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## Body composition and physical activity as mediators in the relationship between socio-economic status and blood pressure in young South African women: A structural equation model analysis

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4 **Body composition and physical activity as mediators in the relationship between socio-economic status and**  
5 **blood pressure in young South African women: A structural equation model analysis**  
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## Abstract

**Objectives** Varying hypertension prevalence across different socio-economic strata within a population has been well reported. However the causal factors and pathways across different settings are less clear, especially in sub-Saharan Africa. Therefore, this study aimed to compare blood pressure levels, and investigate the extent to which socioeconomic status (SES) is associated with blood pressure, in rural and urban South Africa women.

**Setting** Rural and urban South Africa.

**Design** Cross-section.

**Participants** Cross-sectional data on SES, total moderate-vigorous physical activity (PA), anthropometric and blood pressure data were collected on rural (n=509) and urban (n=510) young black women (18-23 years age). Pregnant and mentally or physically disabled women were excluded from the study.

**Results** The prevalence of combined overweight and obesity (46.5% versus 38.8%) and elevated blood pressure (27.0% versus 9.3%) were higher in urban than rural women respectively. Results from the structural equation modelling showed significant direct positive effects of BMI and SBP in rural, urban and combined datasets. Negative direct effects of SES on SBP and positive total effects of SES on SBP were observed in the rural and combined datasets respectively. In rural young women, SES had direct positive effects on BMI and was negatively associated with MVPA in urban and combined analyses. Body mass index mediated the positive total effects association between SES and SBP in combined analyses ( $\beta$ ; 95%CI, 0.46; 0.15 to 0.76).

**Conclusions** Though South Africa is undergoing nutritional and epidemiological transitions; the prevalence of elevated BP still varies between rural and urban young women. The association between socioeconomic status and SBP varies considerably in economically diverse populations with BMI being the most significant mediator. There is need to tailor prevention strategies to take account optimizing BMI when designing strategies to reduce future risk of hypertension in young women.

**Keywords** Blood pressure, Body mass index, Hypertension, Obesity, Urban, Rural, Socioeconomic status, Structural equation model, Physical activity

### Strengths

1. The use of structural modelling allowed us to explore direct and indirect (mediation) effects of social economic status, physical activities and body mass index on elevated blood pressure from representative sample of rural and urban population of South African young women.
2. Although the urban and rural cohorts were from two different studies, the same research unit conducted both studies and, therefore, the methodology was harmonized between the two sites, thereby allowing for accurate comparison.

### Limitations

1. Other unmeasured data, such as undernutrition in infancy, and dietary patterns were not included in the current analyses. We are currently working on research to address this limitation.
2. The low reliability of self-report data on physical activity could introduce bias. Thus, there is need for more precise, objective measures of physical activity to strengthen the results of our analysis.
3. There is need to do comparison on longitudinal data, especially as the socioeconomic environment is changing rapidly due to rural-urban labor migration and other factors would be helpful to examine these associations over time.

## Introduction

High blood pressure (hypertension) is a leading risk factor contributing to the global disease burden, accounting for 7% of global disability-adjusted life years (DALYs) and contributing to the 34.5 million non-communicable disease (NCD) related deaths in 2010 [1, 2]. A recent global meta-analysis, involving 19.1 million individuals, reported that on average there has been a decrease in blood pressure globally, but the low- to middle-income countries (LMICs) have seen an increase in hypertension [3]. The prevalence of high blood pressure in LMICs is estimated at 30% [4, 5] and it is the most significant risk factor for cardiovascular disease, most notably stroke [6]. In 2000, hypertension was estimated to have caused 9% of all deaths and over 390 000 DALYs in South Africa. Further, hypertension contributed to 50% of all strokes and 42% of ischaemic heart disease (IHD), signifying a substantial public health burden [7]. A systematic review of sub-Saharan African (SSA) data shows prevalence rates of hypertension of up to 41% with higher prevalence rates noted in urban compared to rural populations [8, 9]. A recent study in men and women aged 40 to 60 years of age in six sites across four SSA countries, including South Africa, showed the same trend with South African urban and rural cohorts having the highest prevalence (41.6 to 54.1%) [10].

Low and middle-income countries are experiencing both epidemiological and nutritional transitions with urban populations further along the transition as demonstrated by the higher prevalence of obesity and NCDs [4, 5, 8, 10-15]. Some evidence has shown that there are differences in the levels of blood pressure between rural and urban settings [8], while other studies have found no significant differences [16]. According to Glass and McAtee, internal biological systems are sculpted by an interaction between genes and prolonged exposure to particular external environments, a principle they call embodiment [17]. Thus the differences in built and social environments between rural and urban settings may explain the differences in disease prevalence. A Ghanaian study showed that both systolic and diastolic blood pressure were significantly lower in rural participants compared to urban participants [18]. However, a similar study in adolescents found that blood pressure levels were only lower in rural boys, with no difference in the girls [19]. Pediatric and adolescent hypertension have been reported to track into adulthood in a South African urban population [20]. Results on elevated blood pressure from studies in rural South African children have reported prevalence rates varying from 1.0% to 25.4% [21-24]. The factors explaining these differences have not been fully studied in LMICs.

Socioeconomic factors such as education, household income and household assets have been associated with blood pressure levels [25-27]. In a US cohort of young adults, a higher household income remained associated with lower systolic blood pressure (SBP) even after controlling for all potential covariates including age, sex and bio-behavioral factors [28]. Similarly, in a French sample of 30-79 year olds, SBP independently increased and was inversely associated with both individual education and residential neighborhood education [29]. Studies in African countries have also found varying associations between SES and blood pressure patterns, with both positive and negative associations reported [8, 30, 31]. Some studies have speculated that the association between SES and body mass index (BMI), physical activity levels, diet, smoking, alcohol intake and malnutrition may influence blood pressure

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3 patterns [18, 28, 31, 32]. Physical activity has been inversely associated with blood pressure and BMI directly  
4 associated with BP in more advanced economies, but inconsistent associations have been reported in LMICs [25,  
5 33-37].  
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9 There is a need to examine blood pressure and its determinants in young South African adults given the high rates of  
10 overweight and obesity and hypertension observed in this age group [20, 38]. Recent South African reports also  
11 indicate that the highest pregnancy rates occur in the age range of 20-24 years, with 26.2% of births reported,  
12 followed closely by the 25-29 year age group (25.7%) [39], and therefore targeting young adult women would also  
13 reduce adverse health outcomes in their children. To better target policies or programmes in future to address  
14 hypertension and obesity in the different settings, it is important to examine more closely rural-urban differences in  
15 hypertension due to differences in the epidemiology of obesity, SES divergence in the South African context [23,  
16 26, 30, 40-43]. Therefore, this study aims to compare blood pressure between rural and urban young adult South  
17 African women, and to determine whether there is an association between SES and blood pressure and whether it is  
18 mediated physical activity and BMI.  
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## 25 **Methods**

### 26 **Study sample and site**

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28 The rural Agincourt site, 2016 potential the female participants between the ages of 18 and 23 years were in the  
29 existing Agincourt Health and Socio-demographic Surveillance System database [44]. Only 996 were located during  
30 the data collection period and were invited to participate, of these 509 female participants were recruited after giving  
31 consent to participate. The urban sample consisted of 510 young women between the ages of 21 and 24 years who  
32 were randomly selected from the sample of 720 females who were part of the Birth-to-Twenty plus (BT20+) Young  
33 Adult Survey [45, 46]. Young women (n=51) who were pregnant at the time of the study were excluded.  
34 Measurements and questionnaires were completed by trained research assistants and nurses, and were standardised  
35 between both sites, to eliminate biases. The study protocols were approved by the Human Research Ethics  
36 Committee of the University of the Witwatersrand (Clearance certificates M120138 for the Ntshembo-Hope Cross  
37 Sectional Survey in Agincourt and M111182 for the BT20+ survey). A written consent to participate was provided  
38 by participants and mentally or physically disabled women were excluded from the study.  
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### 46 **Blood pressure**

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48 Blood pressure (mm Hg) was the outcome variable and it was measured using an Omron 6 automated machine  
49 (Kyoto, Japan). A five minute seated rest was observed before taking the blood pressure measurements. Participants'  
50 seated blood pressure was measured three times on the right side, with a 2 min interval between each measurement.  
51 The mean for the second and third readings was recorded for the current analysis.  
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55 According to the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and  
56 Treatment of High Blood Pressure [47], five categories of blood pressure have been established for adults 18 years  
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of age and older as shown in Table 1. These cut-offs were utilized in the current study. Prehypertension and hypertension were combined to create a new variable called elevated BP.

**Table 1:** Blood pressure classification [47]

<b>Classification</b>	<b>Systolic Blood Pressure</b>	<b>or</b>	<b>Diastolic Blood Pressure</b>
Low	<90	or	< 60
Normal	<120	and	<80
Prehypertension	120-139	or	80-90
High: Stage 1 Hypertension	140-159	or	90-99
High: Stage 2 hypertension	≥160	or	≥100

Systolic Blood Pressure was used in structural equation models (SEM) as it is more relevant in adults, and a good predictor of adverse health outcomes later in life [48], such as CVDs.

### **Anthropometry**

At both sites, participants' height and weight were measured by trained research assistants using standard techniques [49, 50]. Weight was measured in light clothing and barefoot to the nearest 0.1 kg using a digital scale (Tanita model TBF-410; Arlington Heights; USA). Height was measured barefoot to the nearest 0.1 cm using a stadiometer (Holtain, Crymych, UK). Waist circumference was measured with a non-stretchable fibreglass tape at the level of the umbilicus. Body mass index (BMI) was calculated as  $\text{weight/height}^2$  ( $\text{kg/m}^2$ ).

### **Socio-economic status (SES)**

Physical assets owned in the participants' household were used as a proxy for socio-economic status index [51]. It was generated by summing the number of assets owned in the household from the following: television, car, washing machine, fridge, phone, radio, microwave, cell phone, DVD/Video, DSTV (cable channel), computer, internet, medical aid. Previous studies in this population have shown that the sum of physical assets (household assets) is closely related to the household per capital expenditure and household income [51-53]. The household SES is regarded as a good measure of accumulated household wealth so it is a more reflective wealth index than income of a household's wealth over time.

### **Physical activity**

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3 The Global Physical Activity Questionnaire (GPAQ), developed for global physical activity surveillance, was  
4 completed via interview to obtain self-reported physical activity [54]. Total moderate-vigorous intensity physical  
5 activity (MVPA) in minutes per week (mins/wk) was calculated by adding occupation, travel-related and leisure  
6 time moderate and vigorous intensity physical activity. Sitting time (mins/wk) was used as a proxy for sedentary  
7 time.  
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## 10 11 **Statistical analyses**

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13 Analysis of variance and student's t test, and Chi-squared tests and Wilcoxon rank sum test for non-parametric  
14 variables, were conducted to compare study characteristics between urban and rural young women. Structural  
15 equation modeling (SEM), with missing data option, was used to test and estimate the direct and indirect  
16 associations between variables, most especially the mediation roles of physical activity (MVPA) or sedentary time  
17 (sitting), and body composition (BMI and waist circumference), in the association between SES and blood pressure  
18 (systolic blood pressure).  
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23 Direct, indirect and total effects were computed and recorded, and the proportion of the total effect mediated was  
24 calculated. To evaluate the best fitting model for our data, we calculated different goodness of fit indices including  
25 Chi-squared test, Root mean squared error of approximation (RMSEA), Comparative fit index (CFI), Tucker-Lewis  
26 index (TLI) and Standardized root mean squared residual (SRMR) [55]. Though the Chi-squared test has been  
27 popularly used as a goodness of fit index, it has been reported to be biased and not reliable as the only goodness of  
28 fit index. It is also highly sensitive to sample size [56, 57], and often inflated with non-normal data such as physical  
29 activity data and we therefore employed the Hu and Bentler's Two-Index Presentation Strategy (1999) combination  
30 rule, with cut off values depending on the fitness index, to determine the best model fit [55, 58].  
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35 If the direct and indirect effects had opposite signs (negative or positive effects) the proportion mediated was  
36 assessed using the absolute values for all indirect and direct effects [59]. All the analyses were conducted using  
37 STATA (version 13.0; STATA Corp., College Station, TX, USA).  
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## 40 **Results**

### 41 42 **Study characteristics**

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44 Descriptive statistics for the non-pregnant study participants (urban, n=492; rural, n=476) are presented in Table 2.  
45 There was no difference in BMI or waist circumference between the urban and rural participants, but the prevalence  
46 of overweight and obesity was significantly higher in the urban (46.5%) compared to the rural young women  
47 (38.8%). Household SES was significantly higher in the urban compared to the rural group. Self reported physical  
48 activity (total MVPA) was significantly higher in the rural than urban women ( $p<0.001$ ), and the urban women spent  
49 significantly more time sitting than their rural counterparts ( $p<0.001$ ). Systolic and diastolic BP were significantly  
50 higher in the urban group, as was the prevalence of elevated BP (27.0 vs. 9.3%).  
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### Structural equation models for BMI and waist circumference

Results from the SEMs for SES associations with SBP via MVPA and BMI are presented in Tables 3a, 3b and 3c for urban, rural and combined analyses respectively, and also shown in Figures 1, 2, 3. No significant direct or indirect effects via (MVPA or BMI) of SES on SBP were observed in either the urban or rural women, but there were significant direct effects of SES on MVPA. Results showed that individuals with a higher SES index were less likely to be physically active in pooled data and urban women. In rural women, a one-unit increase in total household assets was associated with a decrease of 0.65 mmHg (-1.19 to -0.10) in SBP and an increase of 0.27 kg/m<sup>2</sup> in BMI (0.1 to 0.53) (Tables 3a, 3b and Figures 1, 2). The SEM for the combined sample showed a significant indirect effect of household SES on SBP via BMI, with 50% of the total effect being mediated by BMI (Table 3c and Figure 3). Direct positive effects of BMI on SBP were observed in both settings and the pooled sample with a 1 kg/m<sup>2</sup> increase in BMI being associated with an increase of 0.37 mmHg (0.21 to 0.53) and 0.33 (0.12 to 0.54) mmHg SBP in urban and rural young women, respectively. Similar results were observed when including waist circumference as the body composition indicator (data not shown).

### Discussion

A rising prevalence of hypertension has been reported in South Africa, with Peer et al. reporting a higher prevalence in 2008 (35.6%) compared to 1990 (21.6 %) in men and women aged 25-74 years in an urban black community in Cape Town, South Africa [40]. We have shown in young adult women from urban and rural South Africa, an overall elevated BP prevalence of 18.4 % (27.0 % in urban and 9.3 % in rural). We have also shown a direct effect of BMI on SBP in the urban and rural women separately, as well as when pooled, thereby providing further evidence of an association between overall adiposity and blood pressure. The total effects of SES on SBP were the same in both settings.

Prevalence data on elevated BP and hypertension from other countries in sub-Saharan Africa have shown conflicting results when comparing urban and rural communities. In Malawi, a higher prevalence of hypertension in urban compared to rural communities has been reported and attributed to differences in lifestyle as rural communities participate in subsistence based agricultural activities while the urban community has a more westernized lifestyle with higher salt intake and physical inactivity [9]. Similarly, data from Ghana have shown a higher mean SBP and DBP and a higher prevalence of hypertension in urban communities [18, 60]. In the PURE study in South Africa, Pisa and colleagues reported that both urban adult men and women had higher mean blood pressures in comparison to their rural peers though the overall CVD risk factors were equally prevalent in both settings [41]. In contrast, findings from Cameroon have reported a higher BP prevalence in rural compared to urban men and women older than 40 years old, while Kenyan studies have reported no significant differences [16, 61]. Results from six urban and rural sites in four sub-Saharan African countries – Kenya, South Africa, Ghana and Burkina Faso – have reported a prevalence of hypertension in women aged between 40 and 60 years ranging from 15.1% in rural Burkina Faso to 54.1% in urban South Africa [10]. It was also reported that in all three South African sites, both rural and urban, the

