The association between anthropometric measures and physical performance in black adults of the North West Province, South Africa

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Abstract

Objective: Few studies have investigated the association between anthropometric measurements and physical performance over time in low and middle-income countries. This study investigated the associations between anthropometric measures and physical performance in black South African adults.

Methods: Black human immunodeficiency virus (HIV) negative men and women (aged 32-93 years) participating in the Prospective Urban and Rural Epidemiology (PURE) study were enrolled at baseline in 2005 (N=1428). Men and women's anthropometry, socio-demographics and physical activity (PA) were assessed at baseline, 5- and 10-year follow-up. Physical performance (walk speed, chair stand and handgrip strength (HGS) were assessed at 10-year follow up. Linear regression models adjusted for potential confounders were used to evaluate the association between anthropometric measures and physical performance.

Results: The combined overweight and obesity prevalence of both men (p=0.02) and women (p<0.001) increased significantly over 10 years, with significant increases over time in BMI and calf circumference (CC) in the women, whereas PA decreased significantly over time in both men and women (p<0.0001). BMI and CC were positively associated with HGS in the men (p=0.02, p<0.0001) and women (p<0.0001 for both), while CC was positively associated with walk speed in men only (p=0.006) in the cross-sectional analysis of 2015 measurements.

Conclusion: BMI and CC in both men and women were positively associated with HGS, but CC was associated with walk speed in the men only. Our study suggests that CC may be a useful predictor of physical performance in black men and to a limited extent in black women.

Key words: Body mass index, Calf circumference, Physical performance, Hand grips strength, Adults

1 | INTRODUCTION

South Africa (SA), like many low and middle income countries (LMICs), is undergoing urbanisation with a rapid socio-economic and nutritional transition that may affect the body composition and physical activity patterns of individuals (World Health Organization, 2013, 2015). Modifiable risk factors that contribute to the development of non-communicable diseases (NCDs), such as obesity and physical inactivity, require attention. A recent pooled analysis showed that obesity prevalence increased from 1975 to 2014 and surpassed 30% in women in southern and northern Africa (NCD Risk Factor Collaboration, 2016). Approximately 5% of deaths globally can be attributed to obesity and 3.2 million deaths each year are due to insufficient physical activity (World Health Organization, 2008). Urgent action is needed in order to understand and address the effects of lifestyle changes on the needs of aging population (Tucker & Buranapin, 2001).

Overweight and obesity have been defined as conditions in which excessive body fat increases with adverse effects on the well-being of individuals (World Health Organization, 2013). According to Lee, Shook, Drenowatz, and Blair (2016), body mass index (BMI) is easy to measure and used as a measure of whole body obesity, but does not differentiate between muscle mass, defined as a determinant of metabolic homeostasis, physical strength and daily living activities, and fat mass, defined as the proportion of the human body composed of fat (Burini & Maestá, 2012). Being overweight (BMI 25-30 kg/m^2) and obese (BMI>30 kg/m^2) are major public health problems in both high income countries and LMICs (World Health Organization, 2013). SA has the highest overweight and obesity prevalence in Sub-Saharan Africa with up to 70% of women and a third of men classified as overweight or obese (Mungal-Singh, 2012). In southern Africa, the age-standardised mean BMI increased in men from 21 kg/m^2 to 24 kg/m^2 and in women from 26 kg/m^2 to 29 kg/m^2 from 1975 to 2014 (NCD Risk Factor Collaboration, 2016). Obesity is associated with numerous adverse health problems, including impaired physical performance and quality of life, the development of type 2 diabetes, hypertension, dyslipidaemia and cardiovascular diseases (Villareal, Apovian, Kushner, & Klein, 2005).

Studies have shown that physical activity is associated with a lower fat mass and an increase in muscular strength and function and has been recognised as a key lifestyle factor to prevent and delay muscle loss and obesity during ageing (Cruz-Jentoft, Baeyens, Bauer, Boirie, Cederholm, Landi, Martin, Michel, Rolland, Schneider, Topinkova, Vandewoude, & Zamboni, 2010; Lee et al., 2016). Thus a low level of physical activity is associated with a higher BMI (Fogelholm & Kukkonen-Harjula, 2000). Physical inactivity contributes to sarcopenia in a vicious cycle by causing the elderly to become weaker and less able to participate in daily living activities (Kruger, Havemann-Nel, Ravyse, Moss, & Tieland, 2016). Maintaining or increasing physical activity levels may decrease the decline of age-associated physical performance (Martinez-Gomez, Bandinelli, Del-Panta, Patel, Guralnik, & Ferrucci, 2017). Physical performance measurements assess physical function and can be used to investigate association with mortality and disability in the elderly (Roshanravan, Robinson-Cohen, Patel, Ayers, Littman, De Boer, Ikizler, Himmelfarb, Katzel, & Kestenbaum, 2013).

