			
Middle	1.068	0.715	1.593	0.749
High	0.915	0.59	1.42	0.693
Employment status				
Not employed	1			
Employed	1.579	1.071	2.329	0.021
Smoking history				
Never	1			
Prior	0.758	0.37	1.55	0.447
Current	0.709	0.373	1.349	0.295
Alcohol use				
Not in past 30 days	1			
Less than weekly	0.717	0.345	1.492	0.373
Weekly	1.07	0.652	1.755	0.789
Physical activity[b]				
Low	1			
Moderate	0.781	0.447	1.364	0.385

High	0.57	0.319	1.018	0.057
High waist circumference[c]				
No	1			
Yes	1.557	1.074	2.259	0.02
Diabetes[d]				
No	1			
Yes	0.932	0.399	2.178	0.87
High triglycerides[e]				
No	1			
Yes	1.297	0.932	1.805	0.123

[a] Based on a household asset index score.
[b] Based on the International Physical Activity Questionnaire (IPAQ).
[c] Greater than 102cm for men and 88cm for women.
[d] Blood glucose greater than or equal to 11.1.
[e] Greater than or equal to 1.7 mmol/l.

Table 4. Multivariable Poisson regression of incident hypertension on sociodemographic, health and behavioural risk factors, and HIV and ART status among those completing both time points (n=581).

		95% CI		
	IRR	**Lower**	**Upper**	**p-value**
Gender				
Male	1			
Female	0.854	0.533	1.369	0.512
Age groups				
40-49	1			
50-59	1.846	1.183	2.879	0.007
60-69	2.128	1.281	3.535	0.004
70-79	2.339	1.256	4.356	0.007
80+	2.139	0.978	4.676	0.057
Education				
None	1			
Less than secondary	1.124	0.765	1.652	0.552
Secondary or more	0.754	0.368	1.542	0.439
Union status				
Not in union	1			
In union	0.939	0.662	1.332	0.724
SES[a]				
Low	1			
Middle	0.97	0.647	1.454	0.883
High	0.812	0.519	1.269	0.36
Employment status				
Not employed	1			
Employed	1.604	1.064	2.419	0.024
Smoking history				
Never	1			
Prior	0.727	0.34	1.554	0.411
Current	0.661	0.345	1.267	0.213
Alcohol use				
Not in past 30 days	1			
Less than weekly	0.751	0.358	1.574	0.448
Weekly	1.111	0.668	1.846	0.685
Physical activity[b]				
Low	1			
Moderate	0.77	0.434	1.365	0.371

High	0.56	0.309	1.015	0.056
High waist circumference[c]				
No	1			
Yes	1.448	0.975	2.149	0.066
Diabetes[d]				
No	1			
Yes	0.907	0.392	2.102	0.82
High triglycerides[e]				
No	1			
Yes	1.34	0.956	1.877	0.089
HIV and ART status				
Negative	1			
Positive, not on ART	0.484	0.301	0.778	0.003
Positive, on ART	0.462	0.197	1.082	0.075

[a] Based on a household asset index score.
[b] Based on the International Physical Activity Questionnaire (IPAQ).
[c] Greater than 102cm for men and 88cm for women.
[d] Blood glucose greater than or equal to 11.1.
[e] Greater than or equal to 1.7 mmol/l.

Supplementary Materials

Online Supplemental Tables 1-6

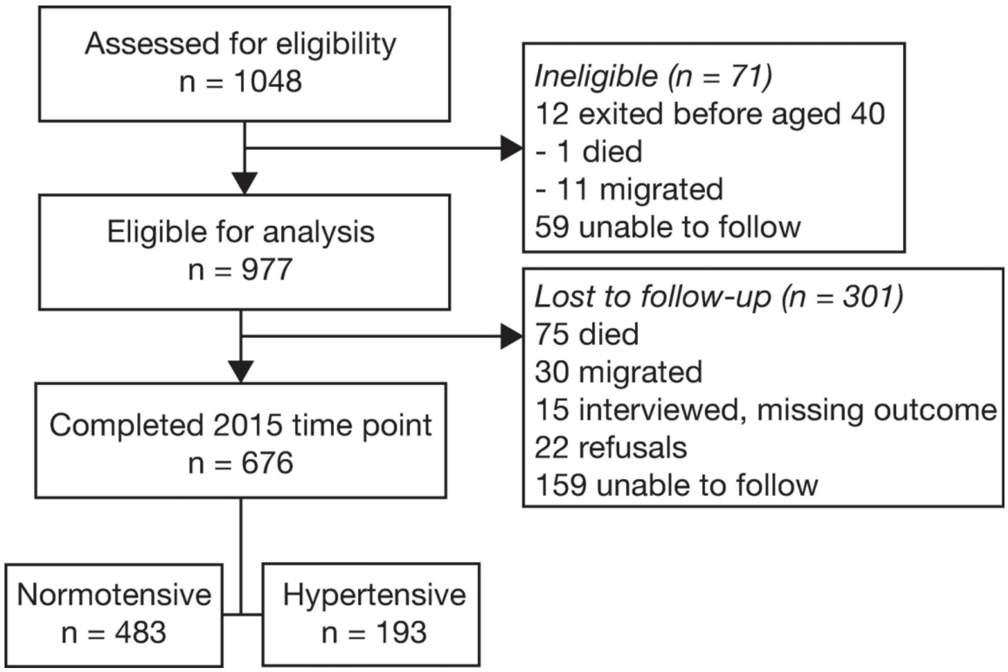


Figure 1

134x89mm (300 x 300 DPI)

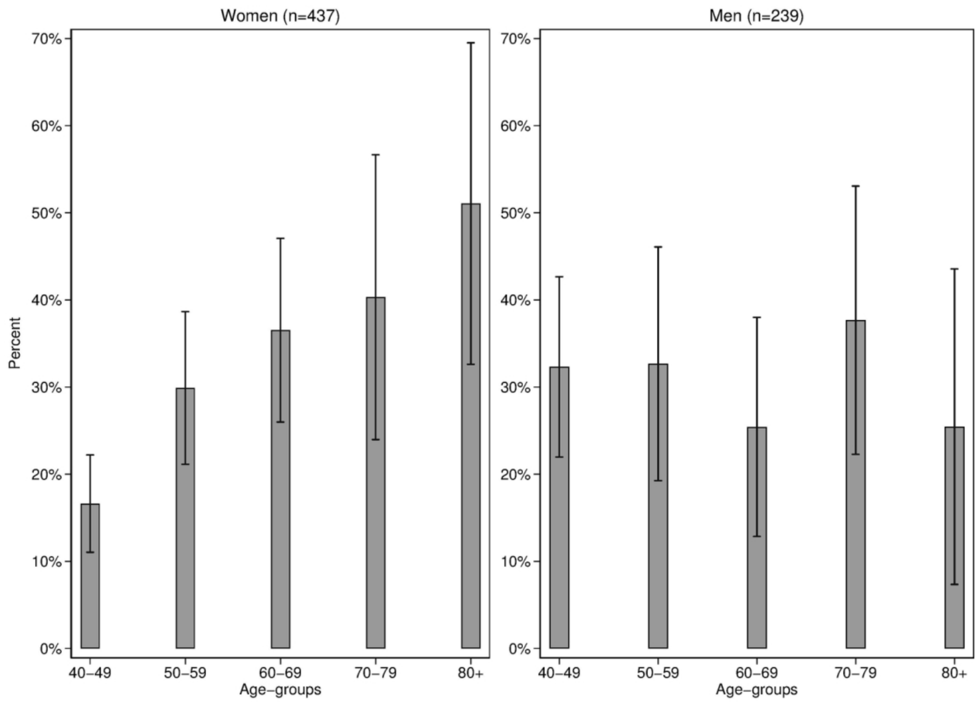


Figure 2

139x101mm (300 x 300 DPI)

SUPPLEMENTARY MATERIALS

Supplemental Table 1. Hypertension incidence rates and incidence rate ratios per 100 person-years over 5 years of follow-up (2010-2015), by sociodemographic, health and behavioral factors among the full eligible sample.

				95% CI			95% CI		
Value	**Events**	**PYRS**	**IR**	**Lower**	**Upper**	**IRR**	**Lower**	**Upper**	**p-value**
Overall	193	3187	4.579	3.911	5.361				
Gender									
Male	74	1203	5.14	4.078	6.548	1			
Female	119	1984	4.408	3.641	5.369	0.858	0.632	1.163	0.323
Age groups									
40-49	56	1418	2.795	2.117	3.755	1			
50-59	47	727	5.092	3.731	7.069	1.821	1.191	2.786	0.006
60-69	42	514	5.478	3.876	7.848	1.96	1.25	3.073	0.003
70-79	28	316	6.244	4.127	9.655	2.233	1.347	3.704	0.002
80+	20	212	8.825	5.585	14.45	3.157	1.83	5.445	<0.001
Education									
None	85	1134	6.774	5.397	8.574	1			
Less than secondary	92	1258	6.158	4.919	7.769	0.909	0.658	1.257	0.563
Secondary or more	16	298	3.756	2.19	6.868	0.555	0.305	1.008	0.053
Union status									
Not in union	91	1508	4.237	3.38	5.357	1			
Formal/informal union	102	1679	4.928	3.984	6.144	1.163	0.849	1.593	0.347
SES[a]									
Low	68	1248	3.909	3.01	5.138	1			
Middle	64	975	5.612	4.325	7.372	1.436	0.986	2.089	0.059
High	60	946	4.464	3.362	6.007	1.142	0.772	1.69	0.507
Employment status									
Not employed	144	1970	6.057	5.062	7.284	1			
Employed	48	706	6.503	4.83	8.911	1.074	0.754	1.529	0.694
Smoking history									
Never	163	2573	4.638	3.92	5.514	1			
Prior	11	218	4.314	2.36	8.558	0.93	0.49	1.765	0.825
Current	19	396	3.89	2.441	6.48	0.839	0.506	1.391	0.496
Alcohol use									
Not in past 30 days	153	2546	4.522	3.805	5.401	1			
Less than weekly	10	227	3.557	1.875	7.414	0.787	0.399	1.549	0.488

Weekly	30	414	5.546	3.691	8.558	1.227	0.784	1.92	0.372
Physical activity[b]									
Low	20	199	6.424	3.801	11.185	1			
Moderate	71	913	6.323	4.899	8.246	0.984	0.548	1.769	0.958
High	100	2017	3.798	3.073	4.733	0.591	0.335	1.043	0.07
High waist circumference[c]									
No	104	2106	3.629	2.936	4.523	1			
Yes	78	974	5.796	4.544	7.455	1.597	1.151	2.215	0.005
Diabetes[d]									
No	186	3095	4.513	3.851	5.311	1			
Yes	6	81	6.868	2.92	18.668	1.522	0.64	3.621	0.342
High triglycerides[e]									
No	122	2269	4.084	3.367	4.989	1			
Yes	59	817	5.344	4.014	7.203	1.309	0.922	1.857	0.132
HIV and ART status									
Negative	155	1522	10.254	8.726	12.104	1			
Positive, not on ART	25	490	4.615	3.054	7.246	0.45	0.286	0.708	0.001
Positive, on ART	6	178	3.553	1.52	10.122	0.346	0.145	0.827	0.017

[a] Based on a household asset index score.
[b] Based on the International Physical Activity Questionnaire (IPAQ).
[c] Greater than 102cm for men and 88cm for women.
[d] Blood glucose greater than or equal to 11.1.
[e] Greater than or equal to 1.7 mmol/l.