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3 prevalence of hypertension was higher than in the other three countries [10]. These findings show the complex  
4 health transitions occurring in SSA and the impact that this is having on cardio-metabolic disease risk.  
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7 Our study showed significant differences in SES between the urban and rural samples, as well a big variation in SES  
8 between these two settings. The social patterning of CVD risk factors, including hypertension, in SSA and LMICs  
9 has in part been attributed to differences in countries' socioeconomic development. Previous results from five  
10 countries, (two high income and three LMICs), reported that hypertension and other CVD risk factors were  
11 substantially associated with education and wealth status; individuals with less education and lower wealth generally  
12 showing higher prevalence of CVD risk factors [62]. The effect of SES in this study is most evident in the rural  
13 women for whom household SES was lower (compared to urban) and who may be transitioning faster (both  
14 nutritionally and economically) than the urban women. Though SES is positively associated with BMI in rural  
15 young women, it is negatively associated with SBP. There may be other factors, such as physical activity due to  
16 agricultural activities or dietary patterns, which were not recorded. In addition, the weight gain observed might not  
17 be due to fat mass but rather to muscle mass and bone mass, which has been reported to be associated with SBP  
18 before [63].  
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25 In Mexico, women in rural and upper SES categories were likely to have a higher SBP, while we have reported that  
26 a higher SES was associated with a decrease in SBP in rural communities. At population level, there is a need to  
27 consider different SES categories and monitor the effect of transitioning from one category to another on  
28 hypertension, since these categories may respond differently to an increase or a decrease in their SES. Kagura and  
29 colleagues tracked SES in South African children and reported that moving from the low SES in infancy to a higher  
30 SES in adolescence had a protective effect on SBP level in young adulthood [26]. Our results have shown that this  
31 could be more pronounced in rural areas.  
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36 We observed a positive association between SES and BMI in the rural sample and the same direction of effects was  
37 observed in the urban (though not significant), which is in line with results reported in many LMICs including South  
38 Africa, but in contrast with those reported in higher income populations [33, 34, 62]. A systematic review of studies  
39 between 1989 to 2007 reported that SES was positively associated with obesity in the middle transitioning  
40 economies such as South Africa and Jamaica [64]. We have shown that both in the rural and urban participants (not  
41 significant), a higher SES resulted in reduced SBP, while the pooled (combined) analysis showed a positive total  
42 effect association between SES and SBP. This could be due to the introduction of more variation in SES when data  
43 from both sites are combined; with many individuals with low SES in the rural area, the associations became skewed  
44 towards the low SES individuals. This may suggest that different transitional levels of SES have different effects on  
45 hypertension risk depending on the environment (either urban or rural). Though not significant, the total effects of  
46 SES on SBP are the same in both rural and urban hence the differences in prevalence cannot be explained by the  
47 setting or SES alone. In urban and rural settings of four countries (Kenya, Namibia, Nigeria and Tanzania), the  
48 prevalence of age standardized hypertension was similarly high and ranging from 19.3 % to 38.0 % [11]. Cois and  
49 colleagues reported that a higher SES was associated with lower SBP in a nationally representative sample of South  
50 African women [25] using SEM models. Physical exercise, alcohol use, smoking and resting heart rate and BMI  
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3 were reported to be the mediators of the indirect of the association between SES and SBP in men but not in women,  
4 suggesting that other factors may play a major role in women [25]. Similarly, our results show that neither PA nor  
5 BMI mediate the association between SES and SBP in urban and rural settings, suggesting that other factors may  
6 explain the association. Among those, dietary patterns and stress have been reported to be independently associated  
7 with SBP [65, 66].  
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11 The significant direct associations between BMI and SBP or hypertension are in line with other findings in South  
12 Africa and within the SSA region [11, 33, 40, 42, 67, 68]. This link was consistent in rural, urban and combined data  
13 sets, indicating the importance of BMI in the aetiology of blood pressure. Munthali et al reported that the link  
14 between obesity and hypertension could be observed as early as five years of age. Children with early onset of  
15 obesity were at higher risk of developing hypertension in late adolescence [38].  
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19 In this study, using SEM models to explore the mediation role of BMI and PA helped quantify potential  
20 contributions of these variables to the effect of SES on SBP. The results show that PA was not a significant mediator  
21 in the association between SES and BP in the urban or the rural samples. SES was negatively associated with  
22 MVPA in urban and pooled samples, indicating that as individuals transition from low to higher SES, they reduce  
23 their physical activity level. We speculate that these differences in the association between SES and SBP in both our  
24 rural and urban results and in those from high-income countries are due to differences in levels of nutritional and  
25 epidemiological transition in these regions [69, 70]. Those with low SES in high-income countries are likely to  
26 consume cheaper, more energy dense foods, participate in less leisure time physical activity and be more sedentary  
27 [71, 72] In LMICs, agricultural activities remain a part of everyday life and a day-to-day activity in rural living,  
28 while those with higher SES in the same settings rapidly adopt the westernized life style with less PA, fewer  
29 agricultural activities and home grown food. However, this speculation is not supported by the data on PA in this  
30 study despite the rural participants having a higher PA. Our understanding of the Agincourt rural economy is that  
31 agriculture is quite a minor aspect though very useful to augment the household income.  
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39 The limitations of this study are that other unmeasured data, such as undernutrition in infancy, which is a known risk  
40 factor for high blood pressure later in life [73], and dietary patterns were not included in the current analyses. We  
41 are currently working on research to address this limitation. We can also not rule out the role of genetics. Secondly,  
42 the low reliability of self-report data on physical activity could introduce bias. Thus, there is need for more precise,  
43 objective measures of physical activity to strengthen the results of our analysis. Lastly, longitudinal data, especially  
44 as the socioeconomic environment is changing rapidly due to rural-urban labor migration and other factors would be  
45 helpful to examine these associations over time.  
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## 49 **Conclusions**

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51 Though the prevalence of overweight or obesity is relatively higher in both rural and urban than those reported in  
52 other SSA countries, women in the urban setting were at more risk for elevated blood pressure than their rural  
53 counterparts. The link between socioeconomic status and SBP varies in a more economically diverse population, as  
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3 seen with the combined rural and urban dataset, with BMI being the most likely mediator. There is need to consider  
4 optimizing BMI as a key intervention strategy in young adults in part to combat hypertension.  
5

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15  
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### 17 18 **Conflict of interest**

19 Authors have no conflicts of interest to disclose.

### 20 21 **Consent for publication**

22 Not applicable

### 23 24 **Availability of data and material**

25 The datasets used and/or analysed during the current study are available from the Developmental Pathways  
26 for Health Research Unit data management department by contacting Prof. Shane A Norris on reasonable request  
27

### 28 29 **Competing interest**

30 The authors declare that they have no competing interests

### 31 32 **Authors' contributions**

33 RJM and SAN conceptualized the manuscript. RJM analyzed the data. RJM MM RSM JK ST KK FXG LKM DD  
34 SAN interpreted the data. RJM wrote the manuscript and all authors were involved in editing and approving the final  
35 manuscript.  
36

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41

### 42 43 **Ethics Approval and Consent to Participate**

44 Prior to the study, the study protocols were approved by the Human Research Ethics Committee of the  
45 University of the Witwatersrand (Clearance certificates M120138 for the Ntshembo-Hope Cross Sectional  
46 Survey in Agincourt and M111182 for the BT20+ survey). Independent written informed consent to  
47 participate was obtained from participants.  
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Table 2: Descriptive characteristics

	Total	n	Urban	n	Rural	p value
Age (years)	22.04 (1.24)	492	22.77 (0.49)	476	21.28 (1.31)	0.001
Weight (kg)	64.62 (14.82)	492	64.67 (15.6)	473	64.55 (14.03)	0.90
Height (m)	1.61 (0.007)	492	1.60 (0.07)	475	1.61 (0.07)	0.001
BMI (kg/m <sup>2</sup> )	25.05 (5.59)	492	25.32 (5.91)	473	24.78 (5.24)	0.13
BMI classification (%)						0.015
Underweight (<18.4 kg/m <sup>2</sup> )	5.98		7.10		4.82	
Normal weight (18.5-24.9 kg/m <sup>2</sup> )	51.34		46.45		56.39	
Overweight (25-29.9 kg/m <sup>2</sup> )	26.19		29.21		23.06	
Obese (≥30 kg/m <sup>2</sup> )	16.49		17.24		15.72	
Waist circumference (cm)	80.60 (12.08)	493	80.18 (12.63)	477	81.03 (11.47)	0.26
Household SES index (sum of assets)	7.24 (2.70)	493	8.83 (2.37)	476	5.59 (1.91)	0.0000
Total MVPA (min/week)*	870(280-1810)	492	420(160-900)	385	1680(970-2580)	<0.001
Sitting time (mins/day)*	300 (240-480)	492	360 (240-480)	385	300 (180-360)	<0.001
Systolic blood pressure	106.68 (11.64)	492	110.30 (11.4)	471	102.89 (10.7)	0.000
Diastolic blood pressure	70.23 (9.00)	492	72.78 (8.3)	471	67.57 (9.0)	0.000
BP classification (%)						0.000
Low BP	12.46		5.49		19.75	
Normal BP	69.16		67.48		70.91	
Prehypertension	16.20		23.58		8.49	
Hypertensive	2.18		3.46		0.85	
Elevated BP (%)	18.38		27.04		9.34	0.000

Data presented as mean (SD) otherwise stated

\* Median(IQR)

**Table 3a:** Structural equation model for SES, MVPA and BMI on SBP in urban women

Effect of: N=489	Outcome:	Direct effects(95% CI)	Indirect effects( 95% CI)	Total effects(95% CI)	Proportion of total effect mediated
<b>Household assets</b>	SBP	-0.34 (-0.75; 0.07)		-0.29 (-0.70; 0.12)	0.13 <sup>a</sup>
	via BMI		0.05 (-0.05; 0.14)		
	BMI	0.13 (-0.09; 0.35)		0.11 (-0.11; 0.33)	0.1 <sup>a</sup>
	via MVPA		-0.014 (-0.05; 0.013)		
	MVPA	-41.71 (-73.48; -9.94)**		-41.71 (-73.48; -9.94)**	
<b>MVPA</b>	SBP	-0.0002 (-0.001; 0.001)		-0.0000 (-0.0012; 0.0011)	0.3 <sup>a</sup>
	via BMI		0.0001 (-0.0001; 0.0004)		
<b>BMI</b>	SBP	0.37 (0.21; 0.53)***		0.37 (0.21; 0.53)***	

Adjusted for age; \* P<0.05; \*\* P< 0.01; \*\*\*P< 0.001; SBP; systolic blood pressure, MVPA; moderate to vigorous intensity physical activity, BMI; body mass index, SES; social economic status, <sup>a</sup> Assessed using the absolute values for both indirect and direct effects

**Urban Fit Indices:** LR test of model vs. saturated: chi2(4) = 0.97, Prob > chi2 = 0.91; RMSEA = 0.00; **CFI= 1.00** Comparative fit index;

TLI= 1.12 Tucker-Lewis index; **SRMR=0.011:** Standardized root mean squared residual, CD= 0.017 Coefficient of determination.

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**Table 3b:** Structural equation model for SES, MVPA and BMI on SBP in rural women

Effect of: N= 378	Outcome:	Direct effects(95% CI)	Indirect effects( 95% CI)	Total effects(95% CI)	Proportion of total effect mediated
<b>Household assets</b>	SBP via BMI	-0.65 (-1.19; -0.096)*	0.08 (-0.04; 0.19)	-0.56 (-1.12; -0.02)*	0.11 <sup>a</sup>
	BMI via MVPA	0.27 (0.01; 0.53)*	-0.01 (-0.04; 0.01)	0.26 (-0.005; 0.53)*	0.04
	MVPA	-29.51 (-87.81; 28.78)		-29.51 (-87.81; 28.78)	
<b>MVPA</b>	SBP via BMI	0.0004 (-.0005729 .0013)	0.0001 (-0.0000; 0.0003)	0.0005 (-0.0005; 0.0015)	0.2
	SBP				
<b>BMI</b>	SBP	0.33 (0.12; 0.54)**		0.33 (0.12; 0.54)**	

Adjusted for age; \* P<0.05; \*\* P< 0.01; \*\*\*P< 0.001; SBP; systolic blood pressure, MVPA; moderate to vigorous physical activity, BMI; body mass index, SES; social economic status, <sup>a</sup> Assessed using the absolute values for both indirect and direct effects

**Rural Fit Indices:** LR test of model vs. saturated: chi2(4) = 10.51, Prob > chi2 = 0.03; RMSEA = 0.066; **CFI= 0.72** Comparative fit index; TLI= 0.37 Tucker-Lewis index; **SRMR= 0.04** : Standardized root mean squared residual, CD= 0.03 Coefficient of determination.

**Table 3c:** Structural equation model for SES, MVPA and BMI on SBP in the pooled sample of urban and rural women

Effect of: N=867	Outcome:	Direct effects(95% CI)	Indirect effects( 95% CI)	Total effects(95% CI)	Proportion of total effect mediated
<b>Household assets</b>	SBP	0.23 (-0.08; 0.54)		0.46 (0.15; 0.76)**	0.5
	via BMI		0.23 (0.10; 0.35)***		
	BMI	0.20 (0.05; 0.34)**		0.15 (0.01; 0.29)*	0.25 <sup>a</sup>
	via MVPA		-0.05 (-.100; 0.003)		
	MVPA	-144.83 (-170.55; -119.12)***		-144.83 (-170.55; -119.12)***	
<b>MVPA</b>	SBP	-0.001 (-0.002; -0.0005)**		-0.001 (-0.002; -0.0003)**	0.1 <sup>a</sup>
	via BMI		0.0001 (-0.0000; 0.0002)		
<b>BMI</b>	SBP	0.35 (0.21; 0.49)***		0.35 (0.21; 0.49)***	

Adjusted for age; \* P<0.05; \*\* P< 0.01; \*\*\*P< 0.001; SBP; systolic blood pressure, MVPA; moderate to vigorous intensity physical activity, BMI; body mass index, SES; social economic status, <sup>a</sup> Assessed using the absolute values for both indirect and direct effects

**Pooled Fit Indices:** LR test of model vs. saturated:  $\chi^2(4) = 24.829$ , Prob >  $\chi^2 = 0.000$ ; RMSEA = 0.077; **CFI= 0.89** Comparative fit index; TLI= 0.75 Tucker-Lewis index; **SRMR=0.033**: Standardized root mean squared residual, CD=0.137 Coefficient of determination.



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**Figure legends**

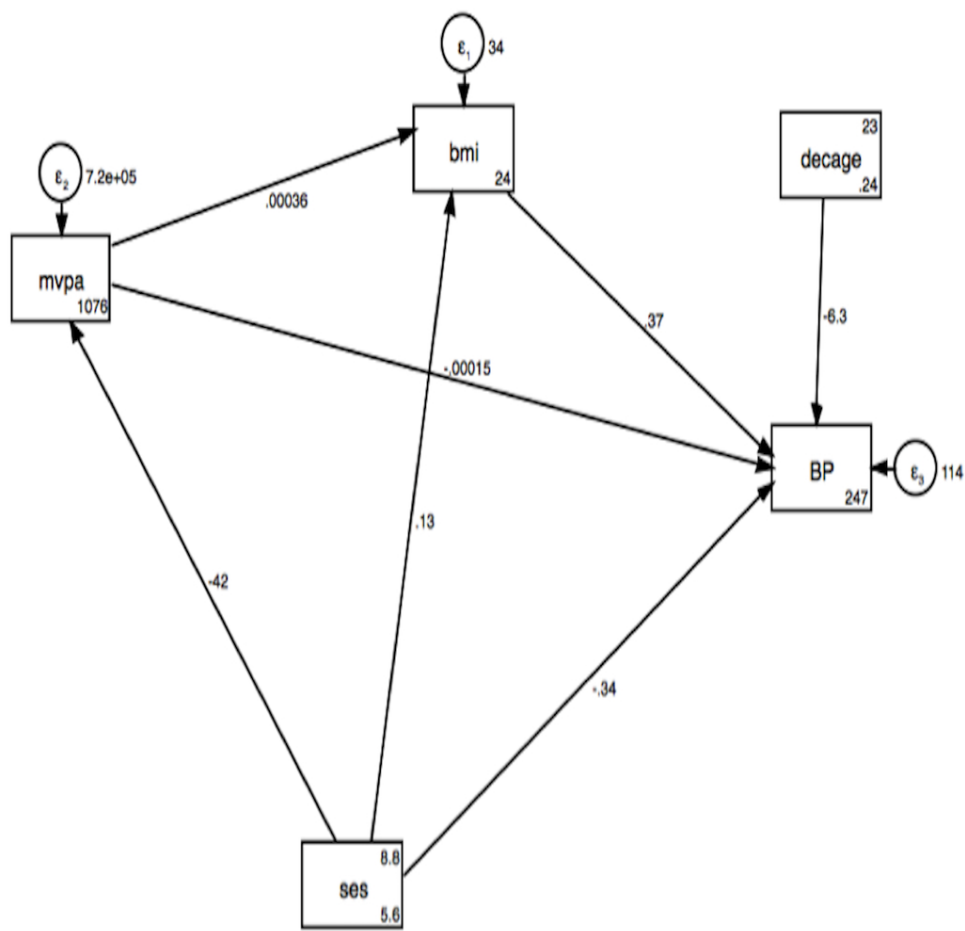
Figure 1: Structural equation model for SES, MVPA and BMI on SBP in urban

