HIV Status and Risk Factors for Hypertension in South African Adults

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Abstract

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Background: As treatment innovations increase the life expectancy of those with HIV, the relationship between HIV infection, hypertension risk and subsequent CVD is increasingly important to understand. We investigated the relationship between HIV infection and hypertension among a cohort of ART-naïve South African adults presenting for voluntary HIV screening.

Methods: We conducted a cross-sectional, observational study among adults (≥18 years) presenting for voluntary HIV testing in an urban township of KwaZulu-Natal, South Africa. We measured resting blood pressure prior to HIV testing among the entire cohort. We then measured another resting blood pressure among HIV-infected adults after they received their HIV test result and a clinical examination. We defined hypertension as having a resting systolic blood pressure ≥ 140 mmHg or a diastolic blood pressure ≥ 90 mmHg. We used logistic regression to analyze the risk factors for hypertension among both the entire cohort and among

HIV-infected adults, to describe the association between HIV infection, CD4 count, and hypertension.

Results: Among 2,904 adults screened for hypertension, mean age was 31.0 years (SD=9.66), 51.0% were female, and 37.9% screened positive for HIV. Diastolic blood pressure was significantly higher after HIV testing, among those testing HIV-positive. In univariate analyses among the entire cohort, older age, male sex, current marriage, having >1 child, higher income, and alcohol use were all significantly associated with hypertension. In a multivariate model, older age, male sex, alcohol use and HIV infection were independently associated with a higher odds of hypertension. In this model, being HIV-positive was associated with a 30% lower odds of having hypertension, compared to those testing HIV-negative (aOR=0.70, 95% CI: 0.54, 0.90, p=0.006). In a separate univariate model restricted to the HIV-positive adults, older age, current marriage, having >1 child, glucose level ≥120 mg/dl, obesity (body mass index >=30 kg/m2), and CD4 count above the median 300 cells/mm^3 were all significantly associated with hypertension. In a multivariate model for this subgroup, older age, obesity (body mass index >=30 kg/m2), and CD4 count above 300 cells/mm^3 were independently associated with a higher odds of having hypertension. In this model, CD4 count above 300 cells/mm^3 was found to be associated with 78% higher odds of having hypertension, compared to those with a CD4 <300 (aOR=1.78, 95% CI: 1.13, 2.80, p=0.013).

Conclusions: At HIV screening, HIV-infected adults had lower odds of hypertension, compared to those testing HIV-negative, after adjustment for other risk factors; among HIV-positive participants, those with lower CD4 counts had lower odds of hypertension. Screening for chronic hypertension at HIV diagnosis may be masked by HIV-status and severe immunosuppression, so

a general approach to CVD screening for hypertension at HIV diagnosis may not reflect the true population risk.

Introduction

Approximately 36.9 million people were living with HIV/AIDS in LMICs in 2014.[1] The dynamics of the HIV/AIDS epidemic are shifting as treatment innovations emerge. As treatment has scaled up to include 16 million people receiving antiretroviral therapy (ART), new HIV infections have fallen by 35% since 2000 and AIDS-related deaths have fallen by 42% since 2004.[1,2] As a global system for HIV/AIDS care and treatment with antiretroviral therapy (ART) has been established, there is a need to provide the infrastructure to screen and treat the growing burden of non-communicable diseases (NCDs).[2,3] Cardiovascular disease (CVD), including heart attacks and strokes, is the leading cause of mortality globally, and the majority of these deaths occur in low- and middle-income countries (LMICs).[4]

Hypertension is a significant risk factor for cardiovascular disease, and the relationship between HIV infection, hypertension risk and subsequent CVD is important to understand.[5] Recent meta-analyses both globally and in sub-Saharan African countries suggest that HIV is associated with significantly lower measurements for both systolic blood pressure (SBP) and diastolic blood pressure (DBP), but that the relationship may be modified by use of antiretroviral therapy (ART).[6,7] A recent meta-analysis of HIV infected adults found risk of hypertension was significantly higher among ART-exposed patients compared to treatment-naïve patients, and a study in Cameroon found that hypertension in HIV-positive patients on treatment was twice that of those not yet on treatment; the biological mechanisms for this difference remain unclear.[7,8] Most studies that have compared HIV-positive patients to those that are HIV-negative have had HIV-positive study populations largely on treatment for infection.[8,9,10,11] A recent study in rural South Africa found lower odds of hypertension among those HIV-positive and not yet on treatment when compared to those HIV-negative, but the result lacked statistical significance.[12]

South Africa has an estimated 6.8 million people living with HIV/AIDS, and around half of those are accessing treatment.[13] Globally, around 22% of adults over the age of 18 had raised blood pressure in 2014; by contrast, 2008 estimates indicated a prevalence of 33.7% in South African adults.[14,15] We sought to understand the relationship between HIV infection and hypertension among a cohort of ART-naïve South African adults at initial diagnosis of HIV. The major aims of this study were to 1) identify risk factors for hypertension in a cohort of ART-naïve South African adults, 2) describe the association between HIV infection status and severity with hypertension in this same population, and a sub-aim was to compare blood pressure measurements pre- and post-HIV diagnosis, among those testing positive for HIV.

Methods

Study design and participants

We conducted a cross-sectional, observational study as part of a cryptococcal screening study among adults in the outpatient department of the iThembalabantu People's Hope Clinic in the Umlazi township of South Africa.

All enrolled participants were ≥18 years of age, antiretroviral-naïve, English or Zulu speaking, and were willing and able to provide written informed consent for study participation. Exclusion criteria include those patients known to be pregnant or having received anti-fungal therapy within three months. Ethical approval was obtained from Partners Healthcare in Boston, the University of Washington in Seattle, and the University of KwaZulu-Natal Biomedical Ethics Research Council in Durban. All participants received routine medical care, including CD4 count testing and initiation of ART according to current South African guidelines.