Supplemental Table 2. Multivariable Poisson regression of incident hypertension on sociodemographic, health and behavioral risk factors among the full eligible sample (n=721).

		95% CI		
	IRR	**Lower**	**Upper**	**p-value**
Gender				
Male	1			
Female	0.783	0.489	1.253	0.307
Age groups				
40-49	1			
50-59	1.871	1.205	2.905	0.005
60-69	1.972	1.146	3.392	0.014
70-79	2.183	1.149	4.146	0.017
80+	2.86	1.305	6.265	0.009
Education				
None	1			
Less than secondary	0.947	0.647	1.387	0.781
Secondary or more	0.607	0.3	1.227	0.164
Union status				
Not in union	1			
Formal/informal union	0.972	0.678	1.392	0.876
SES[a]				
Low	1			
Middle	1.258	0.825	1.918	0.286
High	0.963	0.599	1.55	0.878
Employment status				
Not employed	1			
Employed	1.814	1.195	2.752	0.005
Smoking history				
Never	1			
Prior	0.802	0.381	1.688	0.562
Current	0.71	0.362	1.393	0.32
Alcohol use				
Not in past 30 days	1			
Less than weekly	0.86	0.415	1.779	0.684
Weekly	1.114	0.646	1.922	0.698
Physical activity[b]				
Low	1			
Moderate	0.906	0.495	1.656	0.748

High	0.639	0.342	1.195	0.161
High waist circumference[c]				
No	1			
Yes	1.564	1.047	2.335	0.029
Diabetes[d]				
No	1			
Yes	1.047	0.438	2.506	0.917
High triglycerides[e]				
No	1			
Yes	1.126	0.776	1.633	0.532

[a] Based on a household asset index score.
[b] Based on the International Physical Activity Questionnaire (IPAQ).
[c] Greater than 102cm for men and 88cm for women.
[d] Blood glucose greater than or equal to 11.1.
[e] Greater than or equal to 1.7 mmol/l.

Supplemental Table 3. Multivariable Poisson regression of incident hypertension on sociodemographic, health (using BMI instead of waist circumference) and behavioral risk factors, and HIV and ART status among those completing baseline and follow-up time points (n=579).

		95% CI		
	IRR	**Lower**	**Upper**	**p-value**
Gender				
Male	1			
Female	0.911	0.595	1.396	0.669
Age groups				
40-49	1			
50-59	1.906	1.237	2.938	0.003
60-69	2.38	1.426	3.972	0.001
70-79	2.649	1.444	4.857	0.002
80+	2.335	1.055	5.168	0.036
Education				
None	1			
Less than secondary	1.128	0.775	1.642	0.53
Secondary or more	0.746	0.365	1.525	0.421
Union status				
Not in union	1			
Formal/informal union	0.971	0.685	1.376	0.867
SES[a]				
Low	1			
Middle	0.927	0.619	1.389	0.714
High	0.778	0.498	1.215	0.269
Employment status				
Not employed	1			
Employed	1.526	1.014	2.295	0.043
Smoking history				
Never	1			
Prior	0.732	0.342	1.565	0.421
Current	0.716	0.372	1.378	0.317
Alcohol use				
Not in past 30 days	1			
Less than weekly	0.752	0.363	1.559	0.444
Weekly	1.037	0.628	1.711	0.887
Physical activity[b]				

Low	1			
Moderate	0.721	0.419	1.242	0.239
High	0.506	0.289	0.886	0.017
Obesity[c]				
No	1			
Yes	1.902	1.315	2.751	0.001
Diabetes[d]				
No	1			
Yes	0.916	0.371	2.263	0.849
High triglycerides[e]				
No	1			
Yes	1.346	0.965	1.876	0.08
HIV and ART status				
Negative	1			
Positive, not on ART	0.504	0.315	0.809	0.004
Positive, on ART	0.507	0.221	1.165	0.11

[a] Based on a household asset index score.
[b] Based on the International Physical Activity Questionnaire (IPAQ).
[c] Greater than or equal to 30 BMI.
[d] Blood glucose greater than or equal to 11.1.
[e] Greater than or equal to 1.7 mmol/l.

Supplemental Table 4. Multivariable Poisson regression of incident hypertension (based on BP threshold only) on sociodemographic, health and behavioral risk factors, and HIV and ART status among those completing baseline and follow-up time points (n=581).

		95% CI		
	IRR	**Lower**	**Upper**	**p-value**
Gender				
Male	1			
Female	0.773	0.455	1.315	0.343
Age groups				
40-49	1			
50-59	1.902	1.17	3.093	0.01
60-69	2.06	1.166	3.641	0.013
70-79	1.432	0.658	3.117	0.366
80+	1.888	0.795	4.483	0.15
Education				
None	1			
Less than secondary	0.99	0.648	1.514	0.965
Secondary or more	0.772	0.363	1.644	0.502
Union status				
Not in union	1			
In union	0.8	0.54	1.185	0.266
SES[a]				
Low	1			
Middle	0.899	0.569	1.419	0.647
High	0.657	0.394	1.094	0.106
Employment status				
Not employed	1			
Employed	1.747	1.093	2.792	0.02
Smoking history				
Never	1			
Prior	0.612	0.237	1.581	0.311
Current	0.61	0.291	1.277	0.189
Alcohol use				
Not in past 30 days	1			
Less than weekly	0.738	0.326	1.672	0.467
Weekly	0.959	0.542	1.699	0.887
Physical activity[b]				
Low	1			
Moderate	0.973	0.5	1.894	0.936

High	0.669	0.33	1.355	0.264
High waist circumference[c]				
No	1			
Yes	1.361	0.882	2.102	0.164
Diabetes[d]				
No	1			
Yes	0.341	0.05	2.309	0.27
High triglycerides[e]				
No	1			
Yes	1.19	0.792	1.789	0.402
HIV and ART status				
Negative	1			
Positive, not on ART	0.28	0.151	0.518	<0.001
Positive, on ART	0.313	0.108	0.908	0.033

[a] Based on a household asset index score.
[b] Based on the International Physical Activity Questionnaire (IPAQ).
[c] Greater than 102cm for men and 88cm for women.
[d] Blood glucose greater than or equal to 11.1.
[e] Greater than or equal to 1.7 mmol/l.

Supplemental Table 5. Multivariable competing risk regression (Fine-Grey model) of incident hypertension on sociodemographic, health and behavioral risk factors among the full eligible sample (n=662).

		95% CI		
	SHR	**Lower**	**Upper**	**p-value**
Gender				
Male	1			
Female	0.835	0.526	1.326	0.445
Education				
None	1			
Less than secondary	1.1	0.766	1.58	0.607
Secondary or more	0.968	0.513	1.829	0.921
Union status				
Not in union	1			
Formal/informal union	1.067	0.759	1.5	0.708
SES[a]				
Low	1			
Middle	1.021	0.689	1.512	0.919
High	0.881	0.566	1.371	0.574
Employment status				
Not employed	1			
Employed	1.969	1.374	2.821	<0.001
Smoking history				
Never	1			
Prior	0.772	0.38	1.57	0.475
Current	0.73	0.367	1.451	0.369
Alcohol use				
Not in past 30 days	1			
Less than weekly	0.882	0.432	1.798	0.729
Weekly	0.899	0.506	1.597	0.716
Physical activity[b]				
Low	1			
Moderate	1.184	0.667	2.102	0.564
High	0.914	0.512	1.633	0.761
High waist circumference[c]				
No	1			
Yes	1.399	0.952	2.056	0.088
Diabetes[d]				

No	1			
Yes	1.399	0.677	2.887	0.364
High triglycerides[e]				
No	1			
Yes	1.111	0.778	1.585	0.563

[a] Based on a household asset index score.
[b] Based on the International Physical Activity Questionnaire (IPAQ).
[c] Greater than 102cm for men and 88cm for women.
[d] Blood glucose greater than or equal to 11.1.
[e] Greater than or equal to 1.7 mmol/l.

Supplemental Table 6. Cause of death by broad disease category for the full eligible sample.

Cause group	N	%
HIV/AIDS and TB	20	28
Other infectious diseases	16	23
Noncommunicable diseases	34	48
External	1	1

Cause of death information from InterVA-4. Information on cause of death missing for 4 individuals.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
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	6-7
Bias	9	Describe any efforts to address potential sources of bias	7-8
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	7-8
		(*d*) If applicable, explain how loss to follow-up was addressed	7-8
		(*e*) Describe any sensitivity analyses	8
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	9
		(b) Give reasons for non-participation at each stage	9
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9; Table 1
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	Table 2
Outcome data	15*	Report numbers of outcome events or summary measures over time	9
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	9-10, Table 2, Table 3, Table 4
		(*b*) Report category boundaries when continuous variables were categorized	Table 2, Table 3, Table 4
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11
Discussion			
Key results	18	Summarise key results with reference to study objectives	11-12
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
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	15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Hypertension incidence among middle-aged and older adults: Findings from a 5-year prospective study in rural South Africa, 2010-2015

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2021-049621.R1
Article Type:	Original research
Date Submitted by the Author:	21-Sep-2021

Complete List of Authors:	Houle , Brian ; Australian National University, School of Demography; University of the Witwatersrand School of Public Health, MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt) Gaziano, Thomas A.; Brigham and Women's Hospital, Division of Cardiovascular Medicine; Harvard University, Harvard Medical School Angotti, Nicole; American University, Department of Sociology; University of the Witwatersrand School of Public Health, MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt) Mojola, Sanyu A; Princeton University, Department of Sociology, School of Public and International Affairs, and Office of Population Research; University of the Witwatersrand School of Public Health, MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt) Kabudula, Chodziwadziwa; University of the Witwatersrand School of Public Health, MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt); INDEPTH Network Tollman, Stephen; University of the Witwatersrand School of Public Health, MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt); Umea University, Centre for Global Health Research Gómez-Olivé, F. Xavier; University of the Witwatersrand School of Public Health, MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt); Harvard University, Center for Population and Development Studies

Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Global health, HIV/AIDS
Keywords:	Hypertension < CARDIOLOGY, PUBLIC HEALTH, HIV & AIDS < INFECTIOUS DISEASES, EPIDEMIOLOGY

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Hypertension incidence among middle-aged and older adults: Findings from a 5-year prospective study in rural South Africa, 2010-2015

Brian Houle,[1,2,3] Thomas Gaziano,[4,5] Nicole Angotti,[2,3,6] Sanyu A Mojola,[2,7] Chodziwadziwa W Kabudula,[2,8] Stephen M Tollman,[2,8,9] F Xavier Gómez-Olivé[2,8,10]

1 School of Demography, The Australian National University, Canberra, ACT, Australia

2 MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt), School of Public Health, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa

3 Institute of Behavioral Science, University of Colorado Boulder, Boulder, Colorado, USA

4 Division of Cardiovascular Medicine, Brigham and Women's Hospital, Boston, MA, USA

5 Harvard Medical School, Harvard University, Boston, MA, USA

6 Department of Sociology, American University, Washington, DC, USA

7 Department of Sociology, School of Public and International Affairs, and Office of Population Research, Princeton University, Princeton, NJ, USA

8 INDEPTH Network, Accra, Ghana

9 Centre for Global Health Research, Umeå University, Umeå, Sweden

10 Harvard Center for Population and Development Studies, Harvard University, Cambridge, MA, USA

Correspondence to: Brian Houle; brian.houle@anu.edu.au

Word count: 3,146

ABSTRACT

Objectives: There is a scarcity of longitudinal cohort studies in sub-Saharan Africa to understand the epidemiology of cardiovascular disease as a basis for intervention. We estimated incident hypertension and associated sociodemographic, health and behavioural risk factors in a population aged 40 and older over a 5-year period.