Figure 2: Structural equation model for SES, MVPA and BMI on SBP in rural

Figure 3: Structural equation model for SES, MVPA and BMI on SBP pooled

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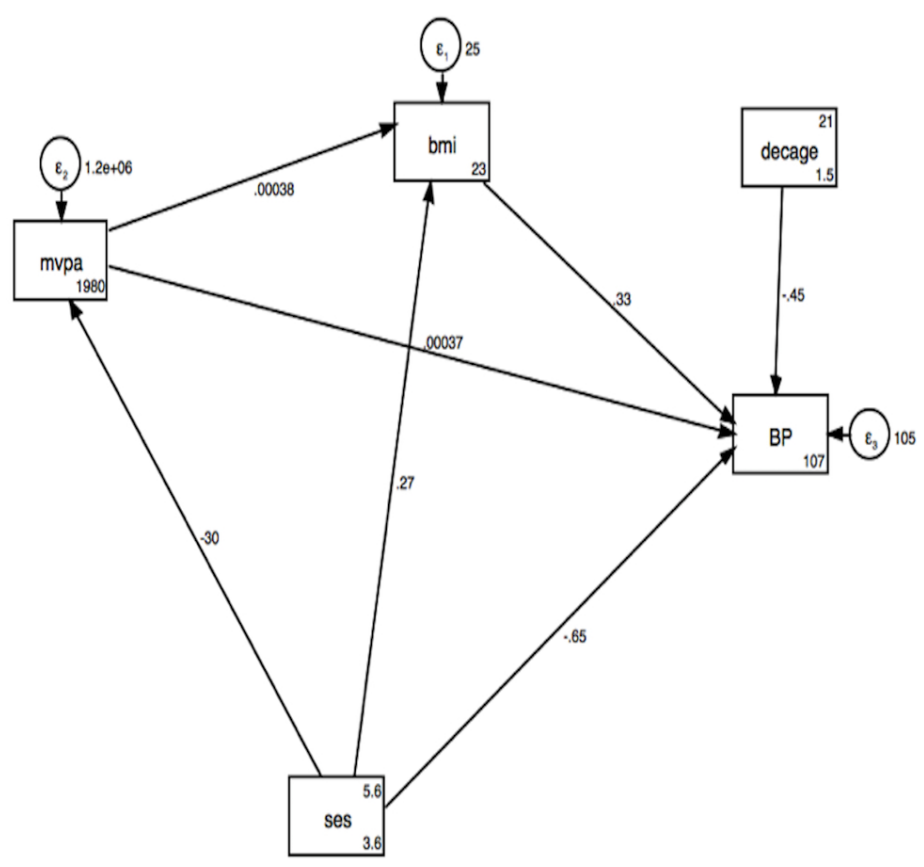
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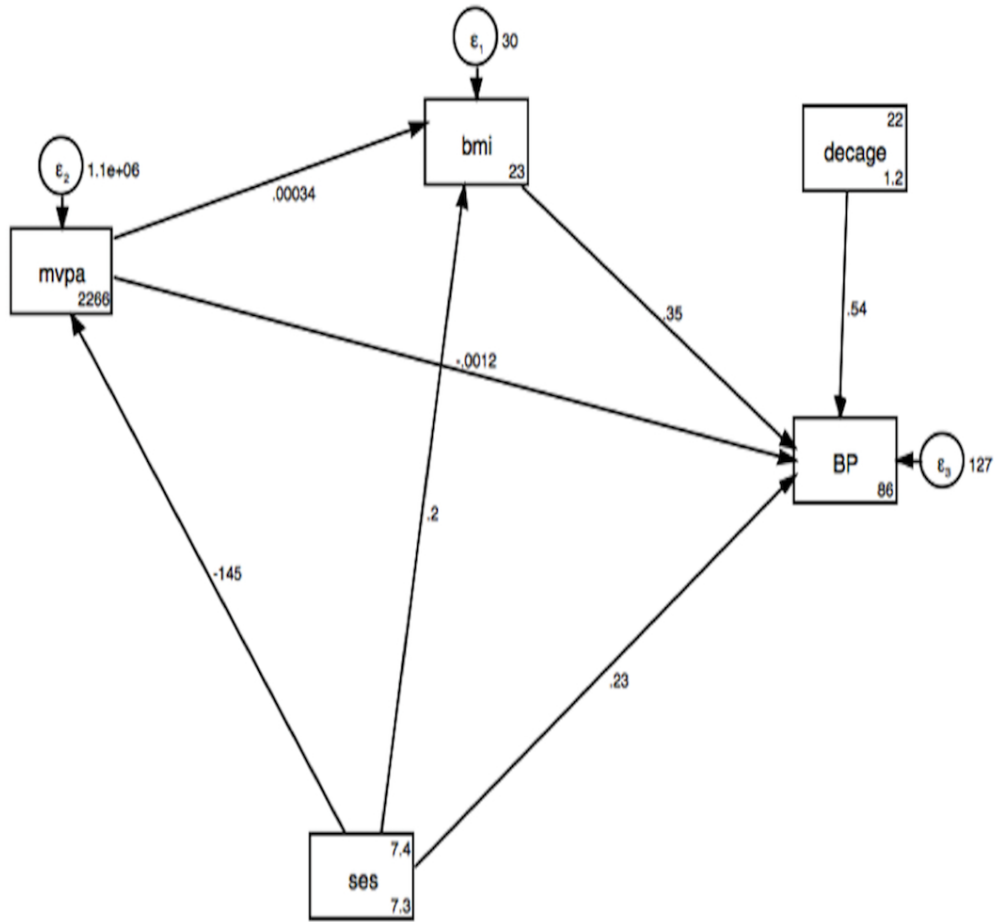
Structural equation model for SES, MVPA and BMI on SBP in urban

90x90mm (300 x 300 DPI)

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Structural equation model for SES, MVPA and BMI on SBP in rural  
90x90mm (300 x 300 DPI)



Structural equation model for SES, MVPA and BMI on SBP pooled

90x90mm (300 x 300 DPI)

## STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract <b>MS Page 4 Par 2</b> (b) Provide in the abstract an informative and balanced summary of what was done and what was found <b>MS Page 4</b>
<b>Introduction</b>		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported <b>MS Pages 5-6</b>
Objectives	3	State specific objectives, including any prespecified hypotheses <b>MS Page 6 Par 2</b>
<b>Methods</b>		
Study design	4	Present key elements of study design early in the paper <b>Methods: MS Page 6 Par 3</b>
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection <b>Methods: MS Page 6 Par 3</b>
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <b>N/A</b>  <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <b>N/A</b> <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants <b>Methods: MS Page 6 Par 3</b> (b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <b>N/A</b> <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case <b>N/A</b>
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable <b>Methods: MS Page 6 Par 4 – Page 8 Par 1</b>
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 <b>Methods: MS Page 6 Par 4 – Page 8 Par 1</b>
Bias	9	Describe any efforts to address potential sources of bias <b>Methods: MS Page 6 Par 3</b>
Study size	10	Explain how the study size was arrived at <b>Methods: MS Page 6 Par 3</b>
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why <b>Methods: MS Page 8 Par 2</b>
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding <b>Statistical analyses: MS Page 8 Par 2 and 3</b> (b) Describe any methods used to examine subgroups and interactions <b>N/A</b> (c) Explain how missing data were addressed <b>Statistical analyses: MS Page 8 Par 2</b> (d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was

1  
2 addressed N/A

3 *Cross-sectional study*—If applicable, describe analytical methods taking account of  
4 sampling strategy N/A

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5 (e) Describe any sensitivity analyses N/A

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## 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 <b>Results: Page 8 Par 5 – Page 9 Par 1</b> (b) Give reasons for non-participation at each stage <b>N/A</b> (c) Consider use of a flow diagram <b>N/A</b>
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders <b>Page 8 Par 5 – Page 9 Par 1</b> (b) Indicate number of participants with missing data for each variable of interest <b>Results: Page 8 Par 5</b> (c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount) <b>N/A</b>
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time <b>N/A</b> <i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure <b>N/A</b> <i>Cross-sectional study</i> —Report numbers of outcome events or summary measures <b>Results: Page 8 Par 5</b>
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 <b>Results: Page 9 Par 1</b> (b) Report category boundaries when continuous variables were categorized <b>N/A</b> (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period <b>N/A</b>
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses <b>N/A</b>

## Discussion

Key results	18	Summarise key results with reference to study objectives <b>Discussion: Page 9 Par 2</b>
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias <b>Discussion: Page 11 Par 4</b>
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence <b>Page 9 Par 3 – Page 11 Par 3</b>
Generalisability	21	Discuss the generalisability (external validity) of the study results <b>Discussion: Page 9 Par 3 – Page 11</b>

## 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 <b>Funding: Page 12 Par 1</b>
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\*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](http://www.strobe-statement.org).

# BMJ Open

## Body composition and physical activity as mediators in the relationship between socio-economic status and blood pressure in young South African women: A structural equation model analysis

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2018-023404.R1
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Date Submitted by the Author:	12-Jul-2018
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<b>Primary Subject Heading</b>:	Epidemiology
Secondary Subject Heading:	Public health, Epidemiology
Keywords:	Hypertension < CARDIOLOGY, Obesity, Socioeconomic status, Physical activity, Structural equation model, Body mass index

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4 2 **Body composition and physical activity as mediators in the relationship between socio-economic status and**  
5 3 **blood pressure in young South African women: A structural equation model analysis**  
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8 6 Richard J Munthali<sup>1</sup>, Mercy Manyema<sup>1,2</sup>, Rihlat Said-Mohamed<sup>1</sup>, Juliana Kagura<sup>1</sup>, Stephen Tollman<sup>3,4,5</sup>, Kathleen  
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34 27 **Conflict of interest:** The views expressed in the submitted article are our own and not an official position of the  
35 28 affiliated institutions or funder. Authors have no financial relationships relevant to this article to disclose.  
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1  
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3 87 **Abstract**

4 88

5 89 **Objectives** Varying hypertension prevalence across different socio-economic strata within a population has been  
6 90 well reported. However the causal factors and pathways across different settings are less clear, especially in sub-  
7 91 Saharan Africa. Therefore, this study aimed to compare blood pressure (BP) levels, and investigate the extent to  
8 92 which socioeconomic status (SES) is associated with blood pressure, in rural and urban South Africa women.  
9 93

10 94 **Setting** Rural and urban South Africa.  
11 95

12 96 **Design** Cross-sectional.  
13 97

14 98 **Participants** Cross-sectional data on SES, total moderate-vigorous physical activity (MVPA), anthropometric and  
15 99 blood pressure were collected on rural (n=509) and urban (n=510) young black women (18-23 years age). Pregnant  
16 100 and mentally or physically disabled women were excluded from the study.  
17 101

18 102 **Results** The prevalence of combined overweight and obesity (46.5% versus 38.8%) and elevated BP (27.0% versus  
19 103 9.3%) were higher in urban than rural women respectively. Results from the structural equation modelling showed  
20 104 significant direct positive effects of body mass index (BMI) on systolic BP (SBP) in rural, urban and pooled  
21 105 datasets. Negative direct effects of SES on SBP and positive total effects of SES on SBP were observed in the rural  
22 106 and pooled datasets respectively. In rural young women, SES had direct positive effects on BMI and was negatively  
23 107 associated with MVPA in urban and pooled analyses. BMI mediated the positive total effects association between  
24 108 SES and SBP in pooled analyses ( $\beta$ ; 95%CI, 0.46; 0.15 to 0.76).  
25 109

26 110 **Conclusions** Though South Africa is undergoing nutritional and epidemiological transitions; the prevalence of  
27 111 elevated BP still varies between rural and urban young women. The association between SES and SBP varies  
28 112 considerably in economically diverse populations with BMI being the most significant mediator. There is a need to  
29 113 tailor prevention strategies to take into account optimizing BMI when designing strategies to reduce future risk of  
30 114 hypertension in young women.  
31 115

32 116 **Keywords** Blood pressure, Body mass index, Hypertension, Obesity, Urban, Rural, Socioeconomic status,  
33 117 Structural equation model, Physical activity  
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### Strengths

1. The use of structural equation modelling allowed us to explore direct and indirect (mediation) effects of social economic status, physical activity and body mass index on elevated blood pressure from a representative sample of rural and urban populations of South African young women.
2. Although the urban and rural cohorts were from two different studies, the same research unit conducted both studies and, therefore, the data collection and management process were consistent between the two sites, thereby allowing for accurate comparison.

### Limitations

1. Other unmeasured data, such as undernutrition in infancy, and dietary patterns were not included in the current analyses.
2. The low reliability of self-report data on physical activity could introduce bias. Thus, there is need for more accurate, objective measures of physical activity to strengthen the results of our analysis.
3. There is a need to do comparison on longitudinal data, especially as the socioeconomic environment is changing rapidly due to rural-urban labor migration and other factors would be helpful to examine these associations over time.

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## 148 Introduction

149  
150 High blood pressure (BP) or hypertension is a leading risk factor accounting for 7% of global disability-adjusted life  
151 years (DALYs) and contributing to the 34.5 million non-communicable disease (NCD) related deaths in 2010 [1, 2].  
152 A recent global meta-analysis, involving 19.1 million individuals, reported that on average there has been a decrease  
153 in BP globally, but low- to middle-income countries (LMICs) have seen an increase in hypertension [3]. The  
154 prevalence of high BP in LMICs is estimated at 30% [4, 5] and it is the most significant risk factor for  
155 cardiovascular disease, most notably stroke [6]. In 2000, hypertension was estimated to have caused 9% of all deaths  
156 and over 390 000 DALYs in South Africa. Further, hypertension contributed to 50% of all strokes and 42% of  
157 ischaemic heart disease (IHD), signifying a substantial public health burden [7]. A systematic review of sub-Saharan  
158 African (SSA) data shows prevalence rates of hypertension of up to 41% with higher prevalence rates noted in urban  
159 compared to rural populations [8, 9]. A study in men and women aged 40 to 60 years of age in six sites across four  
160 SSA countries, including South Africa, showed the same trend with South African urban and rural cohorts having  
161 the highest prevalence of hypertension (41.6 to 54.1%) [10].

162  
163 LMICs are experiencing both epidemiological and nutritional transitions with urban populations further along the  
164 transition as demonstrated by the higher prevalence of obesity and NCDs [4, 5, 8, 10-15]. Some evidence has shown  
165 that there are differences in the levels of BP between rural and urban settings [8], while other studies have found no  
166 significant differences [16]. According to Glass and McAtee, internal biological systems are sculpted by an  
167 interaction between genes and prolonged exposure to particular external environments, a principle they call  
168 embodiment [17]. Thus the differences in built and social environments between rural and urban settings may  
169 explain the differences in disease prevalence. A Ghanaian study showed that both systolic blood pressure (SBP) and  
170 diastolic blood pressure (DBP) were significantly lower in rural participants compared to urban participants [18].  
171 However, a similar study in adolescents found that BP levels were only lower in rural boys, with no difference in the  
172 girls [19]. Pediatric and adolescent hypertension have been reported to track into adulthood in a South African urban  
173 population [20]. Results on elevated BP from studies in rural South African children have reported prevalence rates  
174 varying from 1.0% to 25.4% [21-24]. The factors explaining these differences have not been fully studied in LMICs.

175  
176 Socioeconomic factors such as education, household income and household assets have been associated with BP  
177 levels [25-27]. In a US cohort of young adults, a higher household income remained associated with lower SBP even  
178 after controlling for all potential covariates including age, sex and bio-behavioral factors [28]. Similarly, in a French  
179 sample of 30-79 year olds, SBP independently increased and was inversely associated with both individual  
180 education and residential neighborhood education [29]. Studies in African countries have also found varying  
181 associations between socioeconomic status (SES) and BP patterns, with both positive and negative associations  
182 reported [8, 30, 31]. Some studies have speculated that the association between SES and body mass index (BMI),  
183 physical activity levels, diet, smoking, alcohol intake and malnutrition may influence BP patterns [18, 28, 31, 32].

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3 184 Physical activity has been inversely associated with blood pressure and BMI directly associated with BP in more  
4 185 advanced economies, but inconsistent associations have been reported in LMICs [25, 33-37].

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7 187 There is a need to examine BP and its determinants in young South African adults given the high rates of overweight  
8 188 and obesity and hypertension observed in this age group [20, 38]. Recent South African reports also indicate that the  
9 189 highest pregnancy rates occur in the age range of 20-24 years, with 26.2% of births reported, followed closely by the  
10 190 25-29 year age group (25.7%) [39], and therefore targeting young adult women would also reduce adverse health  
11 191 outcomes in their children. It is important to closely examine rural-urban differences in hypertension due to  
12 192 differences in the epidemiology of obesity and SES divergence in the South African context, in order to better suit  
13 193 interventions to the different settings [23, 26, 30, 40-43]. Therefore, this study aims to compare BP levels between  
14 194 rural and urban young adult South African women, and to determine whether there is an association between SES  
15 195 and BP, and whether it is mediated by physical activity and BMI.

## 196 197 **Methods**

### 198 **Study sample and site**

199 The rural Agincourt site, 2016 potential the female participants between the ages of 18 and 23 years were in the  
200 existing Agincourt Health and Socio-demographic Surveillance System database [44]. Only 996 were located during  
201 the data collection period and were invited to participate and of these, 509 female participants were recruited. The  
202 urban sample consisted of 510 young women between the ages of 22 and 23 years who were randomly selected  
203 from the sample of 720 females who were part of the Birth-to-Twenty plus (BT20+) Young Adult Survey [45, 46].  
204 Young women (n=51; 33 in rural and 18 in urban) who were pregnant at the time of the study were excluded, see the  
205 study design flow chart in **Figure 1**. Measurements and questionnaires were completed by trained research assistants  
206 and nurses, and were standardised between both sites, to eliminate biases. The study protocols were approved by the  
207 Human Research Ethics Committee of the University of the Witwatersrand (Clearance certificates M120138 for the  
208 Ntshembo-Hope Cross Sectional Survey in Agincourt and M111182 for the BT20+ survey). Written consent to  
209 participate was provided by participants, and mentally or physically disabled women were excluded from the study.

### 210 **Patient and Public Involvement**

211 No patients private or public were involved in this study, as it was a community population based.

### 212 213 **Blood pressure**

214 Blood pressure (mm Hg) was the outcome variable and it was measured using an Omron 6 automated machine  
215 (Kyoto, Japan). A five minute seated rest was observed before taking the BP measurements. Participants' seated BP  
216 was measured three times on the right side, with a 2-minute interval between each measurement. The mean for the

217 second and third readings was recorded for the current analysis. We had various cuff sizes and the appropriate size  
218 was used to accommodate differences in arm circumference.

219  
220 According to the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and  
221 Treatment of High Blood Pressure [47], five categories of BP have been established for adults 18 years of age and  
222 older as shown in Table 1. These cut-offs were utilized in the current study. Prehypertension and hypertension were  
223 combined to create a new variable called elevated BP.

224  
225 **Table 1:** Blood pressure classification [47]

Classification	Systolic Blood Pressure	or	Diastolic Blood Pressure	
Low	<90	or	< 60	226
Normal	<120	and	<80	227
Prehypertension	120-139	or	80-90	228
High: Stage 1 Hypertension	140-159	or	90-99	229
High: Stage 2 hypertension	≥160	or	≥100	230
				231
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235 SBP was used in structural equation models (SEM) as it is more relevant in adults, and a good predictor of adverse  
236 health outcomes later in life [48], such as CVDs.

### 237 Anthropometry

238 At both sites, participants' height and weight were measured by trained research assistants using standard techniques  
239 [49, 50] . Weight was measured in light clothing and barefoot to the nearest 0.1 kg using a digital scale (Tanita  
240 model TBF-410; Arlington Heights; USA). Height was measured barefoot to the nearest 0.1 cm using a  
241 stadiometer (Holtain, Crymych, UK). Waist circumference was measured with a non-stretchable fibreglass tape at  
242 the level of the umbilicus. BMI was calculated as weight/height<sup>2</sup> (kg/m<sup>2</sup>).