Data collection

Research assistants in the study clinic identified and enrolled eligible participants prior to HIV testing, collecting basic demographic and health-related measures, including a seated, resting blood pressure (Supplementary Figure 1). Participants were then seen by a counselor for HIV testing and counseling. Those participants who tested HIV-positive were then escorted to a research nurse, and further health-related measurements were taken, including a second blood pressure measurement. Those participants testing HIV-negative did not visit the research nurse but instead were counseled on safe sex practices and advised to return for repeat HIV testing in several months.

Exposures and covariates

All data collected in this study was logged and stored using REDCap software. In this study, the primary exposures of interest were HIV status (positive or negative) and HIV severity among those HIV positive (measured by CD4 count above or below median value of cells/mm^3). The outcome for assessment in this analysis was hypertension, with "hypertensive" defined as systolic blood pressure (SBP) ≥140 mmHg or diastolic blood pressure (DBP) ≥ 90 mmHg, which correlates with Stage I and Stage II hypertension, according to CDC and WHO blood pressure guidelines.[16,17]

Key covariates for consideration in this study for all participants include age (years), sex, marital status (never married, married, widowed/divorced), number of children (none, 1, >1 child), church attendance (none, every week, only occasionally), education (none, primary school or some high school, high school completion or higher), current employment (none, <20 hours/week, >20 hours/week), income (<2,000 ZAR [South African Rand, ~130 USD])/month, ≥2,000 ZAR/month), food insecurity, travel method to the clinic site (walking, public transport, private car, or other), anxiety (Generalized Anxiety [GAD]-7 score ≥ 10), depression (Patient Health Questionnaire [PHQ]-9 score ≥ 10), cigarette or alcohol use (never used, some use but not within last month, use within last month), and intravenous drug or cannabis use (ever used).[18,19] Additional covariates considered in this study only for those participants testing HIV-positive include glucose level (≥120 mg/dl), and body mass index (BMI) (below 18.5, 18.5-24.9, 25.0-29.9, 30.0+ kg/m^2).[20]

Statistical analyses

Risk factors for hypertension were assessed using chi-square tests of association, or Fisher's exact tests for cell counts <5 in two separate cohorts: all participants, or only those

testing HIV+ (due to additional covariates available for these participants, including glucose level, BMI, and CD4 count). Wald tests for association were used in our univariate and multivariate analyses. Backwards logistic regression was used to build multivariate models, initially including all covariates with a p-value threshold of 0.2, and results were reported as odds ratios (ORs) with 95% confidence intervals (CIs). Pre- and post-HIV diagnosis blood pressure measurements were compared for concordance linearly using paired t-tests of SBP and DBP separately, and blood pressure measurements taken before HIV testing were used for all univariate and multivariate analyses. All statistical analyses were performed using Stata 13 (StataCorp, College Station, TX).

Results

We enrolled 3,081 participants and included the 2,904 participants with complete blood pressure data in this analysis. Median age among the entire cohort was 28.7 years, mean age was 31.0 years (SD=9.66), and 51.0% were female (Table 1). Most participants were never married (92.4%), and almost half had completed high school or higher (49.1%). The majority of participants were not currently employed (58.8%) and had an income <2,000 ZAR/month (83.5%). 12.8% of participants had anxiety, and 17.3% had depression. Cigarette and alcohol use were the most commonly used substances, with 22.9% and 32.6% of participants using within the last month, respectively. Overall, 1,102 participants (37.9%) in this study tested positive for HIV. Those found to be hypertensive were more likely to be older, male, married, have >1 child, have an income ≥ 2,000 ZAR/month, and have a history of alcohol use. Of the total eligible participants, 336 (11.6%) were found to be hypertensive.

Among the HIV-positive cohort, the median age was 31.8 years. Females accounted for 59.7% of those testing HIV-positive in this cohort (Table 2). The majority of HIV-positive participants had >1 child (51.4%), and were less likely to have completed high school or higher (36.2%). Anxiety and depression prevalence was 17.4% and 24.1%, respectively. Median glucose level was 98 mg/dl (mean=102.5 mg/dl, SD=33.0), median BMI was 24.1 kg/m^2 (mean=25.5 kg/m^2, SD=6.4) and 20.4% of HIV-positive participants had a BMI over 30.0 kg/m^2. Median CD4 count was 299 cells/mm3 (mean=338.3 $cells/mm^3$, SD=243.9). Those found to be hypertensive in this subgroup were more likely to be older, male, have >1 child, and have a glucose level ≥120 mg/dl, a BMI >30 kg/m^2, and a CD4 count ≥ 300 $cells/mm^3$. Of those testing HIV-positive, 112 (10.2%) were hypertensive.

Older age was significantly associated with hypertension in the entire cohort (Table 3) as well as the HIV-positive subset (Table 4), with the highest ORs among those 50 years of age or older. In the entire cohort, males were 66% more likely than females to be hypertensive (95% CI: 1.32, 2.10), but no significant differences by sex were seen among HIV-positive patients. Being currently married was associated with hypertension in both cohorts when compared to having never been married, as was having had more than one child when compared to having no children.

Among the entire cohort, higher income was associated with hypertension. Alcohol use was also associated with hypertension, both for some use not within the last month and for use within the last month. No similar association was seen for these covariates among the HIV-positive participants.

Three clinical indicators available only for HIV-positive patients were all associated with hypertension: glucose level $\geq$ 120 mg/dl, BMI 30.0 and above when compared to 18.5-24.9, and our main exposure of interest, CD4 count above the median of 300 cells/mm^3 (OR=1.65, 95% CI: 1.07, 2.53).

The results of our multivariate analyses in the entire cohort suggest that older age, male sex, alcohol use, and HIV status are all independently associated with hypertension (Table 3). After adjusting for age, sex, anxiety, and alcohol use, being HIV-positive was associated with a 30% lower odds of hypertension when compared to those who are HIV-negative (aOR=0.70, 95% CI: 0.54, 0.90, p=0.006).