Design: We assessed the association between incident hypertension and sociodemographic, health and behavioural factors using Poisson regression. We adjusted for nonresponse in 2015 using inverse probability sampling weights from a logistic regression including sex and age at baseline.

Setting: Rural South Africa.

Participants: We used a population-based cohort of normotensive adults in 2010 who were ages 40 and older at retest in 2015.

Results: Of 676 individuals completing baseline and 5-year follow-up, there were 193 incident cases of hypertension. The overall hypertension incidence rate was 8.374/100 person-years. In multivariable analyses, those that became hypertensive were more likely to be older, have a high waist circumference (incidence rate ratio (IRR): 1.557 95% CI: 1.074-2.259) and be employed (IRR: 1.579 95% CI 1.071-2.329) at baseline. Being HIV-positive and not on antiretroviral therapy at baseline was associated with lower risk of incident hypertension.

Conclusions: Over a 5-year period, 29% of respondents developed hypertension. Given the high burden of hypertension in South Africa, continued longitudinal follow-up is needed to understand the complex interplay of noncommunicable and infectious diseases and their underlying and modifiable risk factors to inform public health prevention strategies and programs.

Keywords: Hypertension; incidence; South Africa; rural population; cohort

Strengths and limitations of this study

- We provide longitudinal evidence on hypertension incidence from a population-based cohort in rural South Africa including both HIV positive and HIV negative individuals.
- Associations between HIV status and incident hypertension may be sensitive to survivorship bias if those who died due to HIV/AIDS over the five-year period were also more likely to develop hypertension.
- A longer period of follow-up is needed to assess the effects of HIV and ART on hypertension and related cardiometabolic conditions.

INTRODUCTION

Hypertension is one of the most important noncommunicable disease (NCD) risk factors and the largest contributor to the global burden of disease, with high blood pressure accounting for 7% of global disability-adjusted life years.[1] The burden of hypertension is greatest in low and middle-income countries (LMIC),[2] and has increased rapidly in sub-Saharan Africa.[3–7] A study of people aged 50 years and over from six countries found markedly high prevalence in South Africa (77.9%).[8]

Rapid demographic and epidemiological changes in LMICs, such as population aging, are expected to dramatically increase hypertension prevalence. Results from a modelling study found that without any changes in the age-specific prevalence of hypertension, the hypertensive population in South Africa is expected to grow by 105% by 2050.[9] These dramatic changes on the epidemiology of hypertension are further complicated by a lack of awareness by those with a hypertensive condition, with serious consequences of a low proportion of hypertensive individuals being on treatment.[10–12] In South Africa, an estimated 38-64% of hypertensives were aware of their status and 7.8-22.8% effectively controlled.[8,13]

Longitudinal data from sub-Saharan Africa are needed to examine changes in population-specific hypertension risk factors over time,[14] particularly given differences in socio-cultural environments and related health factors (e.g., diet, concurrent infectious diseases), and differentials in rural versus urban risk factor levels.[15] This is particularly important as widescale availability of antiretroviral therapy (ART) has reduced HIV/AIDS-related mortality[16,17] thereby increasing the population of those aging with HIV.[18] The aging population will be at higher risk of developing hypertension, and the effect of HIV and ART may also increase the incidence of hypertension.[19–22] In South Africa, an emerging dual burden of disease, along with urban-rural differences due to the legacy of the apartheid era also highlight the importance of understanding location-specific hypertension risk factors over time.[23] However, there are currently a limited number of longitudinal studies examining risk factors for incident hypertension in the region, with most of these restricted to HIV positive individuals only.[24–27]

METHODS

We use a population-based cohort of adults in rural South Africa who were normotensive in 2010-11 and were 40 years or older in 2014-15 to estimate hypertension incidence and identify sociodemographic, health and behavioural risk factors over a five-year period.

We use data from two survey studies conducted in 2010-11 and 2014-2015 in the Agincourt Health and socio-Demographic Surveillance System (HDSS) study area in rural northeast South Africa.[28] The area is a low rainfall setting with limited subsistence farming. Since 1992, the Medical Research Council (MRC)/Wits Rural Public Health and Health Transitions Unit has been conducting an annual census update of the population living in the study site, including information on vital events (births, deaths, migrations) and household and individual socio-demographic information. In 2010-11, the baseline study (Ha Nakekela) included a sex-age stratified random sample of 7,662 men and women aged 15 and older who were permanent residents from the 2009 HDSS census.[29] A follow-up study from November 2014 to November 2015 (The Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa (HAALSI)) included a random sample of 6,281 men and women aged 40 years and older who were permanent residents from the 2013 HDSS census,[30] including those in the baseline study who fulfilled the inclusion criteria. Both studies included information on sociodemographic factors and self-reported health and conditions, anthropometric and blood pressure measurements, and point of care blood tests for glucose and lipids, and dried blood spots (DBS) for HIV status.

Outcome measure

Blood pressure (BP) and hypertension. BP was measured three times using a Boso BP instrument two minutes apart in 2010 and an Omron M6W automated cuff two minutes apart in 2015. Validation studies of similar blood pressure monitoring devices indicate that they can provide accurate measurements.[31–33] Consistent with national surveillance guidance, we used the average of the second and third measurements.[34] Hypertension was defined as a systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg or if the respondent self-reported taking antihypertensive medication.

2010 risk factors

Anthropometry and high waist circumference. Height, weight, and waist circumference were measured using a flexible stadiometer (Seca). High waist circumference was defined as >102cm for men and >88cm for women.[35] Obesity was classified as a body mass index (BMI; kg/m^2) ≥30.[35]

Random blood glucose and diabetes. Point of care instruments were used to measure glucose (Caresens POP blood glucose meter). Diabetes was defined as a random blood glucose level of ≥11.1 mmol/L or if the respondent self-reported medication use for diabetes.[36]

High triglycerides. A Cardiocheck instrument was used to measure lipid levels. High triglycerides was defined as ≥1.7 mmol/l.[37]

HIV status. HIV DBS were tested using screening assay Vironostika Uniform 11 (Biomeriuex, France); with positive results retested using the SD Bioline HIV ELISA test (SD; Standard Diagnostics Inc., Korea). If the two tests were inconsistent, we conducted a third assay (Elecys, Roche, USA) that determined the final result.

Socio-demographics and behaviours. Respondents were asked about smoking (never, prior, current) and alcohol history (not in past 30 days, less than weekly, weekly), physical activity (using the International Physical Activity Questionnaire (IPAQ)), and if they were using ART. Information on years of completed education, employment (currently working for pay), union (informal or formal) and socioeconomic status (based on tertiles of an asset index[38]) were extracted from the most recent surveillance census.

Cause of death: For those who died between the baseline and follow-up study and for whom a death was identified from census updates, a verbal autopsy (VA) was conducted using a standardized VA instrument. For each identified death, a specially trained team conducted a VA interview with the closest living care taker to record signs and symptoms experienced before the death. We categorized cause of death using InterVA-4[39] – assigning a single cause for the largest likelihood for each death.

Analysis

We calculated hypertension incidence (over five years) for those aged 40 years and older at the time of the second survey overall, and by sex, age, and other socio-demographic factors. We calculated age-adjusted incidence using the Agincourt 2009 census population. We used Poisson regression with robust standard errors to examine the association of hypertension status with socio-demographic, health and behavioural risk factors from the baseline study. To adjust for nonresponse in the follow-up study, we developed inverse probability sampling weights (IPSW) based on a logistic regression including sex and age in August 2010. We multiplied the IPSW for nonresponse by the inverse probability weights from the 2010 sample selection to derive our final weights for analysis. For our fully adjusted multivariable models, we fit separate models with and without HIV/ART status given a reduced sample of 2010 respondents with measured HIV status (particularly for the eligible sample estimates, see below).

We used two approaches to estimating exposure time for our incidence estimates. For the first approach, we included only those individuals who participated in both surveys. For incident cases, we defined exposure time as the midpoint between the dates of the first and second survey assessments. For the second approach, we included all eligible individuals from the first survey who were able to be tracked from census data. For those who out-migrated or died before the start of the second study, we allowed them to contribute exposure time between their blood pressure measurement in the first study and time at death or out-migration. For those who were not found or refused to participate in the second survey, we allowed exposure time between the first study's measurement and the start of the second study. As the second approach includes additional exposure time but no new incident cases, it provides a lower bound for our estimate of hypertension incidence. Individuals who aged to 40 during the follow-up time only contributed to exposure when they had reached 40 years or older. We used Stata 15 for all statistical analyses.[40]

We also tested the sensitivity of our results. We tested models using either BMI or waist-to-hip ratio instead of waist circumference. We also tested a model of hypertension based on only BP thresholds to assess if there were differences in the associations between predictors and incident BP only. Finally, we tested a competing-risk model for those eligible individuals who either died, migrated, or completed the follow-up study to test for bias in our risk factor associations. We modelled incident hypertension as the main event and death due to any cause as a competing event (censoring those who out-migrated) using the Fine-Grey model.[41]

Patient and public involvement

Neither study participants nor public were involved in study design or conduct of the study. The HDSS Learning, Information dissemination and Networking with Community (LINC) office manages community liaison activities with the HDSS study communities and their leaders. Annual feedback of findings from the HDSS census and research projects conducted in the site are provided through open village meetings, with frequent participation from local service providers.

RESULTS

Figure 1 shows the participant flowchart. A total of 977 individuals were eligible for analysis from the first study and 676 (69%) also completed the second study. Table 1 presents sample characteristics from the baseline study comparing those who completed the second study and those who did not. Women, those with a high waist circumference, those in older ages and in a union with lower completed education were more likely to participate in the second study.

There were 193 incident cases of hypertension since baseline. The overall hypertension incidence rate was 8.374 per 100 person-years (95% CI: 7.242-9.721) for those completing both studies (men 9.097 (95% CI: 7.266-11.496); women 8.159 (95% CI: 6.832-9.804); Table 2). The overall age-adjusted hypertension incidence rate for those completing both studies was 8.372 per 100 person-years (men 8.955; women 8.50). Rates were lower when including the full eligible sample (Online supplemental table 1). Men in their 40s and 50s had higher incidence compared to same-aged women; from ages 60-plus, women showed higher rates than men (Figure 2).