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### 245 Socio-economic status (SES)

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3 246 Physical assets owned in the participants' household were used as a proxy for SES index [51]. It was generated by  
4 247 summing the number of assets owned in the household from the following: television, car, washing machine, fridge,  
5 248 phone, radio, microwave, cell phone, DVD/Video, DSTV (cable channel), computer, internet, medical aid. Previous  
6 249 studies in this population have shown that the sum of physical assets (household assets) is closely related to the  
7 250 household per capital expenditure and household income [51-53]. The household SES is regarded as a good measure  
8 251 of accumulated household wealth so it is a more reflective wealth index than income of a household's wealth over  
9 252 time.

### 14 253 **Physical activity**

16 254 The Global Physical Activity Questionnaire (GPAQ), developed for global physical activity surveillance, was  
17 255 completed via interview to obtain self-reported physical activity [54]. Total MVPA in minutes per week (mins/wk)  
18 256 was calculated by adding occupation, travel-related and leisure time moderate and vigorous intensity physical  
19 257 activity. Sitting time (mins/wk) was used as a proxy for sedentary time.

### 23 258 **Statistical analyses**

25 259 Analysis of variance and student's t test, and Chi-squared tests and Wilcoxon rank sum test for non-parametric  
26 260 variables, were conducted to compare study characteristics between urban and rural young women. Structural  
27 261 equation modeling (SEM), with missing data option, was used to test and estimate the direct and indirect  
28 262 associations between variables, most especially the mediation roles of physical activity (MVPA) or sedentary time  
29 263 (sitting), and body composition (BMI and WC), in the association between SES and SBP. SEMs allow us to assess  
30 264 the mediation effects of multiple mediators [55]. SEM decomposed SES-BP associations into two parts, direct  
31 265 (unmediated) and indirect (mediated through MVPA/sitting and BMI/WC).

36 266 Direct, indirect and total effects were computed and recorded, and the proportion of the total effect mediated was  
37 267 calculated. To evaluate the best fitting model for our data, we calculated different goodness of fit indices including  
38 268 Chi-squared test, Root mean squared error of approximation (RMSEA), Comparative fit index (CFI), Tucker-Lewis  
39 269 index (TLI) and Standardized root mean squared residual (SRMR) [56]. Though the Chi-squared test has been  
40 270 popularly used as a goodness of fit index, it has been reported to be biased and not reliable as the only goodness of  
41 271 fit index. It is also highly sensitive to sample size [57, 58], and often inflated with non-normal data such as physical  
42 272 activity data and we therefore employed the Hu and Bentler's Two-Index Presentation Strategy (1999) combination  
43 273 rule, with cut off values depending on the fitness index, to determine the best model fit [56, 59]. We estimated the  
44 274 coefficients ( $\beta$ ) with 95% confidence intervals (95% CI) for the direct, indirect and total effects and also calculated  
45 275 the proportion of association mediated by indirect effects. If the direct and indirect effects had opposite signs  
46 276 (negative or positive effects) the proportion mediated was assessed using the absolute values for all indirect and  
47 277 direct effects [60].

54 278 All the analyses were conducted using STATA (version 13.0; STATA Corp., College Station, TX, USA). We  
55 279 confirmed SEM results by running the SEM with the Satorra-Bentler and Huber-White (Robust) Sandwich



280 Estimator options [61] in STATA (version 15.1; STATA Corp., College Station, TX, USA). These options relax the  
281 normality assumption hence are robust to non-normal data, which would be the case for mvpa and SES in the  
282 current study. A P-value < 0.05 was considered statistically significant.

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284

## 285 **Results**

### 286 **Study characteristics**

287 Descriptive statistics for the non-pregnant study participants (urban, n=492; rural, n=476) are presented in Table 2.  
288 There was no difference in BMI or waist circumference between the urban and rural participants, but the prevalence  
289 of overweight and obesity was significantly higher in the urban (46.5%) compared to the rural young women  
290 (38.8%). Household SES was significantly higher in the urban compared to the rural group. Self-reported MVPA  
291 was significantly higher in the rural than urban women ( $p < 0.001$ ), and the urban women spent significantly more  
292 time sitting than their rural counterparts ( $p < 0.001$ ). Systolic and diastolic BP were significantly higher in the urban  
293 group, as was the prevalence of elevated BP (27.0 vs. 9.3%).

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### 295 **Structural equation models for body mass index and Waist circumference**

296 Results from the SEMs for SES associations with SBP via MVPA and BMI are presented in Tables 3a, 3b and 3c for  
297 urban, rural and pooled analyses respectively, and also shown in Figures 1, 2, 3. No significant direct or indirect  
298 effects via (MVPA or BMI) of SES on SBP were observed in either the urban or rural women, but there were  
299 significant direct effects of SES on MVPA. Results showed that individuals with a higher SES index were less likely  
300 to be physically active in pooled data and urban women. In rural women, a one-unit increase in total household  
301 assets was associated with a decrease of 0.65 mmHg (95% CI: -1.19 to -0.10) in SBP and an increase of 0.27 kg/m<sup>2</sup>  
302 in BMI (95% CI: 0.1 to 0.53) (**Tables 3a, 3b and Figures 2, 3**). The SEM for the pooled sample showed a  
303 significant indirect effect of household SES on SBP via BMI, with 50% of the total effect being mediated by BMI  
304 (**Table 3c and Figure 4**). Direct positive effects of BMI on SBP were observed in both settings and the pooled  
305 sample with a 1 kg/m<sup>2</sup> increase in BMI being associated with an increase of 0.37 mmHg (95% CI: 0.21 to 0.53) and  
306 0.33 (95% CI: 0.12 to 0.54) mmHg SBP in urban and rural young women, respectively. Similar results were  
307 observed when including waist circumference as the body composition indicator (data not shown).

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## 309 **Discussion**

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3 310 A rising prevalence of hypertension has been reported in South Africa. Peer and colleagues reported a higher  
4 311 prevalence in 2008 (35.6%) compared to 1990 (21.6 %) in men and women aged 25-74 years in an urban black  
5 312 community in Cape Town, South Africa [40]. We have shown in young adult women from urban and rural South  
6 313 Africa, an overall elevated BP prevalence of 18.4 % (27.0 % in urban and 9.3 % in rural). We have also shown a  
7 314 direct effect of BMI on SBP in the urban and rural women separately, as well as when pooled, thereby providing  
8 315 further evidence of an association between overall adiposity and blood pressure. The total effects of SES on SBP  
9 316 were the same in both settings.

13  
14 317 Prevalence data on elevated BP and hypertension from other countries in SSA have shown conflicting results when  
15 318 comparing urban and rural communities. In Malawi, a higher prevalence of hypertension in urban compared to rural  
16 319 communities has been reported and attributed to differences in lifestyle as rural communities participate in  
17 320 subsistence based agricultural activities while the urban community has a more westernized lifestyle with higher salt  
18 321 intake and lower physical inactivity [9]. Similarly, data from Ghana have shown a higher mean SBP and DBP and a  
19 322 higher prevalence of hypertension in urban communities [18, 62]. In the PURE study in South Africa, Pisa and  
20 323 colleagues reported that both urban adult men and women had higher mean blood pressures in comparison to their  
21 324 rural peers though the overall CVD risk factors were equally prevalent in both settings [41]. In contrast, findings  
22 325 from Cameroon have reported a higher BP prevalence in rural compared to urban men and women older than 40  
23 326 years old, while Kenyan studies have reported no significant differences [16, 63]. Results from six urban and rural  
24 327 sites in four SSA countries – Kenya, South Africa, Ghana and Burkina Faso – have reported a prevalence of  
25 328 hypertension in women aged between 40 and 60 years ranging from 15.1% in rural Burkina Faso to 54.1% in urban  
26 329 South Africa [10]. It was also reported that in all three South African sites, both rural and urban, the prevalence of  
27 330 hypertension was higher than in the other three countries [10]. These findings show the complex health transitions  
28 331 occurring in SSA and the impact that this is having on cardio-metabolic disease risk.

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36 332 Our study showed significant differences in SES between the urban and rural samples, as well a big variation in SES  
37 333 within these two settings. The social patterning of CVD risk factors, including hypertension, in SSA and LMICs has  
38 334 in part been attributed to differences in countries' socioeconomic development. Previous results from five countries,  
39 335 (two high income and three LMICs), reported that hypertension and other CVD risk factors were substantially  
40 336 associated with education and wealth status; individuals with less education and lower wealth generally showing  
41 337 higher prevalence of CVD risk factors [64]. The effect of SES in this study is most evident in the rural women for  
42 338 whom household SES was lower (compared to urban) and who may be transitioning faster (both nutritionally and  
43 339 economically) than the urban young women. Though SES is positively associated with BMI in rural young women,  
44 340 it is negatively associated with SBP. There may be other factors, such as physical activity due to agricultural  
45 341 activities or dietary patterns, which were not recorded. In addition, the weight gain observed might not be due to fat  
46 342 mass, which has been reported to be positively associated with SBP before [65], but rather to muscle mass and bone  
47 343 mass.

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54 344 In Mexico, women in rural and upper SES categories were likely to have a higher SBP, while we have reported that  
55 345 a higher SES was associated with a decrease in SBP in rural communities. At a population level, there is a need to

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3 346 consider different SES categories and monitor the effects of transitioning from one SES category to another on  
4 347 hypertension, since these categories may respond differently to an increase or a decrease in their SES. Kagura and  
5 348 colleagues tracked SES in South African children and reported that moving from the low SES in infancy to a higher  
6 349 SES in adolescence had a protective effect on SBP level in young adulthood [26]. Our results have shown that this  
7 350 could be more pronounced in rural areas.

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11 351 We observed a positive association between SES and BMI in the rural sample and the same direction of effects was  
12 352 observed in the urban, though not significant. This is in line with results reported in many LMICs including South  
13 353 Africa, but in contrast with those reported in higher income populations [33, 34, 64]. A systematic review of studies  
14 354 between 1989 to 2007 reported that SES was positively associated with obesity in the middle transitioning  
15 355 economies such as South Africa and Jamaica [66]. We have shown that both in the rural and urban participants (not  
16 356 significant), a higher SES resulted in reduced SBP, while the pooled analysis showed a positive total effect  
17 357 association between SES and SBP. This could be due to the introduction of more variation in SES when data from  
18 358 both sites are pooled; with many individuals with low SES in the rural area, the associations became skewed towards  
19 359 the low SES individuals. This may suggest that different transitional levels of SES have different effects on  
20 360 hypertension risk depending on the environment (either urban or rural). Though not significant, the total effects of  
21 361 SES on SBP are the same in both rural and urban hence the differences in prevalence cannot be explained by the  
22 362 setting or SES alone. In urban and rural settings of four countries (Kenya, Namibia, Nigeria and Tanzania), the  
23 363 prevalence of age standardized hypertension was similarly high and ranging from 19.3 % to 38.0 % [11]. Cois and  
24 364 colleagues reported that a higher SES was associated with lower SBP in a nationally representative sample of South  
25 365 African women [25] using SEM models. Alcohol use, PA, smoking and resting heart rate and BMI were reported to  
26 366 be the mediators of the indirect of the association between SES and SBP in men but not in women, suggesting that  
27 367 other factors may play a major role in women [25]. Similarly, our results show that neither PA nor BMI mediate the  
28 368 association between SES and SBP in urban and rural settings, suggesting that other factors may explain the  
29 369 association. Among those, dietary patterns and stress have been reported to be independently associated with SBP  
30 370 [67, 68].

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41 371 The significant direct associations between BMI and SBP are in line with other findings in South Africa and within  
42 372 the SSA region [11, 33, 40, 42, 69, 70]. This link was consistent in rural, urban and pooled data sets, indicating the  
43 373 importance of BMI in the aetiology of high BP. Munthali and colleagues reported that the link between obesity and  
44 374 hypertension could be observed as early as five years of age. Children with early onset of obesity were at higher risk  
45 375 of developing hypertension in late adolescence [38].

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49 376 In this study, using SEM models to explore the mediation role of BMI and PA helped quantify potential  
50 377 contributions of these variables to the effect of SES on SBP. The results show that PA was not a significant mediator  
51 378 in the association between SES and BP in the urban or the rural samples. SES was negatively associated with  
52 379 MVPA in urban and pooled samples, indicating that as individuals transition from low to higher SES, they reduce  
53 380 their physical activity level. We speculate that these differences in the association between SES and SBP in both our  
54 381 rural and urban results and in those from high-income countries are due to differences in levels of nutritional and  
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3 382 epidemiological transition in these regions [71, 72]. Those with low SES in high-income countries are likely to  
4 383 consume cheaper, more energy dense foods, participate in less leisure time PA and be more sedentary [73, 74] In  
5 384 LMICs, agricultural activities remain a part of everyday life and a day-to-day activity in rural living, while those  
6 385 with higher SES in the same settings rapidly adopt the westernized life style with less PA, fewer agricultural  
7 386 activities and home grown food. However, this speculation is not supported by the data on PA in this study despite  
8 387 the rural participants having a higher PA. Our understanding of the Agincourt rural economy is that agriculture is  
9 388 quite a minor aspect though very useful to augment the household income.

10 389 The limitations of this study are that other unmeasured data, such as undernutrition in infancy, which is a known risk  
11 390 factor for high BP later in life [75], and dietary patterns were not included in the current analyses. We are currently  
12 391 working on research to address this limitation. We can also not rule out the role of genetics. Secondly, the low  
13 392 reliability of self-report data on PA could introduce bias. Thus, there is need for more precise, objective measures of  
14 393 physical activity to strengthen the results of our analysis. Lastly, longitudinal data, especially as the socioeconomic  
15 394 environment is changing rapidly due to rural-urban labor migration and other factors would be helpful to examine  
16 395 these associations over time. The cross-sectional design lacks a temporal component between the factors analyzed.  
17 396 Thus, it is difficult to say anything certain about the direction of the associations, hence the need for the longitudinal  
18 397 data.

19 398

## 20 399 **Conclusions**

21 400 Though the prevalence of overweight or obesity is relatively higher in both rural and urban than those reported in  
22 401 other SSA countries, women in the urban setting were at more risk for elevated blood pressure than their rural  
23 402 counterparts. The link between SES and SBP varies in a more economically diverse population, as seen with the  
24 403 pooled rural and urban dataset, with BMI being the most likely mediator. There is need to consider optimizing BMI  
25 404 as a key intervention strategy in young adults in part to combat hypertension. Our findings should be replicated with  
26 405 prospective data.

27 406

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34 413 authors and are not to be attributed to the CoE in Human Development.

## 35 414 **Conflict of interest**

1  
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3 415 Authors have no conflicts of interest to disclose.

4 416 **Consent for publication**

5  
6 417 Not applicable

7 418 **Data Sharing**

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9 419 The datasets used and/or analysed during the current study are available from the Developmental Pathways  
10 420 for Health Research Unit data management department by contacting Prof. Shane A Norris on reasonable request

11 421 **Competing interest**

12 422 The authors declare that they have no competing interests

13 423 **Authors' contributions**

14 424 RJM and SAN conceptualized the manuscript. RJM analyzed the data. RJM MM RSM JK ST KK FXG LKM DD  
15  
16 425 SAN interpreted the data. RJM wrote the manuscript and all authors were involved in editing and approving the final  
17  
18 426 manuscript.

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21  
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23 430

24 431 **Ethics Approval and Consent to Participate**

25 432 Prior to the study, the study protocols were approved by the Human Research Ethics Committee of the University of  
26  
27 433 the Witwatersrand (Clearance certificates M120138 for the Ntshembo-Hope Cross Sectional Survey in Agincourt  
28  
29 434 and M111182 for the BT20+ survey). Independent written informed consent to participate was obtained from  
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31 435 participants.

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**Table 2:** Descriptive characteristics

	Total	n	Urban	n	Rural	p value
Age (years)	22.04 (1.24)	492	22.77 (0.49)	476	21.28 (1.31)	0.001
Weight (kg)	64.62 (14.82)	492	64.67 (15.6)	473	64.55 (14.03)	0.90
Height (m)	1.61 (0.007)	492	1.60 (0.07)	475	1.61 (0.07)	0.001
BMI (kg/m <sup>2</sup> )	25.05 (5.59)	492	25.32 (5.91)	476	24.78 (5.24)	0.13
BMI classification (%)		492		476		0.015
Underweight (<18.4 kg/m <sup>2</sup> )	5.98		7.10		4.82	
Normal weight (18.5-24.9 kg/m <sup>2</sup> )	51.34		46.45		56.39	
Overweight (25-29.9 kg/m <sup>2</sup> )	26.19		29.21		23.06	
Obese (≥30 kg/m <sup>2</sup> )	16.49		17.24		15.72	
Waist circumference (cm)	80.60 (12.08)	492	80.18 (12.63)	476	81.03 (11.47)	0.26
Central obesity, WC ≥ 80 cm , %	43.81	492	45.70	476	44.74	0.55
Household SES index (sum of assets)	7.24 (2.70)	492	8.83 (2.37)	476	5.59 (1.91)	<0.001
Total MVPA (min/week)*	870(280-1810)	492	420(160-900)	385	1680(970-2580)	<0.001
Sitting time (mins/day)*	300 (240-480)	492	360 (240-480)	385	300 (180-360)	<0.001
Systolic blood pressure	106.68 (11.64)	492	110.30 (11.4)	471	102.89 (10.7)	<0.001
Diastolic blood pressure	70.23 (9.00)	492	72.78 (8.3)	471	67.57 (9.0)	<0.001
BP classification (%)		492		471		<0.001
Low BP	12.46		5.49		19.75	
Normal BP	69.16		67.48		70.91	
Prehypertension	16.20		23.58		8.49	
Hypertensive	2.18		3.46		0.85	
Elevated BP (%)	18.38		27.04		9.34	<0.001
Highest Education attained (%)		480		371		<0.001
Primary school	1.18		0		2.70	
Secondary school	60.75		48.33		76.81	
Tertiary education	38.07		51.67		20.49	

Data presented as mean (SD) otherwise stated; \* Median (IQR)

**Table 3a:** Structural equation model for SES, MVPA and BMI on SBP in urban women

Effect of: N=489	Outcome:	Direct effects(95% CI)	Indirect effects( 95% CI)	Total effects(95% CI)	Proportion of total effect mediated
Household assets	SBP	-0.34 (-0.75; 0.07)		-0.29 (-0.70; 0.12)	0.13 <sup>a</sup>
	via BMI		0.05 (-0.05; 0.14)		
	BMI	0.13 (-0.09; 0.35)		0.11 (-0.11; 0.33)	0.1 <sup>a</sup>
	via MVPA		-0.014 (-0.05; 0.013)		
	MVPA	-41.71 (-73.48; -9.94)**		-41.71 (-73.48; -9.94)**	
MVPA	SBP	-0.0002 (-0.001; 0.001)		-0.0000 (-0.0012; 0.0011)	0.3 <sup>a</sup>
	via BMI		0.0001 (-0.0001; 0.0004)		
BMI	SBP	0.37 (0.21; 0.53)***		0.37 (0.21; 0.53)***	

Adjusted for age; \* P<0.05; \*\* P< 0.01; \*\*\*P< 0.001; SBP; systolic blood pressure, MVPA; moderate to vigorous intensity physical activity, BMI; body mass index, SES; social economic status, <sup>a</sup> Assessed using the absolute values for both indirect and direct effects

**Urban Fit Indices:** LR test of model vs. saturated:  $\chi^2(4) = 0.97$ , Prob >  $\chi^2 = 0.91$ ; RMSEA = 0.00; **CFI= 1.00** Comparative fit index;

TLI= 1.12 Tucker-Lewis index; **SRMR=0.011**: Standardized root mean squared residual, CD= 0.017 Coefficient of determination.