Multivariate analyses among the HIV-positive suggest that age and BMI 30+ are independently associated with hypertension. Median glucose level was only available for 492 participants, and was not a confounder in this analysis. Due to the amount of missing data for

this variable, it was excluded from multivariate models. After adjusting for age, anxiety, alcohol use, and BMI, CD4 count above the median 300 cells/mm^3 was found to be associated with 78% higher odds of hypertension compared to those with lower CD4 count in this cohort (aOR=1.78, 95% CI: 1.13, 2.80, p=0.013).

Mean SBP prior to HIV screening was similar among those found to be HIV-negative (118.5 mmHg) and HIV-positive (116.2 mmHg), as was DBP (71.3 mmHg and 68.5 mmHg, respectively). Among those testing HIV-positive, mean SBP as measured after HIV screening (117.7 mmHg) and mean SBP as measured before HIV screening (116.2 mmHg), were not found to be significantly different (p=0.0775). Mean DBP as measured after HIV screening in this same cohort (79.9 mmHg), however, was significantly different from mean DBP measured before screening (68.5 mmHg, p<0.0001) (Figure 1).

Discussion

In this cross-sectional study of ART-naïve South African adults, HIV infection was associated with a 30% lower odds of hypertension among those testing HIV-positive compared to those testing HIV-negative, when adjusting for age, sex, anxiety, and alcohol use. Among HIV-positive participants, we found 78% higher odds of hypertension among those with higher CD4 counts (above the median of 300 cells/mm^3), when adjusting for age, anxiety, alcohol use and BMI. In the entire cohort, older age, male sex, alcohol use and HIV status were all found to be independently associated with hypertension. Among those testing HIV-positive, older age, BMI above 30.0 kg/m^2, and CD4 count were found to be independently associated with hypertension.

Risk factors for hypertension identified in these analyses were in line with results of other studies conducted globally.[8,10,21,22] A recent study among a random sample of 3,641 rural South Africans also found lower odds of hypertension among those with HIV and not yet on treatment when compared to those HIV-negative, comparable to the relationship assessed in our study, though their results lacked statistical significance.[12]

Several studies in Africa and globally have compared HIV-negative and HIV-positive subjects in relation to hypertension, but have had HIV-positive cohorts that were already largely on treatment for the infection.[9,10,21,23,,24] A clinic-based study of 1009 patients in southern Brazil found a high prevalence of hypertension among HIV-infected adults (between 13% and 45%) which was similar to their HIV-negative general population, however 73% of their HIV-infected patients were currently receiving treatment for the infection.[10] A small hospital-based, cross-sectional study of 44 patients in Cameroon found 43.2% of HIV-infected adults with hypertension, but 70.5% of patients were on ART and no stratification by ART use was

conducted.[9] Conversely, a large study of over 65,000 people in rural Uganda, HIV-negative persons had 20% higher odds of hypertension than HIV-positive persons, though prevalence of ART use was not reported.[21]

A recent systematic review and meta-analysis of Sub-Saharan African countries found that HIV infection was significantly associated with lower SBP and DBP separately when compared to HIV-negative persons, but also suggested that the relationship may be modified by use of ART.[6] A case-control study of acute stroke in Malawi found HIV to be a risk factor, but highest risk was in the first six months after starting ART.[23] A US cohort study of 3,141 patients had 90% of all participants on treatment for the infection, and when stratified by time on ART, those taking it for five or more years had the highest incidence rates of hypertension, whereas the lowest incidence rates were among those who had never started taking ART (though not statistically significant).[24]

Studies looking only at HIV-positive cohorts in sub-Saharan African countries have found similar patterns. A clinic-based cross-sectional study in Southwestern Uganda found a high prevalence (17%) of metabolic abnormalities among 250 HIV-positive persons on ART for at least two years, though they found higher rates among females than males.[11] A hospital-based cross-sectional study of 200 HIV-positive patients in Cameroon found hypertension in patients on treatment for the infection was twice that of treatment-naïve patients.[8] A systematic review and meta-analysis of 39 worldwide studies found that exposure to ART was significantly associated with increased SBP and DBP among HIV-infected patients.[7]

Similar to other studies, the results of our analyses suggest that HIV infection is associated with lower odds of hypertension, and that more severe disease is associated with lower odds of hypertension among those testing positive for HIV. As our cohort in this study was

ART-naïve, no information on hypertension in HIV-positive participants on ART is available. The biological mechanisms underlying the relationship between HIV infection, ART use, and hypertension remain unclear, though several pathways have been suggested, including direct vascular injury by the HIV virus and lipodystrophy, dyslipidaemia, direct mitochondrial DNA damage, and insulin resistance resulting from ART use.[25]

Given that many recent studies have been limited by small numbers, a major strength of this analysis was the large sample size of our study cohort.[8,9,10,11] This study also adds to the literature a comparison of an ART-naïve cohort of HIV-positive individuals to HIV-negative persons, comparison groups that have rarely been addressed in previous research. The only other recent study of similar comparison groups also found higher odds of hypertension among HIV-negative participants, though they lacked the statistical significance present in the current analyses.[12] Furthermore, our study considered CD4 count as a measure of disease severity and its relationship with hypertension among those testing HIV-positive; to our knowledge, this relationship has not yet been assessed in an ART-naïve cohort of HIV-positive persons.