Table 2 shows incident rates and ratios (unadjusted) for those completing both studies by baseline socio-demographic, health, and behavioural risk factors. Older individuals had higher incident hypertension risk compared to those ages 40-49. Those with high waist circumference and elevated triglycerides had a higher risk of incident hypertension. Respondents engaging in high physical activity levels had a lower risk of incident hypertension compared to those with low physical activity levels. Compared to those HIV-negative at baseline, those HIV-positive and not on ART had a 55% lower risk of developing hypertension over the 5 years of follow-up, while those on ART also had lower hypertensive risk. Results for the full eligible sample are presented in online supplemental table 1.

Table 3 shows the multivariable-adjusted results from the full Poisson regression excluding HIV status for those completing both studies (see online supplemental table 2 for the full eligible sample results). Older ages (e.g., ages 60-69 aIRR: 2.4 95% CI: 1.463-3.938), being employed (aIRR: 1.579 95% CI: 1.071-2.329), and having a high waist circumference (aIRR: 1.557 95% CI: 1.074-2.259) were associated with higher risk of incident hypertension in 2015. Those engaging in high levels of physical activity had an approximately 43% lower risk of incident hypertension, although the 95% CI overlapped with the null value of 1 (95% CI: 0.319-1.018)

Table 4 shows the same multivariable-adjusted Poisson model as Table 3 including HIV status, with similar results to those risk factors from the model without HIV status. The results for high waist circumference were in the same direction but the 95% CI overlapped with the null value of 1. Those who were HIV-positive and not on ART had an approximately 52% lower risk of incident hypertension compared to those HIV-negative at baseline (95% CI 0.301-0.778), while those HIV-positive and on ART showed similar associations to those not on ART.

Results of the sensitivity analyses of alternate anthropometry measures showed similar associations for BMI as for waist circumference (online supplemental table 3). There were not enough cases of high waist-to-hip ratio to include in the models. A model examining an outcome based only on BP thresholds also showed similar associations to the original models (online supplemental table 4). For the competing risk model, high rates of missing data on HIV/ART status precluded including that indicator. Results omitting HIV/ART status at baseline are presented in online supplemental table 5, showing similar results to the full eligible sample (online supplemental table 2). Cause of death information according to broad cause groups is presented in online supplemental table 6.

DISCUSSION

In 1998, South Africa had approximately 6.3 million adults with hypertension.[42] Now it is estimated to be close to 12 million, nearly doubling despite population growth of about 34% over the same time period, with prevalence increasing from 24% to over 40% in some populations.[43] Based on our finding of 8.37 per 100 person-years, we estimate that roughly 1.4 million adults over the age of 40 will develop hypertension over the next five years. Given an increase of nearly 50% in the risk of ischemic heart disease and stroke death for each 10 mmHg increase,[44] the results suggest both a significant increase in the number of people in need of additional treatment, and premature mortality if not adequately controlled.

We found that 29% of middle-aged and older adults in our study developed hypertension over a five-year period. Our results were similar to another study from South Africa following individuals ages 30-plus over five years (2005-2010) who started with optimal blood pressure. They found a relatively similar incidence of 24%[27] given the slightly younger age range.

We showed that men have higher hypertension incidence rates in mid-life, while women had higher rates at older ages. This is likely due at least in part to the smaller sample size of men in our study. A potentially similar pattern was shown in a study in South Africa (2004-2016) of patients initiating ART at 10 public sector clinics (9 urban, 1 rural) which included a wider age range (ages 18-50-plus).[24] They found that men had higher hypertension incidence rates at ages 18-39, while women had higher rates at ages 40-49 and 50-plus. Our finding may also be due to greater employment for middle-aged men[45] and higher survival[17 46] or obesity[47 48] among older women.

In multivariable-adjusted models, we found that being employed and having a high waist circumference at baseline were risk factors for incident hypertension. Another study in South Africa also found that high waist circumference was a key risk factor, along with alcohol intake.[27] While we showed no association with alcohol use, our sample also had low self-reported use of alcohol, with 80% reporting not drinking in the past month, which may be due to response bias.[49] Given the limited employment opportunities in our setting,[28] a higher risk of hypertension amongst employed individuals may represent those more likely to be exposed to workplace-related stress and other behavioural factors such as diet[50 51] that may differ from those not employed.

We found that being HIV-positive at baseline was associated with a lower risk of incident hypertension. This also aligns with an earlier study in South Africa that showed that being HIV-positive was inversely related to increased BP.[27] However, our results may be sensitive to survivorship bias if those who died due to HIV/AIDS over the five-year period were also more likely to develop hypertension. Of the 71 individuals for whom mortality information is available, about 28% died due to HIV/AIDS or TB. If a substantial portion of those individuals developed hypertension this may affect our estimates of the association between HIV/ART status and risk of incident hypertension. Further, as we lacked information on HIV/ART status for many individuals in the eligible sample who did not complete the follow-up study, this may affect our estimates if those individuals were more likely to be HIV-positive.[52] A longer period of follow-up is needed to assess the effects of HIV and ART on hypertension and related cardiometabolic conditions. Longitudinal studies restricted to HIV-positive individuals have shown high hypertension incident rates over relatively short periods of follow-up and similar risk factors to the HIV-negative population.[25 26]

Our longitudinal findings are particularly important given the complex health transition occurring in South Africa, with a concomitant burden of infectious and noncommunicable diseases.[17 23 29 47] A study from the same community as our study demonstrated a high and increasing burden of stroke morbidity and mortality.[53] While our findings are consistent with hypertension-related risk factors found in other regions, population-specific studies such as ours are important to contextualize the epidemiological findings from elsewhere and inform local prevention and treatment strategies.[14] They also provide an opportunity to understand the interaction between cardiometabolic and infectious diseases such as HIV. A longer period of follow-up, which will be possible as future waves of the study are completed, will permit a greater understanding of the interplay between hypertension, HIV, and treatment of both and related conditions.

We acknowledge our study limitations. While our study is one of the few population-based, longitudinal cohorts on hypertension incidence in Africa, the study comes from a defined region in rural northeast South Africa. Additional studies are needed in other settings, particularly given differences in exposures and differential risk factors in rural and urban contexts. We include a wide range of potential risk factors based on existing studies. Other factors, however, such as migration history, would be important to consider given the high levels of circular labour migration in this setting and potential links of rural to urban migration to increased blood pressure.[54–57] Other important factors to consider include nutritional factors such as consumption of fruits and vegetables and salt intake. Further, food insecurity is highly prevalent in this setting[58] and may lead to differential hypertension risk due to dietary differences. Given the high level of missing data on HIV/ART status amongst the eligible population who did not complete the follow-up study, we were unable to assess the effect of HIV/ART in a competing risk framework. Our measure of ART status is also based on self-report and may be subject to response bias, as well as factors related to HIV awareness such as engagement with health services.[59] Our self-reported measures may also be subject to social desirability and recall bias.

Over a period of five years, 29% of individuals developed hypertension in a population-based cohort of individuals ages 40 and older given an incidence rate of 8.374 per 100 person-years. Abdominal obesity was one of the most consistent risk factors. Being employed was also a predictor of incident hypertension. As South Africa continues to undergo a complex health and epidemiological transition, continued longitudinal follow-up is needed to understand the complex interplay of noncommunicable and infectious diseases, along with their underlying and modifiable risk factors. In response to the call for longitudinal studies from sub-Saharan Africa on hypertension risk, this study contributes to the evidence base that can help inform and target public health strategies to reduce preventable morbidity and mortality.

Acknowledgements

The authors thank the study participants and all those involved in the successful field operations in Ha Nakekela, HAALSI and the Agincourt HDSS.

Contributions: BH wrote the first draft and designed and completed the statistical analyses. FXG, BH, TG and SMT conceptualized the work. FXG, NA, CWK, and SMT designed and implemented the baseline study. TG, FXG, CWK, and SMT designed and implemented the follow-up study. TG, NA, SAM, CWK, SMT, and FXG revised the manuscript for important intellectual content and contributed to interpretation of the data. All authors read and approved the final manuscript.

Funding: The Ha Nakekela study was supported by the National Institutes of Health [R24 AG032112-05] and the William and Flora Hewlett Foundation 2009-4060 African Population Research and Training Program. Data analysis for this study, part of the HIV after 40 in rural South Africa project, was funded by the US National Institute on Aging [R01 AG049634] and the University of Colorado, Innovative Seed Grant [not applicable].

HAALSI was supported by the U.S. National Institute on Aging [P01AG041710; 1R01AG051144-01; 3U54HG006938-03S1].

The MRC/Wits Rural Public Health and Health Transitions Research Unit and Agincourt Health and Socio-Demographic Surveillance System, a node of the South African Population Research Infrastructure Network (SAPRIN), is supported by the Department of Science and Innovation [not applicable], the University of the Witwatersrand [not applicable], and the

Medical Research Council, South Africa [not applicable], and previously the Wellcome Trust, UK (Grants 058893/Z/99/A; 069683/Z/02/Z; 085477/Z/08/Z; 085477/B/08/Z).

Competing interests: None declared.

Ethics approval: Ethical clearance for both surveys and the HDSS were obtained from the University of the Witwatersrand Human Research Ethics Committee (Medical) [M10458 and M141159] and the Mpumalanga Provincial Research and Ethics Committee. The baseline study also received ethical approval from the Institutional Review Board of the University of Colorado – Boulder [11-0549] and the follow-up study from the Harvard TH Chan School of Public Health, Office of Human Research Administration [C13-1608-02]. Written consent to participate was obtained for all participants in the baseline study. Each respondent in the follow-up study also provided written, informed consent (or by a proxy, when needed).

Data sharing: The datasets generated and/or analysed for the follow-up study are available at the Harvard Center for Population and Development Studies (HCPDS) program website: www.haalsi.org. The data supporting the findings of this study are available from the corresponding author on reasonable request.