**Table 3b:** Structural equation model for SES, MVPA and BMI on SBP in rural women

Effect of: N= 378	Outcome:	Direct effects(95% CI)	Indirect effects( 95% CI)	Total effects(95% CI)	Proportion of total effect mediated
<b>Household assets</b>	SBP via BMI	-0.65 (-1.19; -0.096)*	0.08 (-0.04; 0.19)	-0.56 (-1.12; -0.02)*	0.11 <sup>a</sup>
	BMI via MVPA	0.27 (0.01; 0.53)*	-0.01 (-0.04; 0.01)	0.26 (-0.005; 0.53)*	0.04
	MVPA	-29.51 (-87.81; 28.78)		-29.51 (-87.81; 28.78)	
<b>MVPA</b>	SBP via BMI	0.0004 (-.0005729 .0013)	0.0001 (-0.0000; 0.0003)	0.0005 (-0.0005; 0.0015)	0.2
<b>BMI</b>	SBP	0.33 (0.12; 0.54)**		0.33 (0.12; 0.54)**	

Adjusted for age; \* P<0.05; \*\* P< 0.01; \*\*\*P< 0.001; SBP; systolic blood pressure, MVPA; moderate to vigorous physical activity, BMI; body mass index, SES; social economic status, <sup>a</sup> Assessed using the absolute values for both indirect and direct effects

**Rural Fit Indices:** LR test of model vs. saturated: chi2(4) = 10.51, Prob > chi2 = 0.03; RMSEA = 0.066; **CFI= 0.72** Comparative fit index; TLI= 0.37 Tucker-Lewis index; **SRMR= 0.04** : Standardized root mean squared residual, CD= 0.03 Coefficient of determination.

**Table 3c:** Structural equation model for SES, MVPA and BMI on SBP in the pooled sample of urban and rural women

Effect of: N=867	Outcome:	Direct effects(95% CI)	Indirect effects( 95% CI)	Total effects(95% CI)	Proportion of total effect mediated
<b>Household assets</b>	SBP	0.23 (-0.08; 0.54)		0.46 (0.15; 0.76)**	0.5
	via BMI		0.23 (0.10; 0.35)***		
	BMI	0.20 (0.05; 0.34)**		0.15 (0.01; 0.29)*	0.25 <sup>a</sup>
	via MVPA		-0.05 (-.100; 0.003)		
	MVPA	-144.83 (-170.55; -119.12)***		-144.83 (-170.55; -119.12)***	
<b>MVPA</b>	SBP	-0.001 (-0.002; -0.0005)**		-0.001 (-0.002; -0.0003)**	0.1 <sup>a</sup>
	via BMI		0.0001 (-0.0000; 0.0002)		
<b>BMI</b>	SBP	0.35 (0.21; 0.49)***		0.35 (0.21; 0.49)***	

Adjusted for age; \* P<0.05; \*\* P< 0.01; \*\*\*P< 0.001; SBP; systolic blood pressure, MVPA; moderate to vigorous intensity physical activity, BMI; body mass index, SES; social economic status, <sup>a</sup> Assessed using the absolute values for both indirect and direct effects

**Pooled Fit Indices:** LR test of model vs. saturated:  $\chi^2(4) = 24.829$ , Prob >  $\chi^2 = 0.000$ ; RMSEA = 0.077; **CFI= 0.89** Comparative fit index; TLI= 0.75 Tucker-Lewis index; **SRMR=0.033**: Standardized root mean squared residual, CD=0.137 Coefficient of determination.

**Figure legends**

Figure 1: Selection of study participants in rural and urban

Figure 2: Structural equation model for SES, MVPA and BMI on SBP in urban

Figure 3: Structural equation model for SES, MVPA and BMI on SBP in rural

Figure 4: Structural equation model for SES, MVPA and BMI on SBP pooled

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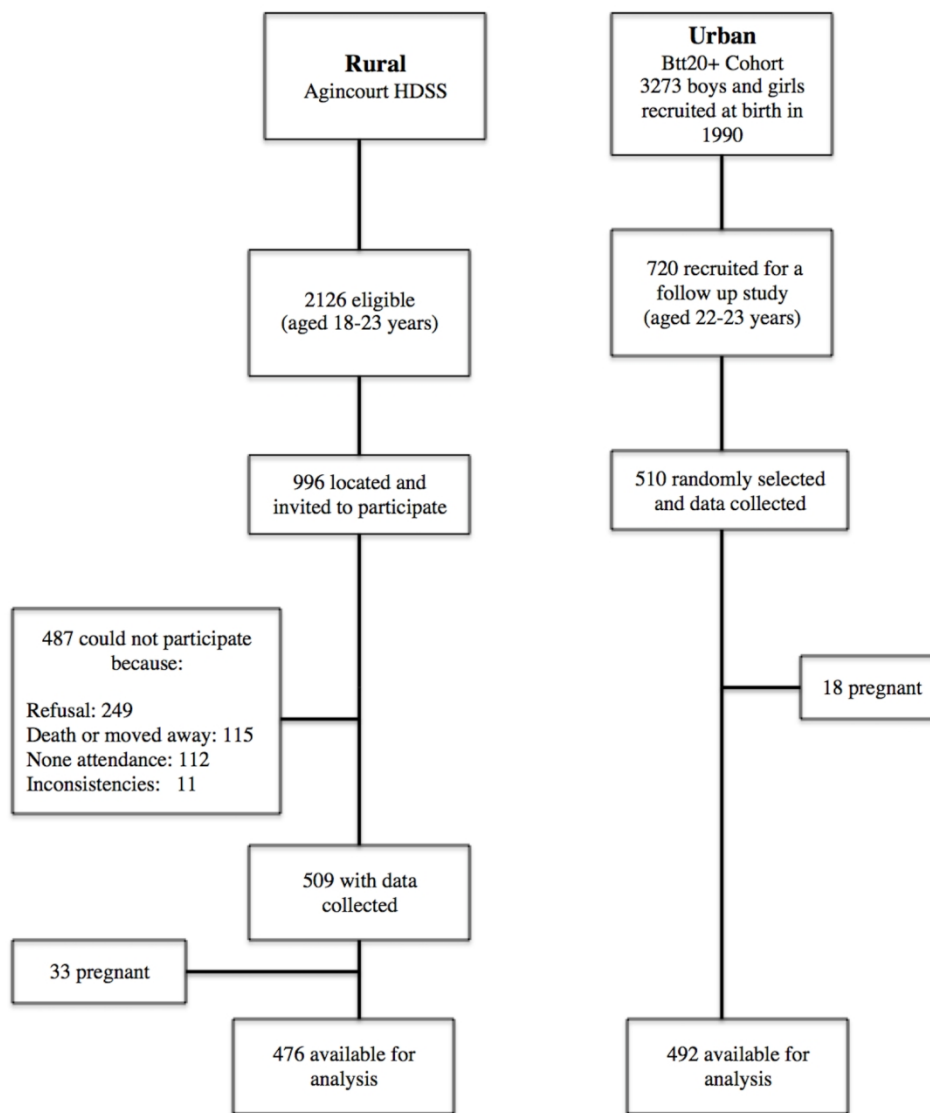


Figure 1: Selection of study participants in rural and urban

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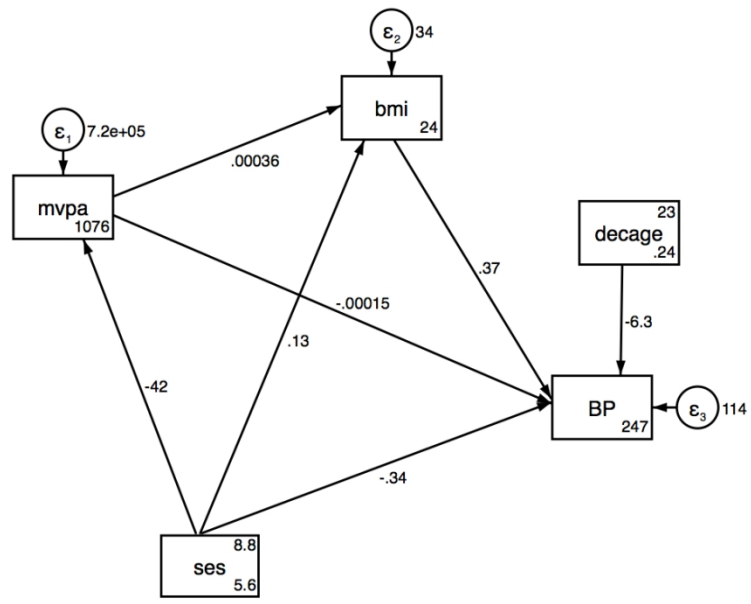


Figure 2: Structural equation model for SES, MVPA and BMI on SBP in urban  
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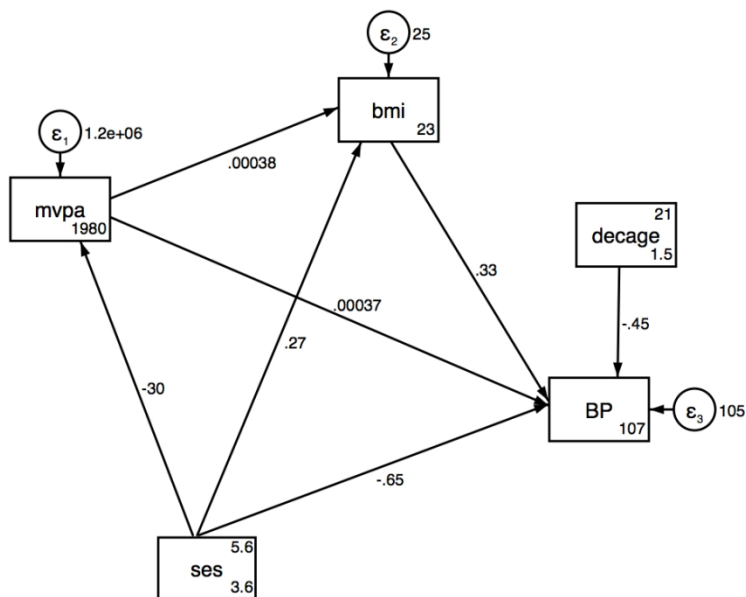


Figure 3: Structural equation model for SES, MVPA and BMI on SBP in rural  
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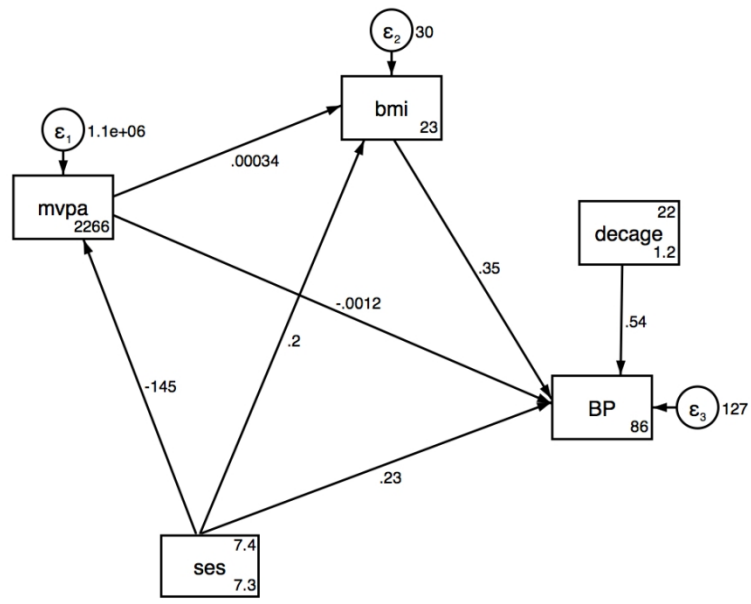


Figure 4: Structural equation model for SES, MVPA and BMI on SBP pooled  
106x70mm (300 x 300 DPI)

## STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract <b>MS Page 4 Par 2</b> (b) Provide in the abstract an informative and balanced summary of what was done and what was found <b>MS Page 4</b>
<b>Introduction</b>		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported <b>MS Pages 5-6</b>
Objectives	3	State specific objectives, including any prespecified hypotheses <b>MS Page 6 Par 2</b>
<b>Methods</b>		
Study design	4	Present key elements of study design early in the paper <b>Methods: MS Page 6 Par 3</b>
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection <b>Methods: MS Page 6 Par 3</b>
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <b>N/A</b>  <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <b>N/A</b>  <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants <b>Methods: MS Page 6 Par 3</b> (b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <b>N/A</b>  <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case <b>N/A</b>
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable <b>Methods: MS Page 6 Par 4 – Page 8 Par 1</b>
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 <b>Methods: MS Page 6 Par 4 – Page 8 Par 1</b>
Bias	9	Describe any efforts to address potential sources of bias <b>Methods: MS Page 6 Par 3</b>
Study size	10	Explain how the study size was arrived at <b>Methods: MS Page 6 Par 3</b>
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why <b>Methods: MS Page 8 Par 2</b>
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding <b>Statistical analyses: MS Page 8 Par 2 and 3</b> (b) Describe any methods used to examine subgroups and interactions <b>N/A</b> (c) Explain how missing data were addressed <b>Statistical analyses: MS Page 8 Par 2</b> (d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was

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addressed **N/A**  
*Cross-sectional study*—If applicable, describe analytical methods taking account of  
sampling strategy **N/A**  

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*(e)* Describe any sensitivity analyses **N/A**

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**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 <b>Results: Page 8 Par 5 – Page 9 Par 1</b> (b) Give reasons for non-participation at each stage <b>N/A</b> (c) Consider use of a flow diagram <b>N/A</b>
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders <b>Page 8 Par 5 – Page 9 Par 1</b> (b) Indicate number of participants with missing data for each variable of interest <b>Results: Page 8 Par 5</b> (c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount) <b>N/A</b>
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time <b>N/A</b> <i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure <b>N/A</b> <i>Cross-sectional study</i> —Report numbers of outcome events or summary measures <b>Results: Page 8 Par 5</b>
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 <b>Results: Page 9 Par 1</b> (b) Report category boundaries when continuous variables were categorized <b>N/A</b> (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period <b>N/A</b>
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses <b>N/A</b>

**Discussion**

Key results	18	Summarise key results with reference to study objectives <b>Discussion: Page 9 Par 2</b>
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias <b>Discussion: Page 11 Par 4</b>
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence <b>Page 9 Par 3 – Page 11 Par 3</b>
Generalisability	21	Discuss the generalisability (external validity) of the study results <b>Discussion: Page 9 Par 3 – Page 11</b>

**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 <b>Funding: Page 12 Par 1</b>
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\*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](http://www.strobe-statement.org).

# BMJ Open

## Body composition and physical activity as mediators in the relationship between socio-economic status and blood pressure in young South African women: A structural equation model analysis

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5 2 **Body composition and physical activity as mediators in the relationship between socio-**  
6 3 **economic status and blood pressure in young South African women: A structural equation**  
7 4 **model analysis**  
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**Abstract**

For peer review only

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3 92 **Objectives** Varying hypertension prevalence across different socio-economic strata within a  
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5 93 population has been well reported. However the causal factors and pathways across different  
6  
7 94 settings are less clear, especially in sub-Saharan Africa. Therefore, this study aimed to  
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9 95 compare blood pressure (BP) levels, and investigate the extent to which socioeconomic status  
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11 96 (SES) is associated with blood pressure, in rural and urban South Africa women.  
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16 98 **Setting** Rural and urban South Africa.  
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20 100 **Design** Cross-sectional.  
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24 102 **Participants** Cross-sectional data on SES, total moderate-vigorous physical activity (MVPA),  
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26 103 anthropometric and blood pressure were collected on rural (n=509) and urban (n=510) young  
27  
28 104 black women (18-23 years age). Pregnant and mentally or physically disabled women were  
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30 105 excluded from the study.  
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33  
34 107 **Results** The prevalence of combined overweight and obesity (46.5% versus 38.8%) and  
35  
36 108 elevated BP (27.0% versus 9.3%) were higher in urban than rural women respectively. Results  
37  
38 109 from the structural equation modelling showed significant direct positive effects of body mass  
39  
40 110 index (BMI) on systolic BP (SBP) in rural, urban and pooled datasets. Negative direct effects of  
41  
42 111 SES on SBP and positive total effects of SES on SBP were observed in the rural and pooled  
43  
44 112 datasets respectively. In rural young women, SES had direct positive effects on BMI and was  
45  
46 113 negatively associated with MVPA in urban and pooled analyses. BMI mediated the positive total  
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48 114 effects association between SES and SBP in pooled analyses ( $\beta$ ; 95%CI, 0.46; 0.15 to 0.76).  
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52 116 **Conclusions** Though South Africa is undergoing nutritional and epidemiological transitions; the  
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54 117 prevalence of elevated BP still varies between rural and urban young women. The association  
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3 118 between SES and SBP varies considerably in economically diverse populations with BMI being  
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5 119 the most significant mediator. There is a need to tailor prevention strategies to take into  
6  
7 120 account optimizing BMI when designing strategies to reduce future risk of hypertension in  
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9 121 young women.  
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14 123 **Keywords** Blood pressure, Body mass index, Hypertension, Obesity, Urban, Rural,  
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16 124 Socioeconomic status, Structural equation model, Physical activity  
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5**Strengths**

1. The use of structural equation modelling allowed us to explore direct and indirect (mediation) effects of social economic status, physical activity and body mass index on elevated blood pressure from a representative sample of rural and urban populations of South African young women.
2. Although the urban and rural cohorts were from two different studies, the same research unit conducted both studies and, therefore, the data collection and management process were consistent between the two sites, thereby allowing for accurate comparison.