Another strength of this analysis was having data on blood pressure both before and after HIV status disclosure for comparison. Conversely, a limitation in this study is the collection of only one blood pressure measurement at each time point. The American Heart Association recommends taking the average of at least two successive measurements while subjects are seated, and have been given a five minute rest period prior to the first measure.[26] Among HIV-positive participants, significantly higher DBP were seen between the first and second blood pressure measurement, which may reflect this measurement error or an important biological phenomenon. The prevalence of masked hypertension, defined as having a normal blood pressure in the clinic but an elevated blood pressure out of the clinic, was found to be 41% in a

study of 101 low-income south African adults.[27] This suggests that blood pressure measurements in our study may be falsely low, underestimating the overall prevalence of hypertension in this cohort.

Participants in this analysis were visiting the study clinic for HIV testing. Some participants may have already known their HIV status prior to test administration and were confirming their status to begin treatment, which could have impacted blood pressure measures. One would expect, however, that this would result in higher blood pressure measurements for those testing HIV-positive, which would have biased our results toward the null, underestimating the difference in odds of hypertension seen between HIV-positive and HIV-negative participants.

The cross-sectional nature of this study prevents us from making claims of causality about relationship between HIV status and hypertension. However, the results of this study support other research that suggests a lower odds of hypertension among those people who are HIV-positive, particularly in those with lower CD4 cell counts.

As treatment innovations increase the life expectancy of those with HIV, the relationship between HIV infection and hypertension risk and subsequent CVD is increasingly important to understand.[5] The results of this study suggest screening implications for hypertension among HIV-positive patients in LMICs, particularly those with low CD4 cell counts. Hypertension in these cohorts may be masked by a combination of undetermined biological and psychological mechanisms, and it is thus increasingly important to screen these patients regularly for CVD risk factors. A study in San Francisco identified two potential biomarkers of cardiovascular risk among HIV-infected patients, ST2 and growth differentiation factor (GDF)-15, which may have potential use in screening HIV-positive patients that are treatment-naïve in addition to regular blood pressure measurements for identifying those at risk for CVDs.[28] Subsequent analysis in

this same cohort of HIV-positive patients will be useful after ART treatment proceeds for further comparison.

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Tables and Figures

Table 1. Descriptive statistics for entire cohort of normal/pre-hypertensive and hypertensive patients, assessed using the first blood pressure measure taken to classify hypertension level.

	Total Cohort (n=2,904)	**Normal or Pre-hypertensive (n=2,568)**	**Hypertensive* (n=336)**	**p-value**
Demographics	n (%)†	n (%)†	n (%)†	
Age (years)				
18-29	1,617 (55.7)	1,481 (57.7)	136 (40.5)	**<0.001**
30-49	1,128 (38.9)	969 (37.8)	159 (47.3)	
50+	156 (5.4)	115 (4.5)	41 (12.2)	
Sex				
Female	1,481 (51.0)	1,347 (52.5)	134 (39.9)	**<0.001**
Male	1,423 (49.0)	1,221 (47.6)	202 (60.1)	
Marital status				
Never married	2,682 (92.4)	2,389 (93.0)	293 (87.2)	**0.001**‡
Married	205 (7.1)	166 (6.5)	39 (11.6)	
Widowed/divorced	17 (0.6)	13 (0.5)	4 (1.2)	
Number of children				
No children	917 (31.7)	824 (32.2)	93 (27.7)	**<0.001**
1 child	867 (30.0)	793 (31.0)	74 (22.0)	
>1 child	1,110 (38.4)	941 (36.8)	169 (50.3)	
Socioeconomics				
Education				
None	871 (30.0)	767 (29.9)	104 (31.0)	0.91
Primary school or some high school	606 (20.9)	538 (21.0)	68 (20.2)	
High school completion or higher	1,427 (49.1)	1,263 (49.2)	164 (48.8)	
Current employment				
No	1,707 (58.8)	1,523 (59.3)	184 (54.8)	0.21
Yes, <20 hours/week	1,016 (35.0)	890 (34.7)	126 (37.5)	
Yes, >20 hours /week	181 (6.2)	155 (6.0)	26 (7.7)	
Income				
<2,000 ZAR/month (~130 USD)	2,411 (83.5)	2,145 (84.0)	266 (79.6)	**0.046**
≥2,000 ZAR/month	478 (16.6)	410 (16.1)	68 (20.4)	
Food insecurity				
Food secure	2,599 (89.5)	2,304 (89.7)	295 (87.8)	0.28
Food insecure (mild, moderate, severe)	305 (10.5)	264 (10.3)	41 (12.2)	
Travel method				
Walk	2,272 (78.4)	2,006 (78.3)	266 (79.4)	0.64
Public transport, private car, other	625 (21.6)	556 (21.7)	69 (20.6)	

Church attendance				
No	343 (13.3)	303 (13.2)	40 (13.7)	0.51
Yes, but only occasionally	1,961 (76.0)	1,745 (76.3)	216 (73.7)	
Yes, every week	277 (10.7)	240 (10.5)	37 (12.6)	
Mental Health				
Anxiety				
No (GAD-7 score <10)[§]	2,532 (87.2)	2,248 (87.5)	284 (84.5)	0.12
Yes (GAD-7 score ≥10)[§]	372 (12.8)	320 (12.5)	52 (15.5)	
Depression				
No (PHQ-9 score <10)[¶]	2,403 (82.8)	2,124 (82.7)	279 (83.0)	0.89
Yes (PHQ-9 score ≥10)[¶]	500 (17.2)	443 (17.3)	57 (17.0)	
Substance Abuse				
Cigarette use				
Never used	2,172 (74.9)	1,931 (75.3)	241 (71.9)	0.40
Some use, but not within last month	64 (2.2)	55 (2.1)	9 (2.7)	
Used within last month	665 (22.9)	580 (22.6)	85 (25.4)	
Alcohol use				
Never used	1,797 (62.1)	1,613 (63.0)	184 (55.1)	**0.005**
Some use, but not within last month	154 (5.3)	127 (5.0)	27 (8.1)	
Used within last month	945 (32.6)	822 (32.1)	123 (36.8)	
Intravenous drug use				
Never used	2,864 (98.8)	2,534 (98.8)	330 (98.5)	0.60[‡]
Ever used	36 (1.2)	31 (1.2)	5 (1.5)	
Cannabis use				
Never used	2,746 (94.9)	2,429 (95.0)	317 (94.6)	0.80
Ever used	147 (5.1)	129 (5.0)	18 (5.4)	
Clinical Indicators				
HIV status				
Negative	1,799 (62.0)	1,575 (61.4)	224 (66.7)	0.062
Positive	1,102 (38.0)	990 (38.6)	112 (33.3)	