REFERENCES

1. Lim, S. S., T. Vos, A. D. Flaxman, G. Danaei, K. Shibuya, H. Adair-Rohani, M. A. AlMazroa, M. Amann, H. R. Anderson, and K. G. Andrews. 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. *The Lancet* 2013;380:2224-2260.
2. Ibrahim, M. M., and A. Damasceno. Hypertension in developing countries. *The Lancet* 2012;380:611-619.
3. Bosu, W. K., S. T. Reilly, J. M. K. Aheto, and E. Zucchelli. Hypertension in older adults in Africa: A systematic review and meta-analysis. *PloS One* 2019;14:e0214934.
4. Guwatudde, D., J. Nankya-Mutyoba, R. Kalyesubula, C. Laurence, C. Adebamowo, I. Ajayi, F. Bajunirwe, M. Njelekela, F. S. Chiwanga, T. Reid, J. Volmink, H. O. Adami, M. D. Holmes, and S. Dalal. The burden of hypertension in sub-Saharan Africa: a four-country cross sectional study. *BMC Public Health* 2015;15:1211.
5. Kaze, A. D., A. E. Schutte, S. Erqou, A. P. Kengne, and J. B. Echouffo-Tcheugui. Prevalence of hypertension in older people in Africa. *Journal of Hypertension* 2017;35:1345-1352.
6. Sarki, A. M., C. U. Nduka, S. Stranges, N. B. Kandala, and O. A. Uthman. Prevalence of Hypertension in Low- and Middle-Income Countries: A Systematic Review and Meta-Analysis. *Medicine* 2015;94:e1959.
7. Twagirumukiza, M., D. De Bacquer, J. G. Kips, G. de Backer, R. V. Stichele, and L. M. Van Bortel. Current and projected prevalence of arterial hypertension in sub-Saharan Africa by sex, age and habitat: an estimate from population studies. *J Hypertens* 2011;29:1243-1252.
8. Lloyd-Sherlock, P., J. Beard, N. Minicuci, S. Ebrahim, and S. Chatterji. Hypertension among older adults in low- and middle-income countries: prevalence, awareness and control. *International Journal of Epidemiology* 2014;43:116-128.
9. Sudharsanan, N., and P. Geldsetzer. Impact of Coming Demographic Changes on the Number of Adults in Need of Care for Hypertension in Brazil, China, India, Indonesia, Mexico, and South Africa. *Hypertension* 2019;73:770-776.
10. Addo, J., L. Smeeth, and D. A. Leon. Hypertension in sub-saharan Africa: a systematic review. *Hypertension* 2007;50:1012-1018.
11. Gómez-Olivé, F. X., S. A. Ali, F. Made, C. Kyobutungi, E. Nonterah, L. Micklesfield, M. Alberts, and R. Boua. Stark Regional and Sex Differences in the Prevalence and Awareness of Hypertension: An H3Africa AWI-Gen Study Across 6 Sites in Sub-Saharan Africa. *Global Heart* 2017
12. Ataklte, F., S. Erqou, S. Kaptoge, B. Taye, J. B. Echouffo-Tcheugui, and A. P. Kengne. Burden of undiagnosed hypertension in sub-saharan Africa: a systematic review and meta-analysis. *Hypertension* 2015;65:291-298.
13. Jardim, T. V., S. Reiger, S. Abrahams-Gessel, F. X. Gomez-Olive, R. G. Wagner, A. Wade, T. W. Bärnighausen, J. Salomon, S. Tollman, and T. A. Gaziano. Hypertension management in a population of older adults in rural South Africa. *Journal of Hypertension* 2017;35:1283-1289.
14. Kengne, A. P., L. M. Ntyintyane, and B. M. Mayosi. A systematic overview of prospective cohort studies of cardiovascular disease in sub-Saharan Africa. *Cardiovascular Journal of Africa* 2012;23:103-112.

15. Holmes, M. D., S. Dalal, J. Volmink, C. A. Adebamowo, M. Njelekela, W. W. Fawzi, W. C. Willett, and H. O. Adami. Non-communicable diseases in sub-Saharan Africa: the case for cohort studies. *PLoS Med* 2010;7:e1000244.
16. Herbst, A. J., G. S. Cooke, T. Bärnighausen, A. KanyKany, F. Tanser, and M. Newell. Adult mortality and antiretroviral treatment roll-out in rural KwaZulu-Natal, South Africa. *Bulletin of the World Health Organization* 2009;87:754-762.
17. Kabudula, C. W., B. Houle, M. A. Collinson, K. Kahn, F. X. Gómez-Olivé, S. J. Clark, and S. Tollman. Progression of the epidemiological transition in a rural South African setting: findings from population surveillance in Agincourt, 1993-2013. *BMC Public Health* 2017;17:424.
18. Vollmer, S., K. Harttgen, T. Alfven, J. Padayachy, P. Ghys, and T. Bärnighausen. The HIV epidemic in sub-Saharan Africa is aging: Evidence from the Demographic and Health Surveys in sub-Saharan Africa. *AIDS Behav* 2016;21:101-113.
19. Anand, A. R., G. Rachel, and D. Parthasarathy. HIV proteins and endothelial dysfunction: Implications in cardiovascular disease. *Front Cardiovasc Med* 2018;5:185.
20. Grinspoon, S., and A. Carr. Cardiovascular risk and body-fat abnormalities in HIV-infected adults. *New England Journal of Medicine* 2005;352:48-62.
21. Dillon, D. G. Association of HIV and ART with cardiometabolic traits in sub-Saharan Africa: a systematic review and meta-analysis. *International Journal of Epidemiology* 2013;42:1754-1771.
22. Rigaud, A.-S., and B. Forette. Hypertension in older adults. *Journal of Gerontology* 2001;56A:M217-M225.
23. Mayosi, B. M., A. J. Flisher, U. G. Lalloo, F. Sitas, S. M. Tollman, and D. Bradshaw. The burden of non-communicable diseases in South Africa. *Lancet* 2009;374:934-947.
24. Brennan, A. T., L. Jamieson, N. J. Crowther, M. P. Fox, J. A. George, K. M. Berry, A. Stokes, M. Maskew, I. Sanne, and L. Long. Prevalence, incidence, predictors, treatment, and control of hypertension among HIV-positive adults on antiretroviral treatment in public sector treatment programs in South Africa. *PloS One* 2018;13:e0204020.
25. Okello, S., M. Kanyesigye, W. R. Muyindike, B. H. Annex, P. W. Hunt, S. Haneuse, and M. J. Siedner. Incidence and predictors of hypertension in adults with HIV-initiating antiretroviral therapy in south-western Uganda. *J Hypertens* 2015;33:2039-2045.
26. Rodríguez-Arbolí, E., K. Mwamelo, A. V. Kalinjuma, H. Furrer, C. Hatz, M. Tanner, M. Battegay, E. Letang, and S. G. KIULARCO. Incidence and risk factors for hypertension among HIV patients in rural Tanzania - A prospective cohort study. *PLoS One* 2017;12:e0172089.
27. Schutte, A. E., R. Schutte, H. W. Huisman, J. M. van Rooyen, C. M. Fourie, N. T. Malan, L. Malan, C. M. Mels, W. Smith, S. J. Moss, G. W. Towers, H. S. Kruger, E. Wentzel-Viljoen, H. H. Vorster, and A. Kruger. Are behavioural risk factors to be blamed for the conversion from optimal blood pressure to hypertensive status in Black South Africans? A 5-year prospective study. *International Journal of Epidemiology* 2012;41:1114-1123.
28. Kahn, K., M. A. Collinson, F. X. Gomez-Olive, O. Mokoena, R. Twine, P. Mee, S. A. Afolabi, B. D. Clark, C. W. Kabudula, A. Khosa, S. Khoza, M. G. Shabangu, B. Silaule, J. B. Tibane, R. G. Wagner, M. L. Garenne, S. J. Clark, and S. M. Tollman. Profile: Agincourt Health and Socio-demographic Surveillance System. *Int J Epidemiol* 2012;41:988-1001.

29. Gómez-Olivé, F. X., N. Angotti, B. Houle, K. Klipstein-Grobusch, C. Kabudula, J. Menken, J. Williams, S. Tollman, and S. J. Clark. Prevalence of HIV among those 15 and older in rural South Africa. *AIDS Care* 2013;25:1122-1128.
30. Gómez-Olivé, F. X., L. Montana, R. G. Wagner, C. W. Kabudula, J. K. Rohr, K. Kahn, T. Bärnighausen, M. Collinson, D. Canning, T. Gaziano, J. A. Salomon, C. F. Payne, A. Wade, S. M. Tollman, and L. Berkman. Cohort Profile: Health and Ageing in Africa: a Longitudinal Study of an INDEPTH Community in South Africa (HAALSI). *International Journal of Epidemiology* 2018;47:689-690j.
31. Altunkan, S., K. Öztas, and E. Altunkan. Validation of the Omron 637IT wrist blood pressure measuring device with a position sensor according to the International Protocol in adults and obese adults. *Blood Pressure Monitoring* 2006;11:79-85.
32. Saladini, F., E. Benetti, and P. Palatini. Accuracy of the visomat handy wrist blood pressure measuring device according to the International Protocol. *Blood Press Monit* 2010;15:281-284.
33. Omboni, S., I. Riva, A. Giglio, G. Caldara, A. Groppelli, and G. Parati. Validation of the Omron M5-I, R5-I and HEM-907 automated blood pressure monitors in elderly individuals according to the International Protocol of the European Society of Hypertension. *Blood Pressure Monitoring* 2007;12:233-242.
34. Centers for Disease Control and Prevention (CDC). National Health and Nutrition Examination Survey: 1999-2000 Data Documentation, Codebook, and Frequencies. 2002
35. US Department of Health and Human Services. 2004. *The seventh report of the Joint National Committee on prevention, detection, evaluation, and treatment of high blood pressure*. National Heart, Lung, and Blood Institute (US), NIH Publication No. 04-5230.
36. World Health Organization. 2007. *Prevention of cardiovascular disease. Pocket guidelines for assessment and management of cardiovascular risk: (WHO/ISH cardiovascular risk prediction charts for the African region)*. World Health Organization, Geneva.
37. US Department of Health and Human Services. 2004. *The seventh report of the Joint National Committee on prevention, detection, evaluation, and treatment of high blood pressure*. National Heart, Lung, and Blood Institute (US),
38. Kabudula, C., B. Houle, M. A. Collinson, K. Kahn, S. Tollman, and S. Clark. Assessing changes in household socioeconomic status in rural South Africa, 2001-2013: a distributional analysis using household asset indicators. *Social Indicators Research* 2016;133:1047-1073.
39. Byass, P., D. Chandramohan, S. J. Clark, L. D'Ambruoso, E. Fottrell, W. J. Graham, A. J. Herbst, A. Hodgson, S. Hounton, K. Kahn, A. Krishnan, J. Leitao, F. Odhiambo, O. A. Sankoh, and S. M. Tollman. Strengthening standardised interpretation of verbal autopsy data: the new InterVA-4 tool. *Glob Health Action* 2012;5:1-8.
40. StataCorp. 2017. *Stata Statistical Software: Release 15*. StataCorp, LP, College Station, TX.
41. Fine, J. P., and R. J. Gray. A Proportional Hazards Model for the Subdistribution of a Competing Risk. *Journal of the American Statistical Association* 1999;94:496-509.
42. Steyn, K., T. A. Gaziano, D. Bradshaw, R. Laubscher, and J. Fourie. Hypertension in South African adults: results from the Demographic and Health Survey, 1998. *Journal of Hypertension* 2001;19:1717-1725.
43. Ntuli, S. T., E. Maimela, M. Alberts, S. Choma, and S. Dikotope. Prevalence and associated risk factors of hypertension amongst adults in a rural community of Limpopo Province, South Africa. *Afr J Prim Health Care Fam Med* 2015;7:847.