**Limitations**

1. Other unmeasured data, such as undernutrition in infancy, and dietary patterns were not included in the current analyses.
2. The low reliability of self-report data on physical activity could introduce bias. Thus, there is need for more accurate, objective measures of physical activity

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155 **Introduction**

156

157 High blood pressure (BP) or hypertension is a leading risk factor accounting for 7% of global  
158 disability-adjusted life years (DALYs) and contributing to the 34.5 million non-communicable  
159 disease (NCD) related deaths in 2010 [1, 2]. A recent global meta-analysis, involving 19.1  
160 million individuals, reported that on average there has been a decrease in BP globally, but low-  
161 to middle-income countries (LMICs) have seen an increase in hypertension [3]. The prevalence  
162 of high BP in LMICs is estimated at 30% [4, 5] and it is the most significant risk factor for  
163 cardiovascular disease, most notably stroke [6]. In 2000, hypertension was estimated to have  
164 caused 9% of all deaths and over 390 000 DALYs in South Africa. Further, hypertension  
165 contributed to 50% of all strokes and 42% of ischaemic heart disease (IHD), signifying a  
166 substantial public health burden [7]. A systematic review of sub-Saharan African (SSA) data  
167 shows prevalence rates of hypertension of up to 41% with higher prevalence rates noted in  
168 urban compared to rural populations [8, 9]. A study in men and women aged 40 to 60 years of  
169 age in six sites across four SSA countries, including South Africa, showed the same trend with  
170 South African urban and rural cohorts having the highest prevalence of hypertension (41.6 to  
171 54.1%) [10].

172

173 LMICs are experiencing both epidemiological and nutritional transitions with urban populations  
174 further along the transition as demonstrated by the higher prevalence of obesity and NCDs [4,  
175 5, 8, 10-15]. Some evidence has shown that there are differences in the levels of BP between  
176 rural and urban settings [8], while other studies have found no significant differences [16].

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3 177 According to Glass and McAtee, internal biological systems are sculpted by an interaction  
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5 178 between genes and prolonged exposure to particular external environments, a principle they call  
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7 179 embodiment [17]. Thus the differences in built and social environments between rural and urban  
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9 180 settings may explain the differences in disease prevalence. A Ghanaian study showed that  
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11 181 both systolic blood pressure (SBP) and diastolic blood pressure (DBP) were significantly lower  
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13 182 in rural participants compared to urban participants [18]. However, a similar study in  
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15 183 adolescents found that BP levels were only lower in rural boys, with no difference in the girls  
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17 184 [19]. Pediatric and adolescent hypertension have been reported to track into adulthood in a  
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19 185 South African urban population [20]. Results on elevated BP from studies in rural South African  
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21 186 children have reported prevalence rates varying from 1.0% to 25.4% [21-24]. The factors  
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23 187 explaining these differences have not been fully studied in LMICs.  
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28 189 Socioeconomic factors such as education, household income and household assets have been  
29  
30 190 associated with BP levels [25-27]. In a US cohort of young adults, a higher household income  
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32 191 remained associated with lower SBP even after controlling for all potential covariates including  
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34 192 age, sex and bio-behavioral factors [28]. Similarly, in a French sample of 30-79 year olds, SBP  
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36 193 independently increased and was inversely associated with both individual education and  
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38 194 residential neighborhood education [29]. Studies in African countries have also found varying  
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40 195 associations between socioeconomic status (SES) and BP patterns, with both positive and  
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42 196 negative associations reported [8, 30, 31]. Some studies have speculated that the association  
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44 197 between SES and body mass index (BMI), physical activity levels, diet, smoking, alcohol intake  
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46 198 and malnutrition may influence BP patterns [18, 28, 31, 32]. Physical activity has been  
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48 199 inversely associated with blood pressure and BMI directly associated with BP in more advanced  
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50 200 economies, but inconsistent associations have been reported in LMICs [25, 33-37].  
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3 202 There is a need to examine BP and its determinants in young South African adults given the  
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5 203 high rates of overweight and obesity, and hypertension observed in this age group [20, 38].  
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7 204 Recent South African reports also indicate that the highest pregnancy rates occur in the age  
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9 205 range of 20-24 years, with 26.2% of births reported, followed closely by the 25-29 year age  
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11 206 group (25.7%) [39], and therefore targeting young adult women would also reduce adverse  
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13 207 health outcomes in their children. It is important to closely examine rural-urban differences in  
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15 208 hypertension due to differences in the epidemiology of obesity and SES divergence in the  
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17 209 South African context, in order to better suit interventions to the different settings [23, 26, 30,  
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19 210 40-43]. Therefore, this study aims to compare BP levels between rural and urban young adult  
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21 211 South African women, and to determine whether there is an association between SES and BP,  
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23 212 and whether it is mediated by physical activity and BMI.  
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## 29 214 **Methods**

### 31 32 215 **Study sample and site**

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35 216 The rural Agincourt site, 2016 potential female participants between the ages of 18 and 23  
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37 217 years were in the existing Agincourt Health and Socio-demographic Surveillance System  
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39 218 database [44]. Only 996 were located during the data collection period and were invited to  
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41 219 participate and of these, 509 female participants were recruited. The urban sample consisted  
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43 220 of 510 young women between the ages of 22 and 23 years who were randomly selected from  
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45 221 the sample of 720 females who were part of the Birth-to-Twenty plus (BT20+) Young Adult  
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47 222 Survey [45, 46]. Young women (n=51; 33 in rural and 18 in urban) who were pregnant at the  
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49 223 time of the study were excluded, see the study design flow chart in **Figure 1**. Measurements  
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51 224 and questionnaires were completed by trained research assistants and nurses, and were  
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54 225 standardised between both sites, to eliminate biases. The study protocols were approved by the  
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3 226 Human Research Ethics Committee of the University of the Witwatersrand (Clearance  
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5 227 certificates M120138 for the Ntshembo-Hope Cross Sectional Survey in Agincourt and M111182  
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7 228 for the BT20+ survey). Written consent to participate was provided by participants, and mentally  
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9 229 or physically disabled women were excluded from the study.

### 12 230 **Patient and Public Involvement**

15 231 No patients private or public were involved in this study, as it was a community  
16  
17 232 population based.

### 21 233 **Blood pressure**

23 234 Blood pressure (mm Hg) was the outcome variable and it was measured using an Omron 6  
24  
25 235 automated machine (Kyoto, Japan). A five minute seated rest was observed before taking the  
26  
27 236 BP measurements. Participants' seated BP was measured three times on the right side, with a  
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29 237 2-minute interval between each measurement. The mean for the second and third readings was  
30  
31 238 recorded for the current analysis. We had various cuff sizes and the appropriate size was used  
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33 239 to accommodate differences in arm circumference.

36 240 According to the Seventh Report of the Joint National Committee on Prevention, Detection,  
37  
38 241 Evaluation, and Treatment of High Blood Pressure [47], five categories of BP have been  
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40 242 established for adults 18 years of age and older as shown in Table 1. These cut-offs were  
41  
42 243 utilized in the current study. Prehypertension and hypertension were combined to create a new  
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44 244 variable called elevated BP.

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49 246 **Table 1:** Blood pressure classification [47]

<b>Classification</b>	<b>Systolic</b>		<b>Diastolic</b>
	<b>Blood Pressure</b>		<b>Blood Pressure</b>
Low	<90	or	< 60
Normal	<120	and	<80
Prehypertension	120-139	or	80-90
High: Stage 1 Hypertension	140-159	or	90-99
High: Stage 2 hypertension	≥160	or	≥100

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256 SBP was used in structural equation models (SEM) as it is more relevant in adults, and a

257 good predictor of adverse health outcomes later in life [48], such as CVDs.

### 258 **Anthropometry**

259 At both sites, participants' height and weight were measured by trained research assistants

260 using standard techniques [49, 50] . Weight was measured in light clothing and barefoot to the

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3 261 nearest 0.1 kg using a digital scale (Tanita model TBF-410; Arlington Heights; USA). Height  
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5 262 was measured barefoot to the nearest 0.1 cm using a stadiometer (Holtain, Crymych, UK).  
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7 263 Waist circumference was measured with a non-stretchable fibreglass tape at the level of the  
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10 264 umbilicus. BMI was calculated as weight/height<sup>2</sup> (kg/m<sup>2</sup>).  
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### 13 265 **Socio-economic status (SES)**

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16 266 Physical assets owned in the participants' household were used as a proxy for SES index [51].  
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18 267 It was generated by summing the number of assets owned in the household from the following:  
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20 268 television, car, washing machine, fridge, phone, radio, microwave, cell phone, DVD/Video, DSTV  
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22 269 (cable channel), computer, internet, medical aid. Previous studies in this population have  
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24 270 shown that the sum of physical assets (household assets) is closely related to the household  
25  
26 271 per capital expenditure and household income [51-53]. The household SES is regarded as a  
27  
28 272 good measure of accumulated household wealth so it is a more reflective wealth index than  
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30 273 income of a household's wealth over time.  
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### 33 274 **Physical activity**

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36 275 The Global Physical Activity Questionnaire (GPAQ), developed for global physical activity  
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38 276 surveillance, was completed via interview to obtain self-reported physical activity [54]. Total  
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40 277 MVPA in minutes per week (mins/wk) was calculated by adding occupation, travel-related and  
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42 278 leisure time moderate and vigorous intensity physical activity. Sitting time (mins/wk) was used  
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44 279 as a proxy for sedentary time.  
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### 48 280 **Statistical analyses**

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51 281 Analysis of variance and student's t test, and Chi-squared tests and Wilcoxon rank sum test for  
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53 282 non-parametric variables, were conducted to compare study characteristics between urban and  
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55 283 rural young women. Structural equation modeling (SEM), was used to test and estimate the  
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3 284 direct and indirect associations between variables, most especially the mediation roles of  
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5 285 physical activity (MVPA) or sedentary time (sitting), and body composition (BMI and WC), in the  
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7 286 association between SES and SBP. SEMs allow us to assess the mediation effects of multiple  
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9 287 mediators [55]. SEM decomposed SES-BP associations into two parts, direct (unmediated) and  
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11 288 indirect (mediated through MVPA/sitting and BMI/WC).

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14 289 Direct, indirect and total effects were computed and recorded, and the proportion of the total  
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16 290 effect mediated was calculated. To evaluate the best fitting model for our data, we calculated  
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18 291 different goodness of fit indices including Chi-squared test, Root mean squared error of  
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20 292 approximation (RMSEA), Comparative fit index (CFI), Tucker-Lewis index (TLI) and Standardized  
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22 293 root mean squared residual (SRMR) [56]. Though the Chi-squared test has been popularly used  
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24 294 as a goodness of fit index, it has been reported to be biased and not reliable as the only  
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26 295 goodness of fit index. It is also highly sensitive to sample size [57, 58] , and often inflated with  
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28 296 non-normal data such as physical activity data and we therefore employed the Hu and  
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30 297 Bentler's Two-Index Presentation Strategy (1999) combination rule, with cut off values  
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32 298 depending on the fitness index, to determine the best model fit [56, 59]. We estimated the  
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34 299 coefficients ( $\beta$ ) with 95% confidence intervals (95% CI) for the direct, indirect and total effects  
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36 300 and also calculated the proportion of association mediated by indirect effects. If the direct and  
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38 301 indirect effects had opposite signs (negative or positive effects) the proportion mediated was  
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40 302 assessed using the absolute values for all indirect and direct effects [60].

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45 303 All the analyses were conducted using STATA (version 13.0; STATA Corp., College Station,  
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47 304 TX, USA). We confirmed SEM results by running the SEM with the Satorra-Bentler and Huber-  
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49 305 White (Robust) Sandwich Estimator options [61] in STATA (version 15.1; STATA Corp.,  
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51 306 College Station, TX, USA). These options relax the normality assumption hence are robust to  
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53 307 non-normal data, which would be the case for mvpa and SES in the current study. A P-value <  
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55 308 0.05 was considered statistically significant.

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12 312 **Results**13  
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15 313 **Study characteristics**

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18 314 Descriptive statistics for the non-pregnant study participants (urban, n=492; rural, n=476) are  
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20 315 presented in Table 2. There was no difference in BMI or waist circumference between the  
21  
22 316 urban and rural participants, but the prevalence of overweight and obesity was significantly  
23  
24 317 higher in the urban (46.5%) compared to the rural young women (38.8%). Household SES was  
25  
26 318 significantly higher in the urban compared to the rural group. Self-reported MVPA was  
27  
28 319 significantly higher in the rural than urban women ( $p<0.001$ ), and the urban women spent  
29  
30 320 significantly more time sitting than their rural counterparts ( $p<0.001$ ). Systolic and diastolic BP  
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32 321 were significantly higher in the urban group, as was the prevalence of elevated BP (27.0 vs.  
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34 322 9.3%).

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38 323 **Structural equation models for body mass index and waist circumference**

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41 324 Results from the SEMs for SES associations with SBP via MVPA and BMI are presented in  
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43 325 Tables 3a, 3b and 3c for urban, rural and pooled analyses respectively, and also shown in  
44  
45 326 Figures 1, 2, 3. No significant direct or indirect effects via (MVPA or BMI) of SES on SBP  
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47 327 were observed in the urban women, but there were significant direct effects of SES on MVPA.  
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49 328 Results showed that individuals with a higher SES index were less likely to be physically active  
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51 329 in pooled data and urban women. In rural women, a one-unit increase in total household  
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53 330 assets was associated with a decrease of 0.65 mmHg (95% CI: -1.19 to -0.10) in SBP and an  
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55 331 increase of 0.27 kg/m<sup>2</sup> in BMI (95% CI: 0.1 to 0.53) (**Tables 3a, 3b and Figures 2, 3**). The

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3 332 SEM for the pooled sample showed a significant indirect effect of household SES on SBP via  
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5 333 BMI, with 50% of the total effect being mediated by BMI (Table 3c and Figure 4). Direct  
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7 334 positive effects of BMI on SBP were observed in both settings and the pooled sample with a 1  
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9 335 kg/m<sup>2</sup> increase in BMI being associated with an increase of 0.37 mmHg (95% CI: 0.21 to 0.53)  
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11 336 and 0.33 (95% CI: 0.12 to 0.54) mmHg SBP in urban and rural young women, respectively.  
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13 337 Similar results were observed when including waist circumference as the body composition  
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15 338 indicator as shown in the SEM path diagrams with estimates in Figure S1 (supplementary  
16  
17 339 data). The results from the SEMs with the Satorra-Bentler adjustment option, accounting for  
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19 340 non-normality of the exposure, are shown in Figure S2 (supplementary data).  
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## 23 341 Discussion

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26 342 A rising prevalence of hypertension has been reported in South Africa. Peer and colleagues  
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28 343 reported a higher prevalence in 2008 (35.6%) compared to 1990 (21.6 %) in men and women  
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30 344 aged 25-74 years in an urban black community in Cape Town, South Africa [40]. We have  
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32 345 shown in young adult women from urban and rural South Africa, an overall elevated BP  
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34 346 prevalence of 18.4 % (27.0 % in urban and 9.3 % in rural). We have also shown a direct  
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36 347 effect of BMI on SBP in the urban and rural women separately, as well as when pooled,  
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38 348 thereby providing further evidence of an association between overall adiposity and blood  
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40 349 pressure. The total effects of SES on SBP were the same in both settings.  
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44 350 Prevalence data on elevated BP and hypertension from other countries in SSA have shown  
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46 351 conflicting results when comparing urban and rural communities. In Malawi, a higher prevalence  
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48 352 of hypertension in urban compared to rural communities has been reported and attributed to  
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50 353 differences in lifestyle as rural communities participate in subsistence based agricultural  
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52 354 activities while the urban community has a more westernized lifestyle with higher salt intake  
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54 355 and lower physical inactivity [9]. Similarly, data from Ghana have shown a higher mean SBP  
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3 356 and DBP and a higher prevalence of hypertension in urban communities [18, 62]. In the  
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5 357 PURE study in South Africa, Pisa and colleagues reported that both urban adult men and  
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7 358 women had higher mean blood pressures in comparison to their rural peers though the overall  
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9 359 CVD risk factors were equally prevalent in both settings [41]. In contrast, findings from  
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11 360 Cameroon have reported a higher BP prevalence in rural compared to urban men and women  
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13 361 older than 40 years old, while Kenyan studies have reported no significant differences [16, 63].  
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15 362 Results from six urban and rural sites in four SSA countries - Kenya, South Africa, Ghana and  
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17 363 Burkina Faso - have reported a prevalence of hypertension in women aged between 40 and 60  
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19 364 years ranging from 15.1% in rural Burkina Faso to 54.1% in urban South Africa [10]. It was  
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21 365 also reported that in all three South African sites, both rural and urban, the prevalence of  
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23 366 hypertension was higher than in the other three countries [10]. These findings show the  
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25 367 complex health transitions occurring in SSA and the impact that this is having on cardio-  
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27 368 metabolic disease risk.