* Hypertension defined as systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥ 90 mmHg

† Values may not add to 100 due to rounding

‡ Fisher's exact test used

§ Generalized Anxiety Disorder 7-item scale

¶ Patient Health Questionnaire-9

Table 2. Descriptive statistics of HIV-positive patients by hypertension level, assessed using the first blood pressure measure taken to classify hypertension level.

	Total Cohort (n = 1102)	**Normal or Pre-hypertensive (n=990)**	**Hypertensive* (n=112)**	**p-value**
Demographics	n (%)[†]	n (%)[†]	n (%)[†]	
Age (years)				
18-29	452 (41.1)	425 (43.0)	27 (24.1)	**<0.001**
30-49	587 (53.3)	515 (52.1)	72 (64.3)	
50+	62 (5.6)	49 (5.0)	13 (11.6)	
Sex				
Female	658 (59.7)	599 (60.5	59 (52.7)	0.11
Male	444 (40.3)	391 (39.5)	53 (47.3)	
Marital status				
Never married	1,009 (91.6)	914 (92.3)	95 (84.8)	**0.016**[‡]
Married	85 (7.7)	70 (7.1)	15 (13.4)	
Widowed/divorced	8 (0.7)	6 (0.6)	2 (1.8)	
Number of children				
No children	187 (17.0)	175 (17.7)	12 (10.7)	**0.008**
1 child	347 (31.6)	320 (32.4)	27 (24.1)	
>1 child	565 (51.4)	492 (49.9)	73 (65.2)	
Socioeconomics				
Education				
None	376 (34.1)	337 (34.0)	39 (34.8)	0.89
Primary school or some high school	327 (29.7)	296 (29.9)	31 (27.7)	
High school completion or higher	399 (36.2)	357 (36.1)	42 (37.5)	
Current employment				
No	607 (55.1)	546 (55.2)	61 (54.5)	0.97
Yes, <20 hours /week	422 (38.3)	379 (38.3)	43 (38.4)	
Yes, >20 hours /week	73 (6.6)	65 (6.6)	8 (7.1)	
Income				
<2,000 ZAR/month (~130 USD)	894 (81.6)	805 (81.6)	89 (80.9)	0.85
≥2,000 ZAR/month	202 (18.4)	181 (18.4)	21 (19.1)	
Food insecurity				
Food secure	974 (88.4)	879 (88.8)	95 (84.8)	0.21
Food insecure (mild, moderate, severe)	128 (11.6)	111 (11.2)	17 (15.2)	
Travel method				
Walk	858 (78.1)	772 (78.2)	86 (76.8)	0.73
Public transport, private car, other	241 (21.9)	215 (21.8)	26 (23.2)	
Church attendance				
No	132 (13.5)	119 (13.6)	13 (13.3)	0.94
Yes, but only occasionally	744 (76.2)	670 (76.3)	74 (75.5)	

Yes, every week	100 (10.3)	89 (10.1)	11 (11.2)	
Mental Health				
Anxiety				
No (GAD-7 score <10)[§]	910 (82.6)	824 (83.2)	86 (76.8)	0.088
Yes (GAD-7 score ≥10)[§]	192 (17.4)	166 (16.8)	26 (23.2)	
Depression				
No (PHQ-9 score <10)[¶]	837 (76.0)	755 (76.3)	82 (73.2)	0.47
Yes (PHQ-9 score ≥10)[¶]	265 (24.1)	235 (23.7)	30 (26.8)	
Substance Abuse				
Cigarette use				
Never used	833 (75.7)	754 (76.2)	79 (71.2)	0.34[‡]
Some use, but not within last month	20 (1.8)	19 (1.9)	1 (0.9)	
Used within last month	247 (22.5)	216 (21.8)	31 (27.9)	
Alcohol use				
Never used	710 (64.7)	646 (65.5)	64 (57.7)	0.17
Some use, but not within last month	51 (4.7)	43 (4.4)	8 (7.2)	
Used within last month	336 (30.6)	297 (30.1)	39 (35.1)	
Intravenous drug use				
Never used	1,090 (99.1)	981 (99.2)	109 (98.2)	0.27**
Ever used	10 (0.9)	8 (0.8)	2 (1.8)	
Cannabis use				
Never used	1,053 (95.9)	948 (96.1)	105 (94.6)	0.46
Ever used	45 (4.1)	39 (4.0)	6 (5.4)	
Clinical Indicators				
Glucose level				
<120 mg/dl	440 (89.4)	396 (90.4)	44 (81.5)	**0.044**
≥120 mg/dl	52 (10.6)	42 (9.6)	10 (18.5)	
BMI (kg/m^2)				
Below 18.5	93 (8.5)	83 (8.4)	10 (8.9)	**0.023**
18.5 – 24.9	528 (48.0)	487 (49.2)	41 (36.6)	
25.0 – 29.9	256 (23.3)	229 (23.2)	27 (24.1)	
30.0 and above	224 (20.4)	190 (19.2)	34 (30.4)	
CD4 count				
Below median (≤ 299)	489 (50.7)	451 (51.9)	38 (39.6)	**0.022**
Above median (≥ 300)	476 (49.3)	418 (48.1)	58 (60.4)	