Ageing is considered as the primary risk factor for many diseases and chronic conditions (Buffa, Floris, Putzu, & Marini, 2011). A critical change associated with human ageing is a progressive decline in skeletal muscle mass associated with a decrease in physical strength and performance (Cruz-Jentoft et al., 2010). Sarcopenia is a gradual loss of skeletal muscle mass and strength coupled with ageing, often associated with a progressive increase in body fat leading to sarcopenic obesity (Batsis, Mackenzie, Barre, Lopez-Jimenez, & Bartels, 2014). The loss of muscle mass starts at around the age of 40 years with an estimated decrease of 8% every decade. Thereafter, muscle mass shows an accelerated loss rate of 15 % after the age of 70 years (Moreira, Zunzunegui, Vafaei, da Câmara, Oliveira, & Maciel, 2016).

In the North West Province in SA, 8.1% of black women were found to be sarcopenic (Kruger, Micklesfield, Wright, Havemann-Nel, & Goedecke, 2015). Generally, sarcopenia is defined in terms of dual-energy X-ray absorptiometry (DXA) that measures muscle mass. However, the cost of DXA and lack of availability in remote areas necessitate alternative measurements (Deurenberg, Deurenberg-Yap, & Schouten, 2002). Anthropometric measurements, such as calf circumference (CC), is inexpensive, simple and non-invasive method that can be used as a muscle mass indicator (Landi, Onder, Russo, Liperoti, Tosato, Martone, Capoluongo, & Bernabei, 2014). In previous studies, CC was positively related to higher muscle strength and physical performance (Landi et al., 2014). Physical performance is assessed using inexpensive, simple and non-invasive tests which are also regarded as predictors of physical performance and possible disabilities (Studenski, Perera, Patel, Rosano, Faulkner, Inzitari, Brach, Chandler, Cawthon, & Connor, 2011).

Sarcopenia and obesity have been independently associated with a decline in physical performance (Chantler, 2014). The economic consequences of being underweight, overweight or obese in SA are high and require interventions directed at achieving normal BMIs (Kengne, Mchiza, Amoah, & Mbanya, 2013). Few studies have assessed anthropometric measures over time in black adults in LMICs (Chantler, 2014; Hughes, Roubenoff, Wood, Frontera, , Evans, & Singh, 2004). Little information is currently available on the relationship among sarcopenia, obesity and physical performance among African populations (Moreira et al., 2016). Therefore, we hypothesised that non-invasive, simple anthropometric measurements, such as CC and BMI may be useful predictors of physical performance in adults and could be useful in public health practice to assess the strength of older adults. The aim of this study was, therefore, to determine the association between anthropometric measures and physical performance of black adult men and women in the North West Province, SA.

2 | METHODS

2.1 | Participants

Participants included black men and women participating in the South African leg of the Prospective Urban and Rural Epidemiology (PURE-SA) study. Baseline data was collected in 2005, with a five-year follow up in 2010 and ten-year follow up in 2015. Data collected comprised of anthropometric measurements, socio-demographic and PA level. A total of 2 010 blacks aged 32-93 years were recruited from two rural (n=1006) and two urban (1004) areas in the North West Province, SA. Of the 2010 recruited at baseline (2005), 1428 had complete data after excluding participants who tested HIV positive, had incomplete data or were pregnant women. At ten-year follow-up (2015), 774 participants remained after participants who tested HIV positive were excluded. Further details on the PURE-SA study design and protocol have been described elsewhere (Kruger, Schutte, Walsh, Kruger, & Rennie, 2015). This study is nested in the North-West Province of South African leg of the multi-national PURE cohort study. The Health Research Ethics Committee of the North-West University, Potchefstroom campus, SA approved the study (04M10 and NWU-00016-10-A1). All participants provided written informed consent prior to participating in the study.