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31 369 Our study showed significant differences in SES between the urban and rural samples, as well  
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33 370 a big variation in SES within these two settings. The social patterning of CVD risk factors,  
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35 371 including hypertension, in SSA and LMICs has in part been attributed to differences in  
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37 372 countries' socioeconomic development. Previous results from five countries, (two high income  
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39 373 and three LMICs), reported that hypertension and other CVD risk factors were substantially  
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41 374 associated with education and wealth status; individuals with less education and lower wealth  
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43 375 generally showing higher prevalence of CVD risk factors [64] . The effect of SES in this study  
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45 376 is most evident in the rural women for whom household SES was lower (compared to urban)  
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47 377 and who may be transitioning faster (both nutritionally and economically) than the urban young  
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49 378 women. Though SES is positively associated with BMI in rural young women, it is negatively  
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51 379 associated with SBP. There may be other factors, such as physical activity due to agricultural  
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53 380 activities or dietary patterns, which were not recorded. In addition, the weight gain observed  
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3 381 might not be due to fat mass, which has been reported to be positively associated with SBP  
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5 382 before [65], but rather to muscle mass and bone mass.  
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8 383 In Mexico, women in rural and upper SES categories were likely to have a higher SBP, while  
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10 384 we have reported that a higher SES was associated with a decrease in SBP in rural  
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12 385 communities. At a population level, there is a need to consider different SES categories and  
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14 386 monitor the effects of transitioning from one SES category to another on hypertension, since  
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16 387 these categories may respond differently to an increase or a decrease in their SES. Kagura  
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18 388 and colleagues tracked SES in South African children and reported that moving from the low  
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20 389 SES in infancy to a higher SES in adolescence had a protective effect on SBP level in young  
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22 390 adulthood [26]. Our results have shown that this could be more pronounced in rural areas.  
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26 391 We observed a positive association between SES and BMI in the rural sample and the same  
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28 392 direction of effects was observed in the urban, though not significant. This is in line with results  
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30 393 reported in many LMICs including South Africa, but in contrast with those reported in higher  
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32 394 income populations [33, 34, 64]. A systematic review of studies between 1989 to 2007  
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34 395 reported that SES was positively associated with obesity in the middle transitioning economies  
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36 396 such as South Africa and Jamaica [66]. We have shown that both in the rural and urban  
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38 397 participants (not significant), a higher SES resulted in reduced SBP, while the pooled analysis  
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40 398 showed a positive total effect association between SES and SBP. This could be due to the  
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42 399 introduction of more variation in SES when data from both sites are pooled; with many  
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44 400 individuals with low SES in the rural area, the associations became skewed towards the low  
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46 401 SES individuals. This may suggest that different transitional levels of SES have different effects  
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48 402 on hypertension risk depending on the environment (either urban or rural). Though not  
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50 403 significant, the total effects of SES on SBP are the same in both rural and urban hence the  
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52 404 differences in prevalence cannot be explained by the setting or SES alone. In urban and rural  
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54 405 settings of four countries (Kenya, Namibia, Nigeria and Tanzania), the prevalence of age  
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3 406 standardized hypertension was similarly high and ranging from 19.3 % to 38.0 % [11]. Cois and  
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5 407 colleagues reported that a higher SES was associated with lower SBP in a nationally  
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7 408 representative sample of South African women [25] using SEM models. Alcohol use, PA,  
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9 409 smoking and resting heart rate and BMI were reported to be the mediators of the indirect of  
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11 410 the association between SES and SBP in men but not in women, suggesting that other factors  
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13 411 may play a major role in women [25]. Similarly, our results show that neither PA nor BMI  
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15 412 mediate the association between SES and SBP in urban and rural settings in isolation,  
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17 413 suggesting that other factors may explain the association. Among those, dietary patterns and  
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19 414 stress have been reported to be independently associated with SBP [67, 68].  
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23 415 The significant direct associations between BMI and SBP are in line with other findings in  
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25 416 South Africa and within the SSA region [11, 33, 40, 42, 69, 70]. This link was consistent in  
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27 417 rural, urban and pooled data sets, indicating the importance of BMI in the aetiology of high BP.  
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29 418 Munthali and colleagues reported that the link between obesity and hypertension could be  
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31 419 observed as early as five years of age. Children with early onset of obesity were at higher risk  
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33 420 of developing hypertension in late adolescence [38].  
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36 421 In this study, using SEM models to explore the mediation role of BMI and PA helped quantify  
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38 422 potential contributions of these variables to the effect of SES on SBP. The results show that  
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40 423 PA was not a significant mediator in the association between SES and BP in the urban or the  
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42 424 rural samples. SES was negatively associated with MVPA in urban and pooled samples,  
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44 425 indicating that as individuals transition from low to higher SES, they reduce their physical  
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46 426 activity level. We speculate that these differences in the association between SES and SBP in  
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48 427 both our rural and urban results, and in those from high-income countries are due to  
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50 428 differences in levels of nutritional and epidemiological transition in these regions [71, 72]. Those  
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52 429 with low SES in high-income countries are likely to consume cheaper, more energy dense  
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54 430 foods, participate in less leisure time PA and be more sedentary [73, 74]. In LMICs,  
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3 431 agricultural activities remain a part of everyday life and a day-to-day activity in rural living,  
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5 432 while those with higher SES in the same settings rapidly adopt the westernized life style with  
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7 433 less PA, fewer agricultural activities and home grown food. However, this speculation is not  
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9 434 supported by the data on PA in this study despite the rural participants having a higher PA.  
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11 435 Our understanding of the Agincourt rural economy is that agriculture is quite a minor aspect  
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14 436 though very useful to augment the household income.

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17 437 The limitations of this study are that other unmeasured data, such as undernutrition in infancy,  
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19 438 which is a known risk factor for high BP later in life [75], and dietary patterns were not  
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21 439 included in the current analyses. We are currently working on research to address this  
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23 440 limitation. We can also not rule out the role of genetics. Secondly, the low reliability of self-  
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25 441 report data on PA could introduce bias. Thus, there is need for more precise, objective  
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27 442 measures of physical activity to strengthen the results of our analysis. Lastly, longitudinal data,  
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29 443 especially as the socioeconomic environment is changing rapidly due to rural-urban labor  
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31 444 migration and other factors would be helpful to examine these associations over time. The  
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33 445 cross-sectional design lacks a temporal component between the factors analyzed. Thus, it is  
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35 446 difficult to say anything certain about the direction of the associations, hence the need for the  
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37 447 longitudinal data.

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## 42 43 449 **Conclusions**

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46 450 Though the prevalence of overweight or obesity is relatively higher in both rural and urban than  
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48 451 those reported in other SSA countries, women in the urban setting were at more risk for  
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50 452 elevated blood pressure than their rural counterparts. The link between SES and SBP varies in  
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52 453 a more economically diverse population, as seen with the pooled rural and urban dataset, with  
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55 454 BMI being the most likely mediator. There is need to consider optimizing BMI as a key

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3 455 intervention strategy in young adults in part to combat hypertension. Our findings should be  
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5 456 replicated with prospective data.  
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25  
26 465 authors and are not to be attributed to the CoE in Human Development.  
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28

#### 29 466 **Conflict of interest** 30

31 467 Authors have no conflicts of interest to disclose.  
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#### 33 468 **Consent for publication** 34

35 469 Not applicable  
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#### 37 470 **Data Sharing** 38

39 471 The datasets used and/or analysed during the current study are available from the  
40  
41 472 Developmental Pathways  
42  
43 473 for Health Research Unit data management department by contacting Prof. Shane A Norris on  
44  
45 474 reasonable request  
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47

#### 48 475 **Competing interest** 49

50 476 The authors declare that they have no competing interests  
51

#### 52 477 **Authors' contributions** 53 54 55 56 57 58 59 60

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3 478 RJM and SAN conceptualized the manuscript. RJM analyzed the data. RJM MM RSM JK ST  
4  
5 479 KK FXG LKM DD SAN interpreted the data. RJM wrote the manuscript and all authors were  
6  
7 480 involved in editing and approving the final manuscript.  
8  
9

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14  
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18 485

#### 19 486 **Ethics Approval and Consent to Participate**

20 487 Prior to the study, the study protocols were approved by the Human Research Ethics  
21  
22 488 Committee of the University of the Witwatersrand (Clearance certificates M120138 for the  
23  
24 489 Ntshembo-Hope Cross Sectional Survey in Agincourt and M111182 for the BT20+ survey).  
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26 490 Independent written informed consent to participate was obtained from participants.  
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**Table 2:** Descriptive characteristics

	Total	n	Urban	n	Rural	p value
Age (years)	22.04 (1.24)	492	22.77 (0.49)	476	21.28 (1.31)	0.001
Weight (kg)	64.62 (14.82)	492	64.67 (15.6)	473	64.55 (14.03)	0.90
Height (m)	1.61 (0.007)	492	1.60 (0.07)	475	1.61 (0.07)	0.001
BMI (kg/m <sup>2</sup> )	25.05 (5.59)	492	25.32 (5.91)	476	24.78 (5.24)	0.13
BMI classification (%)		492		476		0.015
Underweight (<18.4 kg/m <sup>2</sup> )	5.98		7.10		4.82	
Normal weight (18.5-24.9 kg/m <sup>2</sup> )	51.34		46.45		56.39	
Overweight (25-29.9 kg/m <sup>2</sup> )	26.19		29.21		23.06	
Obese (≥30 kg/m <sup>2</sup> )	16.49		17.24		15.72	
Waist circumference (cm)	80.60 (12.08)	492	80.18 (12.63)	476	81.03 (11.47)	0.26
Central obesity, WC ≥ 80 cm , %	43.81	492	45.70	476	44.74	0.55
Household SES index (sum of assets)	7.24 (2.70)	492	8.83 (2.37)	476	5.59 (1.91)	<0.001
Total MVPA (min/week)*	870(280-1810)	492	420(160-900)	385	1680(970-2580)	<0.001
Sitting time (mins/day)*	300 (240-480)	492	360 (240-480)	385	300 (180-360)	<0.001
Systolic blood pressure	106.68 (11.64)	492	110.30 (11.4)	471	102.89 (10.7)	<0.001
Diastolic blood pressure	70.23 (9.00)	492	72.78 (8.3)	471	67.57 (9.0)	<0.001
BP classification (%)		492		471		<0.001
Low BP	12.46		5.49		19.75	
Normal BP	69.16		67.48		70.91	

Prehypertension	16.20		23.58		8.49	
Hypertensive	2.18		3.46		0.85	
Elevated BP (%)	18.38		27.04		9.34	<0.001
Highest Education attained (%)		480		371		<0.001
Primary school	1.18		0		2.70	
Secondary school	60.75		48.33		76.81	
Tertiary education	38.07		51.67		20.49	

Data presented as mean (SD) otherwise stated; \* Median (IQR)

**Table 3a:** Structural equation model for SES, MVPA and BMI on SBP in urban women

Effect of: N=489	Outcome:	Direct effects(95% CI)	Indirect effects( 95% CI)	Total effects(95% CI)	Proportion of total effect mediated
<b>Household assets</b>	SBP via BMI	-0.34 (-0.75; 0.07)	0.05 (-0.05; 0.14)	-0.29 (-0.70; 0.12)	0.13 <sup>a</sup>
	BMI via MVPA	0.13 (-0.09; 0.35)	-0.014 (-0.05; 0.013)	0.11 (-0.11; 0.33)	0.1 <sup>a</sup>
	MVPA	-41.71 (-73.48; -9.94)**		-41.71 (-73.48; -9.94)**	
<b>MVPA</b>	SBP via BMI	-0.0002 (-0.001; 0.001)	0.0001 (-0.0001; 0.0004)	-0.0000 (-0.0012; 0.0011)	0.3 <sup>a</sup>
<b>BMI</b>	SBP	0.37 (0.21; 0.53)***		0.37 (0.21; 0.53)***	

Adjusted for age; \* P<0.05; \*\* P< 0.01; \*\*\*P< 0.001; SBP; systolic blood pressure, MVPA; moderate to vigorous intensity physical activity, BMI; body mass index, SES; social economic status, <sup>a</sup> Assessed using the absolute values for both indirect and direct effects

**Urban Fit Indices:** LR test of model vs. saturated:  $\chi^2(4) = 0.97$ , Prob >  $\chi^2 = 0.91$ ; RMSEA = 0.00; CFI= 1.00 Comparative

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fit index;

TLI= 1.12 Tucker-Lewis index; **SRMR=0.011**: Standardized root mean squared residual, CD= 0.017 Coefficient of determination.

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**Table 3b:** Structural equation model for SES, MVPA and BMI on SBP in rural women

Effect of: N= 378	Outcome:	Direct effects(95% CI)	Indirect effects( 95% CI)	Total effects(95% CI)	Proportion of total effect mediated
<b>Household assets</b>	SBP via BMI	-0.65 (-1.19; -0.096)*	0.08 (-0.04; 0.19)	-0.56 (-1.12; -0.02)*	0.11 <sup>a</sup>
	BMI via MVPA	0.27 (0.01; 0.53)*	-0.01 (-0.04; 0.01)	0.26 (-0.005; 0.53)*	0.04
	MVPA	-29.51 (-87.81; 28.78)		-29.51 (-87.81; 28.78)	
<b>MVPA</b>	SBP via BMI	0.0004 (-.0005729 .0013)	0.0001 (-0.0000; 0.0003)	0.0005 (-0.0005; 0.0015)	0.2
<b>BMI</b>	SBP	0.33 (0.12; 0.54)**		0.33 (0.12; 0.54)**	

Adjusted for age; \* P<0.05; \*\* P< 0.01; \*\*\*P< 0.001; SBP; systolic blood pressure, MVPA; moderate to vigorous physical activity, BMI; body mass index, SES; social economic status, <sup>a</sup> Assessed using the absolute values for both indirect and direct effects

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**Rural Fit Indices:** LR test of model vs. saturated:  $\chi^2(4) = 10.51$ , Prob >  $\chi^2 = 0.03$ ; RMSEA = 0.066; **CFI= 0.72** Comparative fit index;  
TLI= 0.37 Tucker-Lewis index; **SRMR= 0.04**: Standardized root mean squared residual, CD= 0.03 Coefficient of determination.

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**Table 3c:** Structural equation model for SES, MVPA and BMI on SBP in the pooled sample of urban and rural women

Effect of: N=867	Outcome:	Direct effects(95% CI)	Indirect effects( 95% CI)	Total effects(95% CI)	Proportion of total effect mediated
<b>Household assets</b>	SBP	0.23 (-0.08; 0.54)		0.46 (0.15; 0.76)**	0.5
	via BMI		0.23 (0.10; 0.35)***		
	BMI	0.20 (0.05; 0.34)**		0.15 (0.01; 0.29)*	0.25 <sup>a</sup>
	via MVPA		-0.05 (-.100; 0.003)		
	MVPA	-144.83 (-170.55; - 119.12)***		-144.83 (-170.55; - 119.12)***	
<b>MVPA</b>	SBP	-0.001 (-0.002; -0.0005)**		-0.001 (-0.002; -0.0003)**	0.1 <sup>a</sup>
	via BMI		0.0001 (-0.0000; 0.0002)		
<b>BMI</b>	SBP	0.35 (0.21; 0.49)***		0.35 (0.21; 0.49)***	

Adjusted for age; \* P<0.05; \*\* P< 0.01; \*\*\*P< 0.001; SBP; systolic blood pressure, MVPA; moderate to vigorous intensity physical activity, BMI; body mass index, SES; social economic status, <sup>a</sup> Assessed using the absolute values for both indirect and direct effects

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5 **Pooled Fit Indices:** LR test of model vs. saturated:  $\chi^2(4) = 24.829$ , Prob >  $\chi^2 = 0.000$ ; RMSEA = 0.077; **CFI= 0.89**

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### 29 **Figure legends**

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31 Figure 1: Selection of study participants in rural and urban

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33 Figure 2: Structural equation model for SES, MVPA and BMI on SBP in urban

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35 Figure 3: Structural equation model for SES, MVPA and BMI on SBP in rural