***** Hypertension defined as systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥ 90 mmHg

[†] Values may not add to 100 due to rounding

[‡] Fisher's exact test used

[§] Generalized Anxiety Disorder 7-item scale

[¶] Patient Health Questionnaire-9

Table 3. Odds ratios for the association between baseline characteristics and hypertension among the entire cohort, using the first blood pressure measure taken to classify hypertension level (N=2,904)

	# hypertensive* / total at risk	Unadjusted OR (95% CI)	p-value	Adjusted OR (95% CI) †	p-value
Demographics					
Age (years)					
18-29	136/1,617	ref	-	ref	-
30-49	159/1,128	**1.79 (1.40, 2.28)**	**<0.0001**	**1.88 (1.46, 2.43)**	**<0.0001**
50+	41/156	**3.88 (2.61, 5.78)**	**<0.0001**	**3.85 (2.57, 5.79)**	**<0.0001**
Sex					
Female	134/1,481	ref	-	ref	-
Male	202/1,423	**1.66 (1.32, 2.10)**	**<0.0001**	**1.37 (1.06, 1.77)**	**0.016**
Marital status‡					
Never married	293/2,682	ref	-	-	-
Married	39/205	**1.92 (1.32, 2.77)**	**0.0006**	-	-
Widowed/divorced	4/17	2.51 (0.81, 7.74)	0.11	-	-
Number of children‡					
No children	93/917	ref	-	-	-
1 child	74/867	0.83 (0.60, 1.14)	0.24	-	-
>1 child	169/1,110	**1.59 (1.22, 2.08)**	**0.0007**	-	-
Socioeconomics					
Education					
None	104/871	ref	-	-	-
Primary school or some high school	68/606	0.93 (0.67, 1.29)	0.67	-	-
High school completion or higher	164/1,427	0.96 (0.74, 1.24)	0.75	-	-
Current employment‡					
No	184/1,707	ref	-	-	-
Yes, <20 hours/week	126/1,016	1.17 (0.92, 1.49)	0.20	-	-
Yes, >20 hours /week	26/181	1.39 (0.89, 2.16)	0.15	-	-
Income‡					
<2,000 ZAR/month (~130 USD)	266/2,411	ref	-	-	-
≥2,000 ZAR/month	68/478	**1.34 (1.00, 1.78)**	**0.047**	-	-
Food insecurity					
Food secure	295/2,599	ref	-	-	-
Food insecure (mild, moderate, severe)	41/305	1.21 (0.85, 1.72)	0.28	-	-
Travel method					
Walk	266/2,272	ref	-	-	-
Public transport, private car, other	69/625	0.94 (0.71, 1.24)	0.64	-	-

Church attendance					
No	40/343	ref	-	-	-
Yes, but only occasionally	216/1,961	0.94 (0.65, 1.34)	0.73	-	-
Yes, every week	37/277	1.17 (0.72, 1.88)	0.52	-	-
Mental Health					
Anxiety					
No (GAD-7 score <10)[§]	284/2,532	ref	-	ref	-
Yes (GAD-7 score ≥10)[§]	52/372	1.29 (0.94, 1.77)	0.12	1.29 (0.93, 1.80)	0.13
Depression					
No (PHQ-9 score <10)[¶]	279/2,403	ref	-	-	-
Yes (PHQ-9 score ≥10)[¶]	57/500	0.98 (0.72, 1.33)	0.89	-	-
Substance Abuse					
Cigarette use					
Never used	241/2,172	ref	-	-	-
Some use, but not within last month	9/64	1.31 (0.64, 2.69)	0.46	-	-
Used within last month	85/665	1.17 (0.90, 1.53)	0.23	-	-
Alcohol use					
Never used	184/1,797	ref	-	ref	-
Some use, but not within last month	27/154	**1.86 (1.20, 2.90)**	**0.0058**	**1.62 (1.02, 2.57)**	**0.04**
Used within last month	123/945	**1.31 (1.03, 1.67)**	**0.029**	1.19 (0.91, 1.54)	0.20
Intravenous drug use					
Never used	330/2,864	ref	-	-	-
Ever used	5/36	1.24 (0.48, 3.21)	0.66	-	-
Cannabis use					
Never used	317/2,746	ref	-	-	-
Ever used	18/147	1.07 (0.64, 1.77)	0.80	-	-
Clinical Indicators					
HIV status					
Negative	224/1,799	ref	-	ref	-
Positive	112/1,102	0.80 (0.63, 1.01)	0.062	**0.70 (0.54, 0.90)**	**0.006**

*Hypertension defined as systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥ 90 mmHg

[†] Final model included age, sex, anxiety, alcohol use, and HIV status

[‡] Variables removed from multivariate model

[§] Generalized Anxiety Disorder 7-item scale

[¶] Patient Health Questionnaire-9

Table 4. Odds ratios for the association between baseline characteristics and hypertension among HIV-positive patients only, using the first blood pressure measure taken to classify hypertension level (N=1,102).