2.2 | Procedures

2.2.1 | Anthropometry

Anthropometric measures were performed at baseline, 5- and 10- year follow up, following standard procedures of the International Society of the Advancement of Kinanthropometry (Marfell-Jones, Stewart, & de Ridder, 2006). For height (m), a portable stadiometer was used and body mass was measured with an electronic weight scale (Seca, Hamburg, Germany) to the nearest 0.1kg with participants lightly clothed and no shoes. BMI was calculated by dividing body mass (kg) by height squared (m^2). CC was measured on the right calf at maximum calf girth using a non-stretchable tape measure (KDS measure, model F10-02DM 2m, Kyoto, Japan) with each participant standing upright.

2.2.2 | Physical performance

Physical performance was assessed at 10-year follow-up (2015) and included three tests of physical function: chair stand, 6m walk speed and HGS. Participants were provided with a 45cm high armless chair and asked to rise five times as quickly as they could with arms across their chest. The number of completed stands was counted and the time to complete the five chair stands was recorded in seconds using a stopwatch. The inability of participants to complete one chair stand was recorded as a “fail” (Rikli & Jones, 1997). The walk speed test over 6m was performed on a flat surface. Participants wore comfortable footwear and customary walking aids were allowed. The time it took to complete a 6m walk test was recorded in seconds with a stopwatch and walk speed in m/s was calculated (Studenski et al., 2011). HGS was measured on the dominant arm with a Jamar dynamometer (Model 78010 & 78011, Lafayette Instruments, Sagamore Parkway North, USA) to the nearest 0.1kg. The maximum strength of two repeated measurements were recorded (Bohannon, 2001).

2.2.3 | Other assessment

Semi-structured questionnaires were administered in the preferred language of participants by trained fieldworkers residing in the study communities. Basic demographic information regarding age, sex, education level (no high school education versus high school education), and smoking status (current smoker versus non-smoker) of the participants were collected. The Transition of Health during Urbanisation in SA (THUSA) physical activity questionnaire developed from the Baecke questionnaire was used to determine physical activity scores in our study (Kruger, Venter, & Steyn, 2000). The questionnaire contained 20 questions, gathering information on the domains of commuting, stair climbing, sport participation, occupational and leisure time activities. A total physical activity score (range 0–20) was calculated by combining the above indices (Kruger et al., 2000).

2.3 | Statistical analysis

Descriptive statistics were used to present demographic information and anthropometric measures together with physical activity data of the participants. Normality of data was assessed by using histograms, Q-Q plots and Shapiro-Wilk test. Descriptive statistics with a normal distribution was presented as means ± standard deviation (SD) of continuous variables; and frequencies and percentages for categorical variables. Non-normally distributed data were described using median and interquartile ranges (IQR). Pearson correlation was used to explore the relationship between predictor variables (age, PA score and BMI) and dependent variables (chair stand, walk speed and HGS). Proportions of men and women, according to their BMI category in 2005 and 2015 were compared using the McNemar test. Linear mixed models were used to evaluate changes in anthropometric measurements (body mass, BMI and PA) over ten years. Age, physical activity score, smoking status and education level were adjusted for in separate models for men and women with change in BMI as the outcome. Differences between the results for the physical performance test of the tertile groups of CC were compared using an analysis of variance (ANOVA) and post hoc tests were performed with a Bonferroni correction for multiple comparisons. The Wilcoxon signed rank test was used to compare baseline and the end CC of the participants. Multivariable linear regressions were used to determine the cross-sectional association between anthropometric measures (BMI and CC, respectively) and 10-year follow-up physical performance tests (chair stand, walk speed and HGS) as dependent variables. Potential confounders added in a stepwise regression model included: age, physical activity (continuous variables), education and smoking (categorical variables). Confounding variables were selected based on theoretical considerations and existing literature relevant to the topic (Kostka & Bogus, 2007). All statistical analysis was performed using the Statistical Package for the Social Sciences Version 23 (IBM, Armonk, NY, USA) and the significance level was set at $p < 0.05$.

3 | RESULTS

Table 1 displays the basic demographic characteristics of the participants. A higher BMI was observed in the women compared to the men. Figure 1 shows the BMI categories for both men and women in 2005, 2010 and 2015. The prevalence of obesity in men was very low (<7%) in 2005, 2010 and 2015 compared to women, where obesity prevalence increased significantly from 14.3% in 2005 to 17.5% in 2015. However, the prevalence of combined overweight and obesity in men (p=0.02) and women (p< 0.001) increased significantly over the 10 years period.