44. Chobanian, A. V., G. L. Bakris, H. R. Black, W. C. Cushman, L. A. Green, J. L. Izzo Jr, D. W. Jones, B. J. Materson, S. Oparil, and J. T. Wright Jr. The seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure: the JNC 7 report. *JAMA* 2003;289:2560-2571.
45. Blalock, C. L. Labor migration and employment in post-apartheid rural South Africa. *Department of Sociology* 2014;Doctor of Philosophy
46. Houle, B., S. J. Clark, F. X. Gómez-Olivé, K. Kahn, and S. M. Tollman. The unfolding counter-transition in rural South Africa: mortality and cause of death, 1994-2009. *PLoS One* 2014;9:e100420.
47. Clark, S. J., F. X. Gómez-Olivé, B. Houle, M. Thorogood, K. Klipstein-Grobusch, N. Angotti, C. Kabudula, J. Williams, J. Menken, and S. Tollman. Cardiometabolic disease risk and HIV status in rural South Africa: establishing a baseline. *BMC Public Health* 2015;15:372.
48. Gaziano, T. A., S. Abrahams-Gessel, F. X. Gomez-Olive, A. Wade, N. J. Crowther, S. Alam, J. Manne-Goehler, C. W. Kabudula, R. Wagner, J. Rohr, L. Montana, K. Kahn, T. W. Bärnighausen, L. F. Berkman, and S. Tollman. Cardiometabolic risk in a population of older adults with multiple co-morbidities in rural south africa: the HAALSI (Health and Aging in Africa: longitudinal studies of INDEPTH communities) study. *BMC Public Health* 2017;17:206.
49. Houle, B., N. Angotti, F. X. Gómez-Olivé, and S. J. Clark. Fieldworker effects on substance use reporting in rural South Africa. *International Journal of Alcohol and Drug Research* 2018;7:29-39.
50. Maredza, M., K. J. Hofman, and T. Tollman. A hidden menace: cardiovascular disease in South Africa and the costs of an inadequate policy response: health policy and cardiovascular disease. *SA Heart* 2011;8:48-57.
51. Feeley, A. B. B., K. Kahn, R. Twine, and S. A. Norris. Exploratory survey of informal vendor-sold fast food in rural South Africa. *South African Journal of Clinical Nutrition* 2011;24:199-201.
52. Clark, S. J., and B. Houle. Validation, replication, and sensitivity testing of Heckman-type selection models to adjust estimates of HIV prevalence. *PLoS One* 2014;9:e112563.
53. Maredza, M., M. Y. Bertram, and S. M. Tollman. Disease burden of stroke in rural South Africa: an estimate of incidence, mortality and disability adjusted life years. *BMC Neurol* 2015;15:54.
54. Collinson, M. A., M. J. White, P. Bocquier, S. T. McGarvey, S. A. Afolabi, S. J. Clark, K. Kahn, and S. M. Tollman. Migration and the epidemiological transition: insights from the Agincourt sub-district of northeast South Africa. *Global Health Action* 2014;7:23514.
55. Pheiffer, C. F., S. T. McGarvey, C. Ginsburg, M. Collinson, F. X. Gómez-Olivé, S. Tollman, and M. J. White. Dimensions of internal migration and their relationship to blood pressure in South Africa. *J Biosoc Sci* 20191-16.
56. Poulter, N. R., K. T. Khaw, B. E. Hopwood, M. Mugambi, W. S. Peart, G. Rose, and P. S. Sever. The Kenyan Luo migration study: observations on the initiation of a rise in blood pressure. *BMJ* 1990;300:967-972.
57. Steyn, K., D. Bradshaw, R. Norman, and R. Laubscher. Determinants and treatment of hypertension in South Africans: the first Demographic and Health Survey. *South African Medical Journal* 2008;98:376-380.
58. Hunter, L. M., W. Twine, and L. Patterson. "Locusts are now our beef": adult mortality and household dietary use of local environmental resources in rural South Africa. *Scand J Public Health Suppl* 2007;69:165-174.

59. Manne-Goehler, J., L. Montana, F. X. Gómez-Olivé, J. Rohr, G. Harling, R. G. Wagner, A. Wade, C. W. Kabudula, P. Geldsetzer, K. Kahn, S. Tollman, L. F. Berkman, T. W. Bärnighausen, and T. A. Gaziano. The ART advantage: healthcare utilization for diabetes and hypertension in rural South Africa. *JAIDS Journal of Acquired Immune Deficiency Syndromes* 2017;75:561-567.

FIGURE CAPTIONS

Figure 1. Participant flowchart.

Figure 2. Proportion of participants with incident hypertension, by age and gender, 2015.

Table 1. Sample characteristics at baseline (2010), by study participation in 2015 for eligible individuals (n=977).

	Lost to follow-up (n=301)		Completed 2015 (n=676)			Total (n=977)	
	n	%	n	%	p-value	n	%
Gender							
Male	140	(46.5)	239	(35.4)	0.001	379	(38.8)
Female	161	(53.5)	437	(64.6)		598	(61.2)
Age groups							
35-44	130	(43.2)	227	(33.6)	0.003	357	(36.5)
45-54	71	(23.6)	180	(26.6)		251	(25.7)
55-64	34	(11.3)	126	(18.6)		160	(16.4)
65-74	29	(9.6)	81	(12.0)		110	(11.3)
75+	37	(12.3)	62	(9.2)		99	(10.1)
Education							
None	40	(34.2)	277	(41.0)	0.018	317	(40.0)
Less than secondary	54	(46.2)	327	(48.4)		381	(48.0)
Secondary or more	23	(19.7)	72	(10.7)		95	(12.0)
Union status							
Not in union	166	(55.1)	302	(44.7)	0.002	468	(47.9)
Formal/informal union	135	(44.9)	374	(55.3)		509	(52.1)
SES[a]							
Low	130	(43.2)	253	(37.7)	0.258	383	(39.4)
Middle	86	(28.6)	216	(32.2)		302	(31.1)
High	85	(28.2)	202	(30.1)		287	(29.5)
Employment status							
Not employed	80	(68.4)	498	(74.1)	0.196	578	(73.3)
Employed	37	(31.6)	174	(25.9)		211	(26.7)
Smoking history							
Never	236	(78.4)	548	(81.1)	0.206	784	(80.2)
Prior	18	(6.0)	49	(7.2)		67	(6.9)
Current	47	(15.6)	79	(11.7)		126	(12.9)
Alcohol use							
Not in past 30 days	235	(78.1)	544	(80.5)	0.686	779	(79.7)
Less than weekly	24	(8.0)	47	(7.0)		71	(7.3)
Weekly	42	(14.0)	85	(12.6)		127	(13.0)
Physical activity[b]							
Low	27	(9.4)	40	(6.0)	0.128	67	(7.0)

Moderate	80	(27.9)	209	(31.3)		289	(30.3)
High	180	(62.7)	419	(62.7)		599	(62.7)
High waist circumference[c]							
No	205	(72.7)	430	(65.8)	0.04	635	(67.9)
Yes	77	(27.3)	223	(34.2)		300	(32.1)
Diabetes[d]							
No	293	(98.0)	655	(97.2)	0.46	948	(97.4)
Yes	6	(2.0)	19	(2.8)		25	(2.6)
High triglycerides[e]							
No	213	(72.7)	479	(73.5)	0.805	692	(73.2)
Yes	80	(27.3)	173	(26.5)		253	(26.8)

HIV/ART is not included given missing values (n=297) for the vast majority of those lost to follow-up.

[a] Based on a household asset index score.

[b] Based on the International Physical Activity Questionnaire (IPAQ).

[c] Greater than 102cm for men and 88cm for women.

[d] Blood glucose greater than or equal to 11.1.

[e] Greater than or equal to 1.7 mmol/l.

Table 2. Hypertension incidence rates and incidence rate ratios per 100 person-years over 5 years of follow-up (2010-2015), by sociodemographic, health and behavioural factors among those completing both time points.

				95% CI			95% CI		
Value	**Events**	**PYRS**	**IR**	**Lower**	**Upper**	**IRR**	**Lower**	**Upper**	**p-value**
Overall	193	2311	8.374	7.242	9.721				
Gender									
Male	74	815	9.097	7.266	11.496	1			
Female	119	1496	8.159	6.832	9.804	0.897	0.67	1.2	0.463
Age groups									
40-49	56	975	5.04	3.837	6.73	1			
50-59	47	556	8.897	6.667	12.077	1.765	1.177	2.647	0.006
60-69	42	399	11.104	8.282	15.14	2.203	1.464	3.315	<0.001
70-79	28	239	11.875	8.285	17.436	2.356	1.486	3.735	<0.001
80+	20	141	16.197	10.647	25.379	3.213	1.931	5.348	<0.001
Education									
None	85	986	9.256	7.491	11.536	1			
Less than secondary	92	1090	8.21	6.645	10.229	0.887	0.655	1.202	0.439
Secondary or more	16	235	5.318	3.112	9.652	0.575	0.319	1.034	0.065
Union status									
Not in union	91	1034	8.613	6.983	10.709	1			
Formal/informal union	102	1277	8.165	6.685	10.051	0.948	0.706	1.273	0.722
SES[a]									
Low	68	867	8.064	6.328	10.397	1			
Middle	64	736	8.715	6.798	11.305	1.081	0.759	1.539	0.667
High	60	689	8.389	6.449	11.056	1.04	0.723	1.497	0.831
Employment status									
Not employed	144	1701	8.336	7.048	9.911	1			
Employed	48	595	8.511	6.375	11.557	1.021	0.726	1.435	0.905
Smoking history									
Never	163	1861	8.644	7.392	10.155	1			
Prior	11	171	6.356	3.501	12.447	0.735	0.391	1.381	0.339
Current	19	279	6.715	4.293	10.956	0.777	0.478	1.262	0.308
Alcohol use									
Not in past 30 days	153	1852	8.416	7.167	9.931	1			
Less than weekly	10	167	5.459	2.879	11.284	0.649	0.331	1.272	0.208
Weekly	30	292	9.789	6.708	14.649	1.163	0.766	1.765	0.478
Physical activity[b]									

Low	20	122	15.468	9.85	24.91	1			
Moderate	71	687	10.641	8.402	13.61	0.688	0.412	1.149	0.153
High	100	1471	6.98	5.718	8.59	0.451	0.275	0.742	0.002
High waist circumference[c]									
No	104	1512	6.519	5.326	8.046	1			
Yes	78	735	10.571	8.483	13.283	1.621	1.197	2.196	0.002
Diabetes[d]									
No	186	2240	8.298	7.156	9.662	1			
Yes	6	64	10.06	4.451	26.006	1.212	0.529	2.778	0.649
High triglycerides[e]									
No	122	1660	7.262	6.049	8.775	1			
Yes	59	575	10.59	8.177	13.88	1.458	1.057	2.012	0.022
HIV and ART status									
Negative	155	1514	10.452	8.909	12.318	1			
Positive, not on ART	25	486	4.749	3.15	7.439	0.454	0.289	0.713	0.001
Positive, on ART	6	178	3.553	1.52	10.122	0.34	0.142	0.811	0.015

[a] Based on a household asset index score.
[b] Based on the International Physical Activity Questionnaire (IPAQ).
[c] Greater than 102cm for men and 88cm for women.
[d] Blood glucose greater than or equal to 11.1.
[e] Greater than or equal to 1.7 mmol/l.