	# hypertensive* / total at risk	**Unadjusted OR (95% CI)**	**p-value**	**Adjusted OR (95% CI)†**	**p-value**
Demographics					
Age (years)					
18-29	27/452	ref	-	ref	-
30-49	72/587	**2.20 (1.39, 3.49)**	**0.0008**	**2.58 (1.59, 4.51)**	**0.0002**
50+	13/62	**4.18 (2.02, 8.62)**	**0.0001**	**4.83 (2.14, 10.89)**	**0.0001**
Sex‡					
Female	59/658	ref	-	-	-
Male	53/444	1.38 (0.93, 2.04)	0.11	-	-
Marital status‡					
Never married	95/1,009	ref	-	-	-
Married	15/85	**2.06 (1.14, 3.74)**	**0.017**	-	-
Widowed/divorced	2/8	3.21 (0.64, 16.11)	0.16	-	-
Number of children‡					
No children	12/187	ref	-	-	-
1 child	27/347	1.23 (0.61, 2.49)	0.56	-	-
>1 child	73/565	**2.16 (1.15, 4.08)**	**0.017**	-	-
Socioeconomics					
Education					
None	39/376	ref	-	-	-
Primary school or some high school	31/327	0.90 (0.55, 1.49)	0.69	-	-
High school completion or higher	42/399	1.02 (0.64, 1.61)	0.94	-	-
Current employment					
No	61/607	ref	-	-	-
Yes, <20 hours/week	43/422	1.02 (0.67, 1.53)	0.94	-	-
Yes, >20 hours/week	8/73	1.10 (0.50, 2.40)	0.81	-	-
Income					
<2,000 ZAR/month (~130 USD)	89/894	ref	-	-	-
≥2,000 ZAR/month	21/202	1.05 (0.64, 1.73)	0.85	-	-
Food insecurity					
Food secure	95/974	ref	-	-	-
Food insecure (mild, moderate, severe)	17/128	1.42 (0.82, 2.46)	0.22	-	-
Travel method					
Walk	86/858	ref	-	-	-
Public transport, private car, other	26/241	1.09 (0.68, 1.73)	0.73	-	-

Church attendance					
Yes, every week	11/100	ref	-	-	-
Yes, but only occasionally	74/744	0.89 (0.46, 1.75)	0.74	-	-
No	13/132	0.88 (0.38, 2.07)	0.78	-	-
Mental Health					
Anxiety					
No (GAD-7 score <10)[§]	86/910	ref	-	ref	-
Yes (GAD-7 score ≥10)[§]	26/192	1.50 (0.94, 2.40)	0.090	1.48 (0.87, 2.51)	0.15
Depression					
No (PHQ-9 score <10)[¶]	82/837	ref	-	-	-
Yes (PHQ-9 score ≥10)[¶]	30/265	1.18 (0.75, 1.83)	0.47	-	-
Substance Abuse					
Cigarette use[‡]					
Never used	79/833	ref	-	-	-
Some use, but not within last month	1/20	0.50 (0.07, 3.80)	0.51	-	-
Used within last month	31/247	1.37 (0.88, 2.13)	0.16	-	-
Alcohol use					
Never used	64/710	ref	-	ref	-
Some use, but not within last month	8/51	1.88 (0.85, 4.17)	0.12	2.14 (0.88, 5.24)	0.094
Used within last month	39/336	1.33 (0.87, 2.02)	0.19	1.25 (0.77, 2.04)	0.36
Intravenous drug use					
Never used	109/1,090	ref	-	-	-
Ever used	2/10	2.25 (0.47, 10.73)	0.31	-	-
Cannabis use					
Never used	105/1,053	ref	-	-	-
Ever used	6/45	1.39 (0.57, 3.36)	0.47	-	-
Clinical Indicators					
Glucose level					
<120 mg/dl	44/440	ref	-	-	-
≥120 mg/dl	10/52	**2.14 (1.01, 4.57)**	**0.048**	-	-
BMI (kg/m^2)					
Below 18.5	10/93	1.43 (0.69, 2.97)	0.34	1.85 (0.85, 4.04)	0.12
18.5 – 24.9	41/528	ref	-	ref	-
25.0 – 29.9	27/256	1.40 (0.84, 2.33)	0.20	1.59 (0.91, 2.77)	0.10
30.0 and above	34/224	**2.13 (1.31, 3.45)**	**0.0023**	**1.98 (1.11, 3.53)**	**0.021**
CD4 count					
Below median (≤ 299)	38/489	ref	-	ref	-
Above median (≥ 300)	58/476	**1.65 (1.07, 2.53)**	**0.023**	**1.78 (1.13, 2.80)**	**0.013**

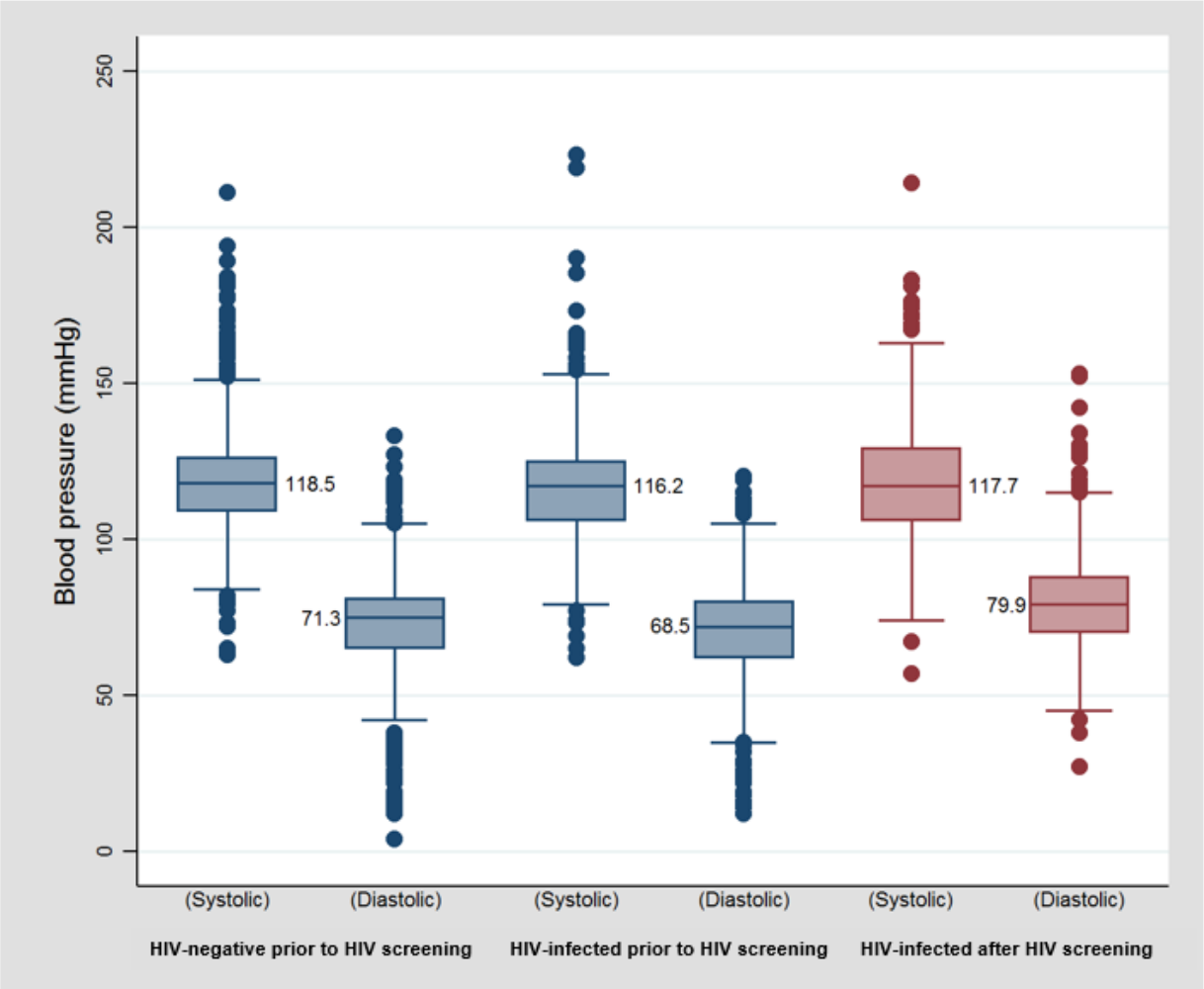
*Hypertension defined as systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥ 90 mmHg