Table 2 presents the anthropometric changes in continuous variables in ten years. There was a significant increase over time in body mass (p=0.014), BMI (p=0.001) and CC (p<0.0001) in women, whereas physical activity decreased significantly in both men and women (p<0.0001). Table 3 shows the BMI change of the participants adjusted for confounding variables in 2005. The participants who smoked at baseline had a smaller increase in BMI over the ten year period than those who did not smoke (p<0.05). BMI increased more in the participants with high school education than in participants with no high school education (p<0.0001). The education level at baseline (2005) was, therefore, a significant predictor of an increase in BMI in this study.

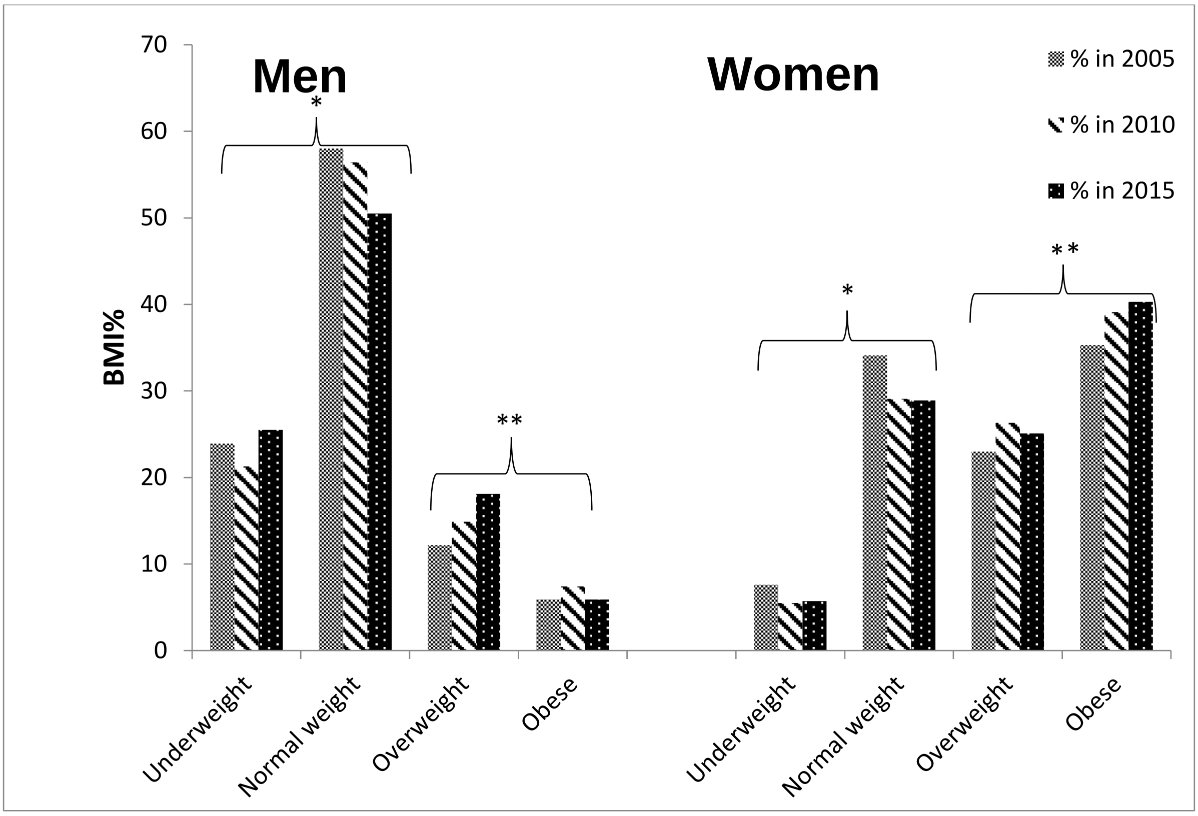
Table 4 presents a correlation among possible confounding factors, such as age and physical activity score, and the physical performance tests measured in 2015. Physical activity score correlated positively with HGS in both men (p<0.0001) and women (p=0.015) while age correlated negatively with walk speed (p=0.002 and p<0.0001, respectively) and HGS (p<0.0001 and p<0.0001, respectively) in both men and women. Chair stand time correlated positively with age (p=0.007 and p=0.004, respectively) but negatively with physical activity (p=0.001 for both) in men and women.

Table 5 presents the results of the physical performance strength tests by CC tertile groups in 2015. Statistically significant differences between HGS in the tertile groups of CC were found in both men (p=0.002) and women (p<0.0001). Table 6 presents the association between anthropometric measures and physical performance in 2015. Chair stand time was not significantly associated with BMI or CC and this phenomenon was observed in both men and women. The walk speed of the men and women was not significantly associated with BMI, even after adjusting for possible confounders. However, walk speed was positively associated with CC in the men ($p=0.006$), but not in the women. A significant positive association was found among HGS, BMI and CC in both men and women. A positive association was maintained in all of the models after adjusting the models for age, physical activity, education status and smoking ($p<0.05$).