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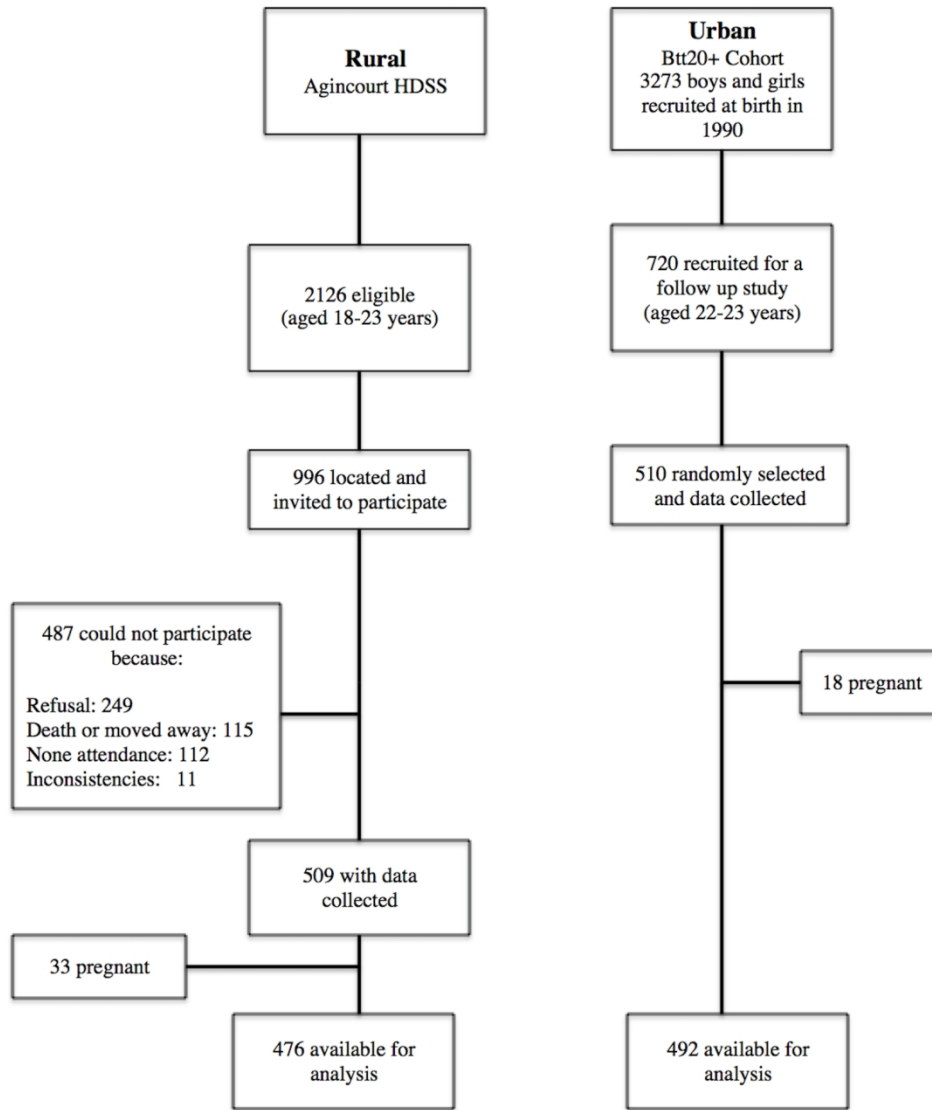


Figure 1: Selection of study participants in rural and urban

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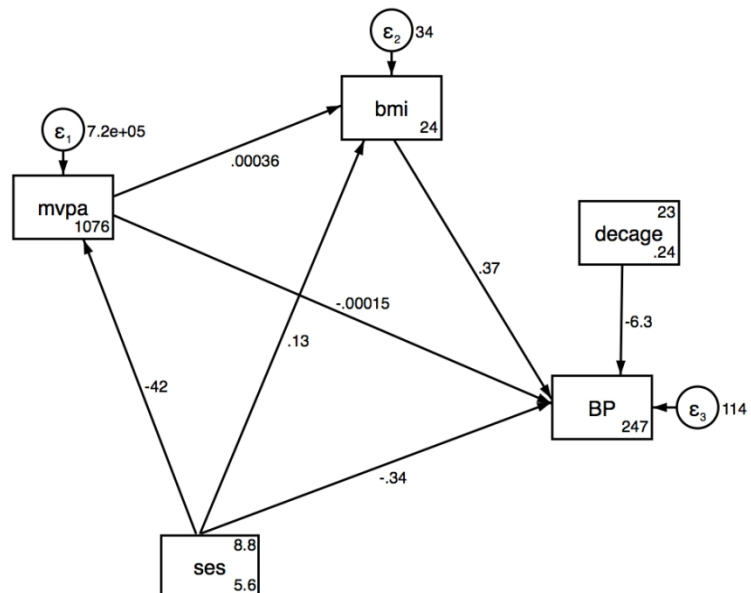


Figure 2: Structural equation model for SES, MVPA and BMI on SBP in urban  
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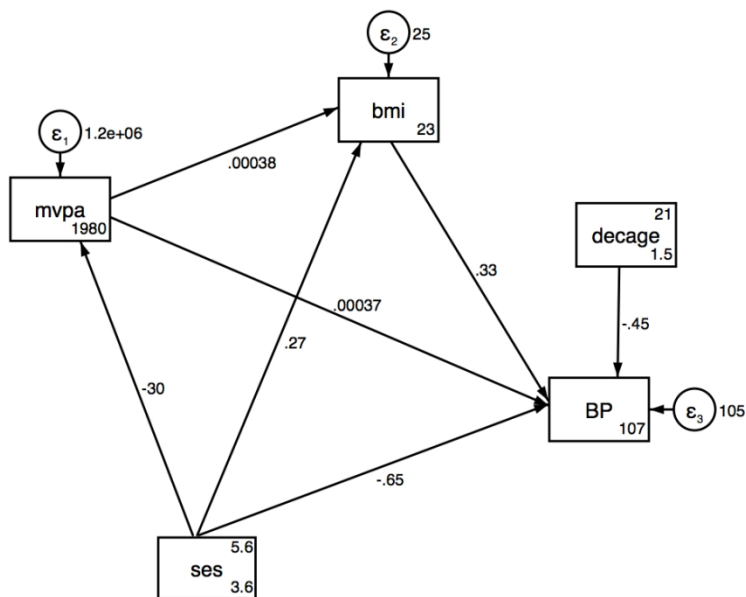


Figure 3: Structural equation model for SES, MVPA and BMI on SBP in rural  
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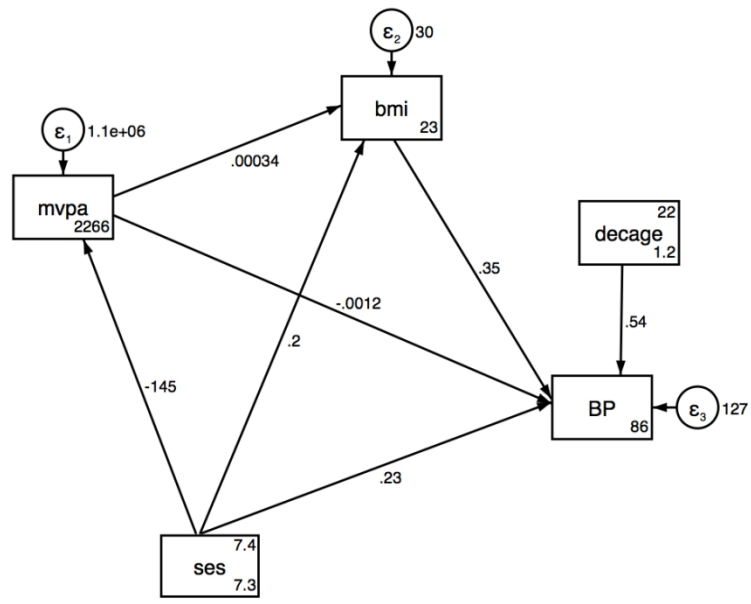


Figure 4: Structural equation model for SES, MVPA and BMI on SBP pooled  
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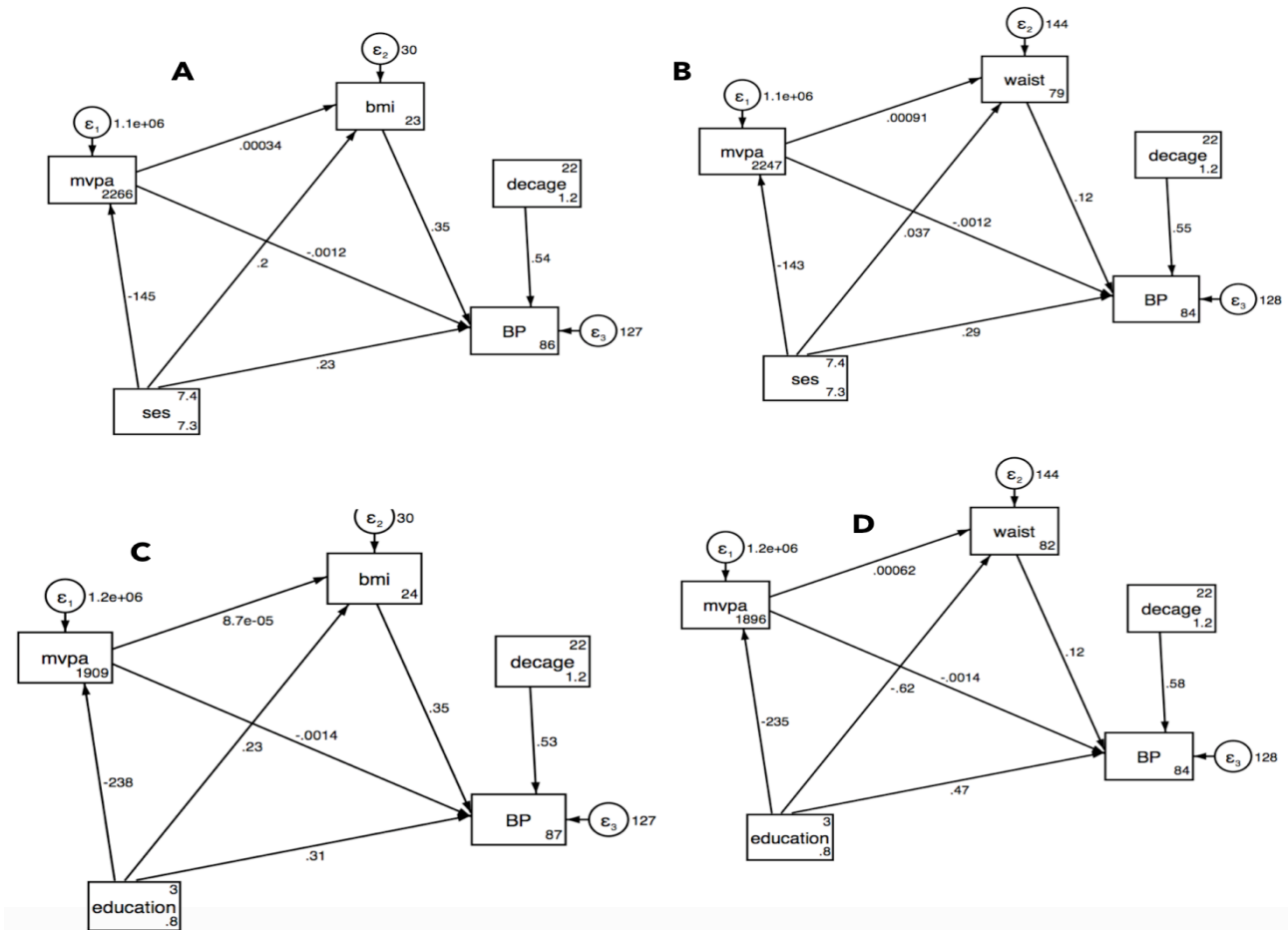


Figure SI; A: Structural equation model for **SES**, MVPA and **BMI** on SBP pooled; B: Structural equation model for **SES**, MVPA and **WC** on SBP pooled; C: Structural equation model for **education**, MVPA and **BMI** on SBP pooled; D: Structural equation model for **education**, MVPA and **WC** on SBP pooled.

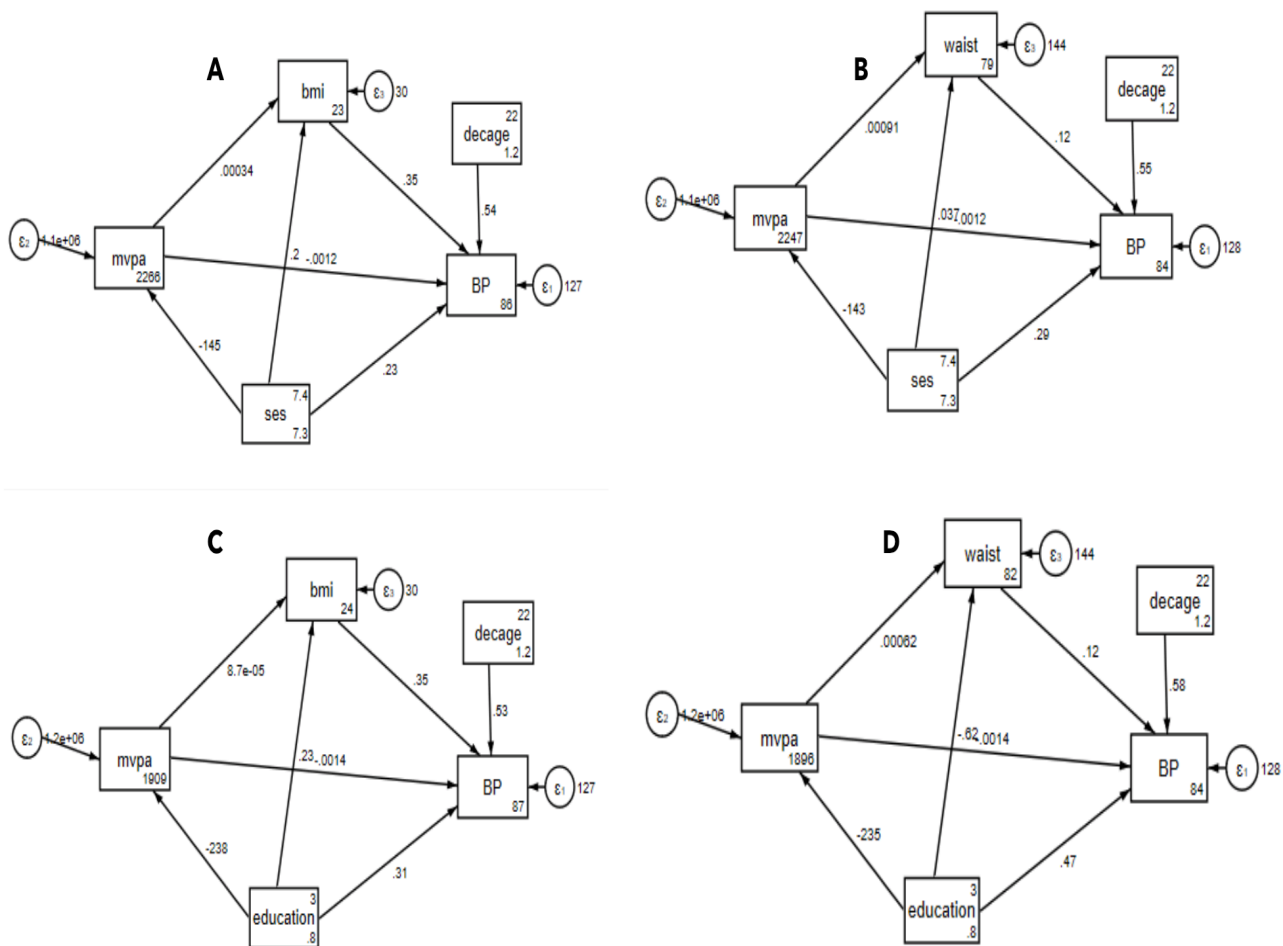


Figure S2 - SEMs based on Satorra–Bentler; A: Structural equation model for **SES**, **MVPA** and **BMI** on **SBP** pooled; B: Structural equation model for **SES**, **MVPA** and **WC** on **SBP** pooled; C: Structural equation model for **education**, **MVPA** and **BMI** on **SBP** pooled; D: Structural equation model for **education**, **MVPA** and **WC** on **SBP** pooled.



## STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract <b>MS Page 4 Par 2</b> (b) Provide in the abstract an informative and balanced summary of what was done and what was found <b>MS Page 4</b>
<b>Introduction</b>		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported <b>MS Pages 5-6</b>
Objectives	3	State specific objectives, including any prespecified hypotheses <b>MS Page 6 Par 2</b>
<b>Methods</b>		
Study design	4	Present key elements of study design early in the paper <b>Methods: MS Page 6 Par 3</b>
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection <b>Methods: MS Page 6 Par 3</b>
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <b>N/A</b>  <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <b>N/A</b>  <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants <b>Methods: MS Page 6 Par 3</b> (b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <b>N/A</b>  <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case <b>N/A</b>
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable <b>Methods: MS Page 6 Par 4 – Page 8 Par 1</b>
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 <b>Methods: MS Page 6 Par 4 – Page 8 Par 1</b>
Bias	9	Describe any efforts to address potential sources of bias <b>Methods: MS Page 6 Par 3</b>
Study size	10	Explain how the study size was arrived at <b>Methods: MS Page 6 Par 3</b>
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why <b>Methods: MS Page 8 Par 2</b>
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding <b>Statistical analyses: MS Page 8 Par 2 and 3</b> (b) Describe any methods used to examine subgroups and interactions <b>N/A</b> (c) Explain how missing data were addressed <b>Statistical analyses: MS Page 8 Par 2</b> (d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was

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addressed **N/A**  
*Cross-sectional study*—If applicable, describe analytical methods taking account of  
sampling strategy **N/A**  

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*(e)* Describe any sensitivity analyses **N/A**

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**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 <b>Results: Page 8 Par 5 – Page 9 Par 1</b> (b) Give reasons for non-participation at each stage <b>N/A</b> (c) Consider use of a flow diagram <b>N/A</b>
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders <b>Page 8 Par 5 – Page 9 Par 1</b> (b) Indicate number of participants with missing data for each variable of interest <b>Results: Page 8 Par 5</b> (c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount) <b>N/A</b>
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time <b>N/A</b> <i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure <b>N/A</b> <i>Cross-sectional study</i> —Report numbers of outcome events or summary measures <b>Results: Page 8 Par 5</b>
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 <b>Results: Page 9 Par 1</b> (b) Report category boundaries when continuous variables were categorized <b>N/A</b> (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period <b>N/A</b>
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses <b>N/A</b>

**Discussion**

Key results	18	Summarise key results with reference to study objectives <b>Discussion: Page 9 Par 2</b>
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias <b>Discussion: Page 11 Par 4</b>
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence <b>Page 9 Par 3 – Page 11 Par 3</b>
Generalisability	21	Discuss the generalisability (external validity) of the study results <b>Discussion: Page 9 Par 3 – Page 11</b>

**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 <b>Funding: Page 12 Par 1</b>
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\*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](http://www.strobe-statement.org).