Table 3. Multivariable Poisson regression of incident hypertension on sociodemographic, health and behavioural risk factors among those completing both time points (n=616).

		95% CI		
	aIRR	Lower	Upper	p-value
Gender				
Male	1			
Female	0.818	0.512	1.305	0.399
Age groups				
40-49	1			
50-59	1.831	1.193	2.811	0.006
60-69	2.4	1.463	3.938	<0.001
70-79	2.607	1.451	4.684	<0.001
80+	2.561	1.196	5.488	<0.001
Education				
None	1			
Less than secondary	1.061	0.732	1.537	0.755
Secondary or more	0.741	0.372	1.478	0.395
Union status				
Not in union	1			
Formal/informal union	1.023	0.724	1.445	0.899
SES[a]				
Low	1			
Middle	1.068	0.715	1.593	0.749
High	0.915	0.59	1.42	0.693
Employment status				
Not employed	1			
Employed	1.579	1.071	2.329	0.021
Smoking history				
Never	1			
Prior	0.758	0.37	1.55	0.447
Current	0.709	0.373	1.349	0.295
Alcohol use				
Not in past 30 days	1			
Less than weekly	0.717	0.345	1.492	0.373
Weekly	1.07	0.652	1.755	0.789
Physical activity[b]				
Low	1			
Moderate	0.781	0.447	1.364	0.385

High	0.57	0.319	1.018	0.057
High waist circumference[c]				
No	1			
Yes	1.557	1.074	2.259	0.02
Diabetes[d]				
No	1			
Yes	0.932	0.399	2.178	0.87
High triglycerides[e]				
No	1			
Yes	1.297	0.932	1.805	0.123

[a] Based on a household asset index score.
[b] Based on the International Physical Activity Questionnaire (IPAQ).
[c] Greater than 102cm for men and 88cm for women.
[d] Blood glucose greater than or equal to 11.1.
[e] Greater than or equal to 1.7 mmol/l.

Table 4. Multivariable Poisson regression of incident hypertension on sociodemographic, health and behavioural risk factors, and HIV and ART status among those completing both time points (n=581).

		95% CI		
	aIRR	**Lower**	**Upper**	**p-value**
Gender				
Male	1			
Female	0.854	0.533	1.369	0.512
Age groups				
40-49	1			
50-59	1.846	1.183	2.879	0.007
60-69	2.128	1.281	3.535	0.004
70-79	2.339	1.256	4.356	0.007
80+	2.139	0.978	4.676	0.057
Education				
None	1			
Less than secondary	1.124	0.765	1.652	0.552
Secondary or more	0.754	0.368	1.542	0.439
Union status				
Not in union	1			
In union	0.939	0.662	1.332	0.724
SES[a]				
Low	1			
Middle	0.97	0.647	1.454	0.883
High	0.812	0.519	1.269	0.36
Employment status				
Not employed	1			
Employed	1.604	1.064	2.419	0.024
Smoking history				
Never	1			
Prior	0.727	0.34	1.554	0.411
Current	0.661	0.345	1.267	0.213
Alcohol use				
Not in past 30 days	1			
Less than weekly	0.751	0.358	1.574	0.448
Weekly	1.111	0.668	1.846	0.685
Physical activity[b]				
Low	1			
Moderate	0.77	0.434	1.365	0.371

High	0.56	0.309	1.015	0.056
High waist circumference[c]				
No	1			
Yes	1.448	0.975	2.149	0.066
Diabetes[d]				
No	1			
Yes	0.907	0.392	2.102	0.82
High triglycerides[e]				
No	1			
Yes	1.34	0.956	1.877	0.089
HIV and ART status				
Negative	1			
Positive, not on ART	0.484	0.301	0.778	0.003
Positive, on ART	0.462	0.197	1.082	0.075

[a] Based on a household asset index score.

[b] Based on the International Physical Activity Questionnaire (IPAQ).

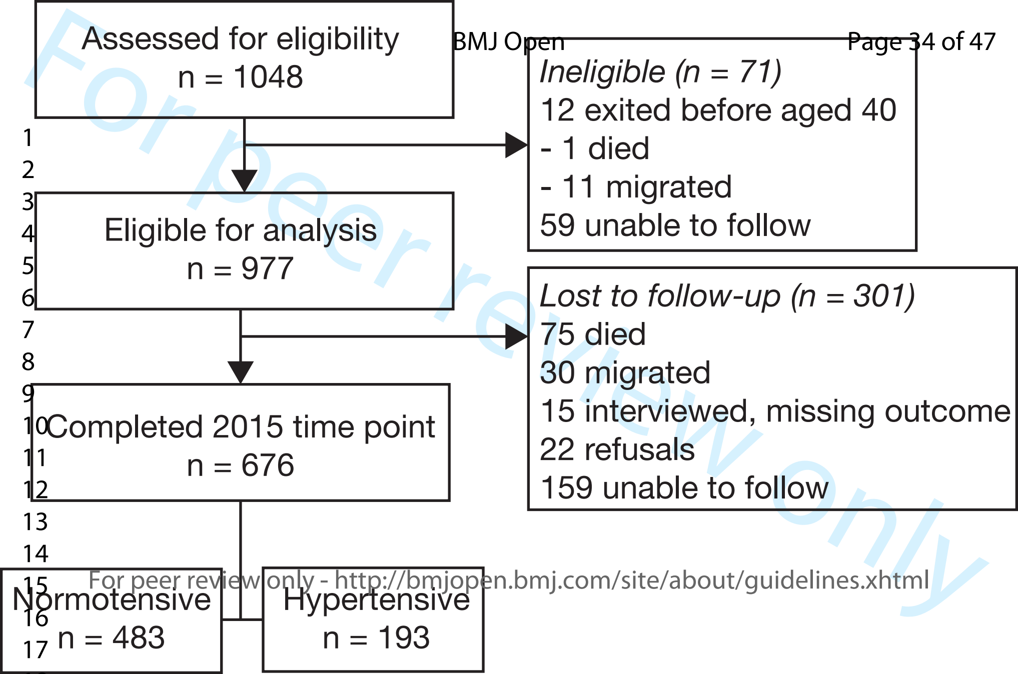
[c] Greater than 102cm for men and 88cm for women.

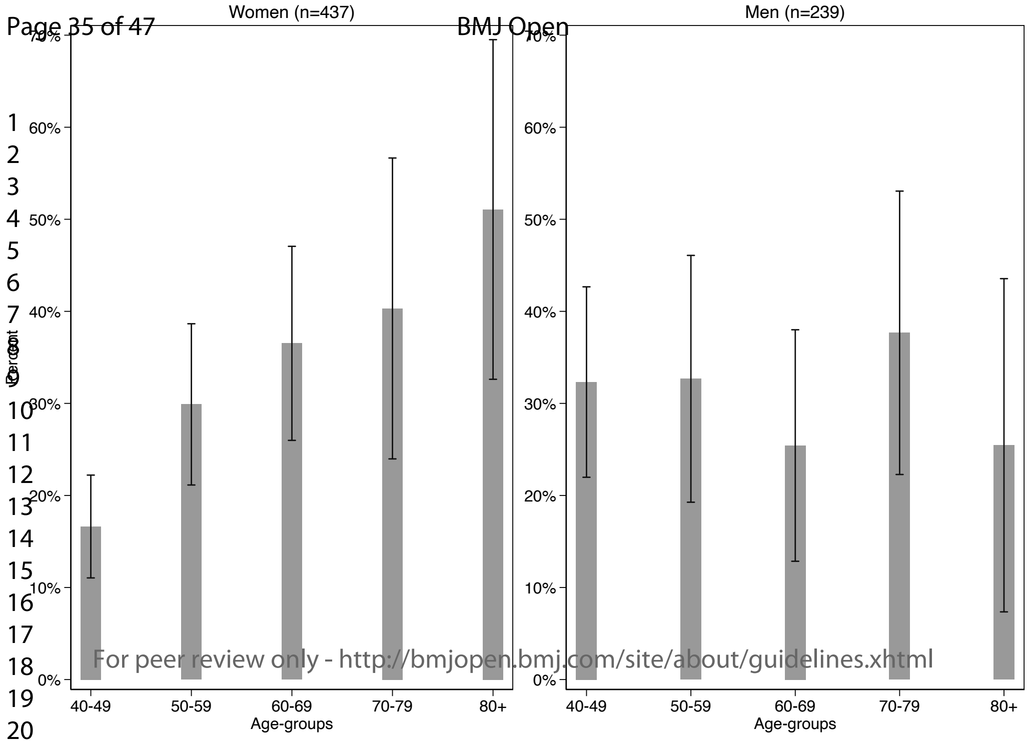
[d] Blood glucose greater than or equal to 11.1.

[e] Greater than or equal to 1.7 mmol/l.

Supplementary Materials

Online Supplemental Tables 1-6


Assessed for eligibility
n = 1048
Ineligible (n = 71)
12 exited before aged 40
- 1 died
- 11 migrated
59 unable to follow
Eligible for analysis
n = 977
Lost to follow-up (n = 301)
75 died
30 migrated
15 interviewed, missing outcome
22 refusals
159 unable to follow
Completed 2015 time point
n = 676
Normotensive
n = 483
Hypertensive
n = 193


Women (n=437)
Men (n=239)
Percent
0%
10%
20%
30%
40%
50%
60%
70%
40-49
50-59
60-69
70-79
80+
Age-groups

SUPPLEMENTARY MATERIALS

Supplemental Table 1. Hypertension incidence rates and incidence rate ratios per 100 person-years over 5 years of follow-up (2010-2015), by sociodemographic, health and behavioral factors among the full eligible sample.