† Final model included age, anxiety, alcohol use, BMI and CD4 count

‡ Variables removed from multivariate model

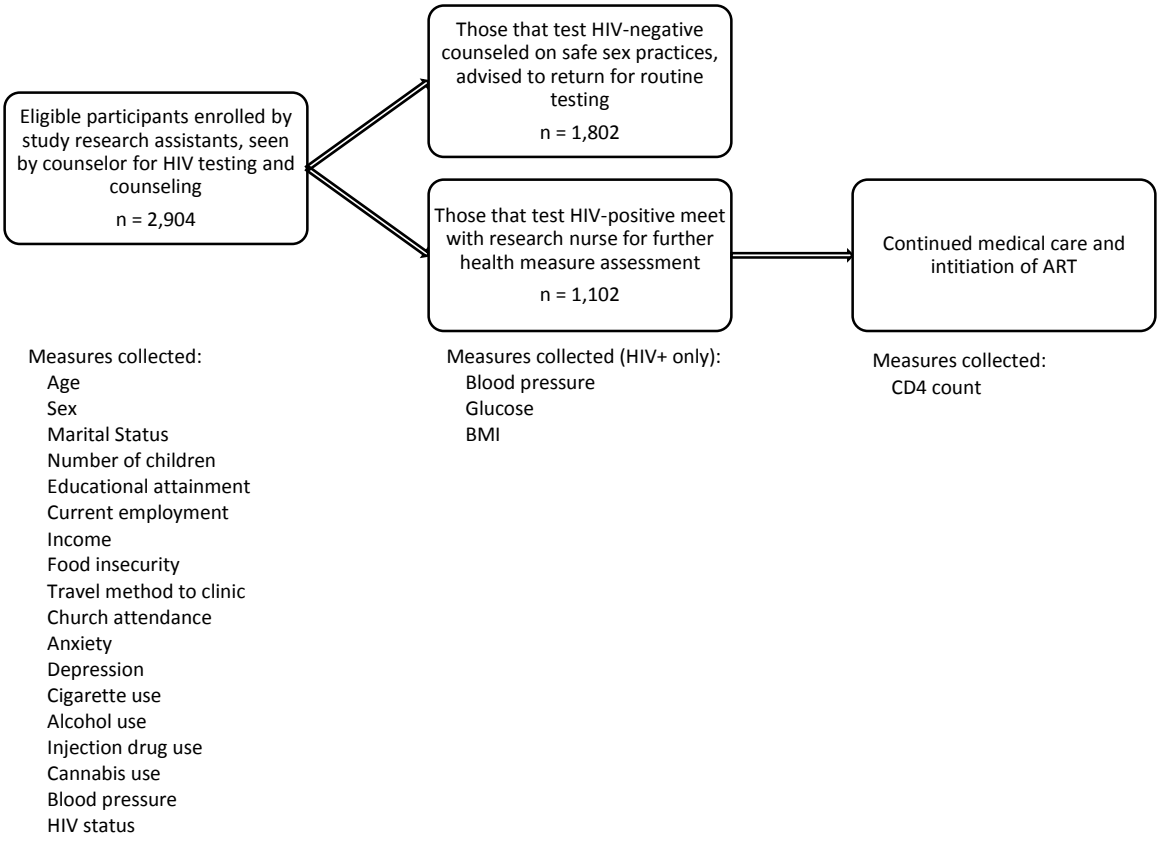
§ Generalized Anxiety Disorder 7-item scale
¶ Patient Health Questionnaire-9

Figure 1. Systolic and diastolic blood pressure (mmHg) measured before HIV status disclosure (coded blue) and after HIV status disclosure (coded red). Measurement after disclosure available for HIV-positive participants only.



Supplementary Figures

Supplementary Figure 1. Diagram showing study measurement point for covariates of interest.



Supplementary figure 2. Systolic and diastolic blood pressure (mmHg) measured before HIV status disclosure (coded blue) and after HIV status disclosure (coded red), by CD4 count (above or below median of 300 cells/mm^3)