				95% CI			95% CI		
Value	**Events**	**PYRS**	**IR**	**Lower**	**Upper**	**IRR**	**Lower**	**Upper**	**p-value**
Overall	193	3187	4.579	3.911	5.361				
Gender									
Male	74	1203	5.14	4.078	6.548	1			
Female	119	1984	4.408	3.641	5.369	0.858	0.632	1.163	0.323
Age groups									
40-49	56	1418	2.795	2.117	3.755	1			
50-59	47	727	5.092	3.731	7.069	1.821	1.191	2.786	0.006
60-69	42	514	5.478	3.876	7.848	1.96	1.25	3.073	0.003
70-79	28	316	6.244	4.127	9.655	2.233	1.347	3.704	0.002
80+	20	212	8.825	5.585	14.45	3.157	1.83	5.445	<0.001
Education									
None	85	1134	6.774	5.397	8.574	1			
Less than secondary	92	1258	6.158	4.919	7.769	0.909	0.658	1.257	0.563
Secondary or more	16	298	3.756	2.19	6.868	0.555	0.305	1.008	0.053
Union status									
Not in union	91	1508	4.237	3.38	5.357	1			
Formal/informal union	102	1679	4.928	3.984	6.144	1.163	0.849	1.593	0.347
SES[a]									
Low	68	1248	3.909	3.01	5.138	1			
Middle	64	975	5.612	4.325	7.372	1.436	0.986	2.089	0.059
High	60	946	4.464	3.362	6.007	1.142	0.772	1.69	0.507
Employment status									
Not employed	144	1970	6.057	5.062	7.284	1			
Employed	48	706	6.503	4.83	8.911	1.074	0.754	1.529	0.694
Smoking history									
Never	163	2573	4.638	3.92	5.514	1			
Prior	11	218	4.314	2.36	8.558	0.93	0.49	1.765	0.825
Current	19	396	3.89	2.441	6.48	0.839	0.506	1.391	0.496
Alcohol use									
Not in past 30 days	153	2546	4.522	3.805	5.401	1			
Less than weekly	10	227	3.557	1.875	7.414	0.787	0.399	1.549	0.488

Weekly	30	414	5.546	3.691	8.558	1.227	0.784	1.92	0.372
Physical activity[b]									
Low	20	199	6.424	3.801	11.185	1			
Moderate	71	913	6.323	4.899	8.246	0.984	0.548	1.769	0.958
High	100	2017	3.798	3.073	4.733	0.591	0.335	1.043	0.07
High waist circumference[c]									
No	104	2106	3.629	2.936	4.523	1			
Yes	78	974	5.796	4.544	7.455	1.597	1.151	2.215	0.005
Diabetes[d]									
No	186	3095	4.513	3.851	5.311	1			
Yes	6	81	6.868	2.92	18.668	1.522	0.64	3.621	0.342
High triglycerides[e]									
No	122	2269	4.084	3.367	4.989	1			
Yes	59	817	5.344	4.014	7.203	1.309	0.922	1.857	0.132
HIV and ART status									
Negative	155	1522	10.254	8.726	12.104	1			
Positive, not on ART	25	490	4.615	3.054	7.246	0.45	0.286	0.708	0.001
Positive, on ART	6	178	3.553	1.52	10.122	0.346	0.145	0.827	0.017

[a] Based on a household asset index score.
[b] Based on the International Physical Activity Questionnaire (IPAQ).
[c] Greater than 102cm for men and 88cm for women.
[d] Blood glucose greater than or equal to 11.1.
[e] Greater than or equal to 1.7 mmol/l.

Supplemental Table 2. Multivariable Poisson regression of incident hypertension on sociodemographic, health and behavioral risk factors among the full eligible sample (n=721).

		95% CI		
	aIRR	**Lower**	**Upper**	**p-value**
Gender				
Male	1			
Female	0.783	0.489	1.253	0.307
Age groups				
40-49	1			
50-59	1.871	1.205	2.905	0.005
60-69	1.972	1.146	3.392	0.014
70-79	2.183	1.149	4.146	0.017
80+	2.86	1.305	6.265	0.009
Education				
None	1			
Less than secondary	0.947	0.647	1.387	0.781
Secondary or more	0.607	0.3	1.227	0.164
Union status				
Not in union	1			
Formal/informal union	0.972	0.678	1.392	0.876
SES[a]				
Low	1			
Middle	1.258	0.825	1.918	0.286
High	0.963	0.599	1.55	0.878
Employment status				
Not employed	1			
Employed	1.814	1.195	2.752	0.005
Smoking history				
Never	1			
Prior	0.802	0.381	1.688	0.562
Current	0.71	0.362	1.393	0.32
Alcohol use				
Not in past 30 days	1			
Less than weekly	0.86	0.415	1.779	0.684
Weekly	1.114	0.646	1.922	0.698
Physical activity[b]				
Low	1			
Moderate	0.906	0.495	1.656	0.748

High	0.639	0.342	1.195	0.161
High waist circumference[c]				
No	1			
Yes	1.564	1.047	2.335	0.029
Diabetes[d]				
No	1			
Yes	1.047	0.438	2.506	0.917
High triglycerides[e]				
No	1			
Yes	1.126	0.776	1.633	0.532

[a] Based on a household asset index score.
[b] Based on the International Physical Activity Questionnaire (IPAQ).
[c] Greater than 102cm for men and 88cm for women.
[d] Blood glucose greater than or equal to 11.1.
[e] Greater than or equal to 1.7 mmol/l.

Supplemental Table 3. Multivariable Poisson regression of incident hypertension on sociodemographic, health (using BMI instead of waist circumference) and behavioral risk factors, and HIV and ART status among those completing baseline and follow-up time points (n=579).

		95% CI		
	aIRR	**Lower**	**Upper**	**p-value**
Gender				
Male	1			
Female	0.911	0.595	1.396	0.669
Age groups				
40-49	1			
50-59	1.906	1.237	2.938	0.003
60-69	2.38	1.426	3.972	0.001
70-79	2.649	1.444	4.857	0.002
80+	2.335	1.055	5.168	0.036
Education				
None	1			
Less than secondary	1.128	0.775	1.642	0.53
Secondary or more	0.746	0.365	1.525	0.421
Union status				
Not in union	1			
Formal/informal union	0.971	0.685	1.376	0.867
SES[a]				
Low	1			
Middle	0.927	0.619	1.389	0.714
High	0.778	0.498	1.215	0.269
Employment status				
Not employed	1			
Employed	1.526	1.014	2.295	0.043
Smoking history				
Never	1			
Prior	0.732	0.342	1.565	0.421
Current	0.716	0.372	1.378	0.317
Alcohol use				
Not in past 30 days	1			
Less than weekly	0.752	0.363	1.559	0.444
Weekly	1.037	0.628	1.711	0.887
Physical activity[b]				

Low	1			
Moderate	0.721	0.419	1.242	0.239
High	0.506	0.289	0.886	0.017
Obesity[c]				
No	1			
Yes	1.902	1.315	2.751	0.001
Diabetes[d]				
No	1			
Yes	0.916	0.371	2.263	0.849
High triglycerides[e]				
No	1			
Yes	1.346	0.965	1.876	0.08
HIV and ART status				
Negative	1			
Positive, not on ART	0.504	0.315	0.809	0.004
Positive, on ART	0.507	0.221	1.165	0.11

[a] Based on a household asset index score.
[b] Based on the International Physical Activity Questionnaire (IPAQ).
[c] Greater than or equal to 30 BMI.
[d] Blood glucose greater than or equal to 11.1.
[e] Greater than or equal to 1.7 mmol/l.

Supplemental Table 4. Multivariable Poisson regression of incident hypertension (based on BP threshold only) on sociodemographic, health and behavioral risk factors, and HIV and ART status among those completing baseline and follow-up time points (n=581).

		95% CI		
	aIRR	**Lower**	**Upper**	**p-value**
Gender				
Male	1			
Female	0.773	0.455	1.315	0.343
Age groups				
40-49	1			
50-59	1.902	1.17	3.093	0.01
60-69	2.06	1.166	3.641	0.013
70-79	1.432	0.658	3.117	0.366
80+	1.888	0.795	4.483	0.15
Education				
None	1			
Less than secondary	0.99	0.648	1.514	0.965
Secondary or more	0.772	0.363	1.644	0.502
Union status				
Not in union	1			
In union	0.8	0.54	1.185	0.266
SES[a]				
Low	1			
Middle	0.899	0.569	1.419	0.647
High	0.657	0.394	1.094	0.106
Employment status				
Not employed	1			
Employed	1.747	1.093	2.792	0.02
Smoking history				
Never	1			
Prior	0.612	0.237	1.581	0.311
Current	0.61	0.291	1.277	0.189
Alcohol use				
Not in past 30 days	1			
Less than weekly	0.738	0.326	1.672	0.467
Weekly	0.959	0.542	1.699	0.887
Physical activity[b]				
Low	1			
Moderate	0.973	0.5	1.894	0.936

High	0.669	0.33	1.355	0.264
High waist circumference[c]				
No	1			
Yes	1.361	0.882	2.102	0.164
Diabetes[d]				
No	1			
Yes	0.341	0.05	2.309	0.27
High triglycerides[e]				
No	1			
Yes	1.19	0.792	1.789	0.402
HIV and ART status				
Negative	1			
Positive, not on ART	0.28	0.151	0.518	<0.001
Positive, on ART	0.313	0.108	0.908	0.033

[a] Based on a household asset index score.
[b] Based on the International Physical Activity Questionnaire (IPAQ).
[c] Greater than 102cm for men and 88cm for women.
[d] Blood glucose greater than or equal to 11.1.
[e] Greater than or equal to 1.7 mmol/l.

Supplemental Table 5. Multivariable competing risk regression (Fine-Grey model) of incident hypertension on sociodemographic, health and behavioral risk factors among the full eligible sample (n=662).

		95% CI		
	SHR	Lower	Upper	p-value
Gender				
Male	1			
Female	0.835	0.526	1.326	0.445
Education				
None	1			
Less than secondary	1.1	0.766	1.58	0.607
Secondary or more	0.968	0.513	1.829	0.921
Union status				
Not in union	1			
Formal/informal union	1.067	0.759	1.5	0.708
SES[a]				
Low	1			
Middle	1.021	0.689	1.512	0.919
High	0.881	0.566	1.371	0.574
Employment status				
Not employed	1			
Employed	1.969	1.374	2.821	<0.001
Smoking history				
Never	1			
Prior	0.772	0.38	1.57	0.475
Current	0.73	0.367	1.451	0.369
Alcohol use				
Not in past 30 days	1			
Less than weekly	0.882	0.432	1.798	0.729
Weekly	0.899	0.506	1.597	0.716
Physical activity[b]				
Low	1			
Moderate	1.184	0.667	2.102	0.564
High	0.914	0.512	1.633	0.761
High waist circumference[c]				
No	1			
Yes	1.399	0.952	2.056	0.088
Diabetes[d]				

No	1			
Yes	1.399	0.677	2.887	0.364
High triglycerides[e]				
No	1			
Yes	1.111	0.778	1.585	0.563

[a] Based on a household asset index score.
[b] Based on the International Physical Activity Questionnaire (IPAQ).
[c] Greater than 102cm for men and 88cm for women.
[d] Blood glucose greater than or equal to 11.1.
[e] Greater than or equal to 1.7 mmol/l.

Supplemental Table 6. Cause of death by broad disease category for the full eligible sample.

Cause group	N	%
HIV/AIDS and TB	20	28
Other infectious diseases	16	23
Noncommunicable diseases	34	48
External	1	1

Cause of death information from InterVA-4. Information on cause of death missing for 4 individuals.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
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	6-7
Bias	9	Describe any efforts to address potential sources of bias	7-8
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	7-8
		(*d*) If applicable, explain how loss to follow-up was addressed	7-8
		(*e*) Describe any sensitivity analyses	8
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	9
		(b) Give reasons for non-participation at each stage	9
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9; Table 1
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	Table 2
Outcome data	15*	Report numbers of outcome events or summary measures over time	9
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	9-10, Table 2, Table 3, Table 4
		(*b*) Report category boundaries when continuous variables were categorized	Table 2, Table 3, Table 4
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11
Discussion			
Key results	18	Summarise key results with reference to study objectives	11-12
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
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	15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.