TABLE 1 Descriptive data of the participants, at baseline, 5- and 10-year follow up categorised by sex

Variables		Men (n=188)			Women (n=422)		
		2005	2010	2015	2005	2010	2015
Age (years)†		50.8(44.3–58.3)	55.3(48.8–62.7)	60.8(54.3–68.3)	50.32(44.0–57.5)	54.9(48.5–62)	60.4(54–67.5)
Body mass (kg)†		56.6(50.4–66.6)	57.3(52–67.7)	57.8(51.2–67.9)	65.2(54–81.5)	68.8(57–83.3)	68.9(55.8–83.7)
Height (m) ‡		1.7±0.1	1.7±0.1	1.7±0.1	1.6±0.06	1.6±0.06	1.6±0.06
Body mass index (kg/m^2)†		20(18.6–23)	20.5(18.6–24.4)	20.5(18.4–24.6)	26.5(22–32.7)	27.7(23.3–33.9)	28(23–33.6)
Calf circumference (cm) ‡§		32.3±3.4	~	32.1±3.7	34.6±4.7	~	35.1±5.1 **
Physical activity score†		2.9(2.5–3.3)	3(2.7–3.2)	2.4(1.9–2.9)	2.9(2.6–3.3)	3(2.7–3.1)	2.1(1.9–2.5)
Urbanisation area (n/%)	**Rural**	105(55.9%)	105(55.9%)	105(55.9%)	252(59.7%)	252(59.7%)	252(59.7%)
Educational status (n/%)	**High School**	107(56.9%)	107(56.9%)	107(56.9%)	259(61.4%)	259(61.4%)	259(61.4%)
Tobacco user (n/%)	**Smoking**	105(55.9%)	93(49.7%)	92(48.9%)	182(43.1%)	180(43.1%)	279(66.1%)

n: number of participants with complete data in all three years; †: Data are presented as median and IQR; or ‡: as mean ± standard deviation; §: Measurements done in 2005 and 2015 only; **: Significant difference between 2005 and 2015 (Wilcoxon signed rank test). The *p*-values for other significant changes are presented in Table 5



McNemar test; ⏉: increase or decrease from 2005 to 2015; *: significant decrease in underweight/normal weight; **significant increase in overweight/obesity from 2005 to 2015 (P<0.05); Two by two table; underweight and normal weight=0; overweight and obese=1

FIGURE 1 BMI categories stratified by sex for baseline, 5- and 10-year follow-up

TABLE 2 Change over time (2005, 2010 and 2015) in continuous variables using linear mixed models in men and women (crude models)

	Men (n=220)			Women (n=559)		
Variable	**β estimate**	**95%CI**	***p-value***	**β estimate**	**95%CI**	***p-value***
Body mass(kg)	0.27	-0.4 ;0.94	0.46	0.76	0.15;1.37	**0.014**
BMI (kg/m²)	0.19	-0.05;0.43	0.12	0.42	0.17;0.66	**0.001**
PA score	-0.30	-0.39;-0.22	**<0.0001**	-0.37	-0.40;-0.33	**<0.0001**

BMI, body mass index; PA, physical activity; Linear mixed models; estimates of fixed effects; separate models for each variable; one unit is equal to five years.

TABLE 3 Body mass index change over ten years adjusted for age, physical activity score, smoking status and education level using linear mixed models

Anthropometric measures	Men (n=220)			Women (n=559)		
	β estimate	**95%CI**	***p-value***	**β estimate**	**95%CI**	***p-value***
Dependent variable: BMI adjusted for confounding variables						
Age (years)	0.09	0.05;0.13	**<0.0001**	0.07	0.03;0.12	**0.001**
Physical activity score	-0.12	-0.30;0.07	0.23	0.25	-0.03;0.52	0.08
Smoking (smoking as reference)	0.45	0.10;0.79	**0.01**	0.74	0.40;1.07	**<0.0001**
Education (high school education as reference)	-1.52	-2.39;-0.65	**0.001**	-2.83	-3.71;-1.94	**<0.0001**

Linear mixed models; estimates of fixed effects; one unit is equal to five years; adjusted for age, physical activity score, smoking status & education level.

Table 4 The correlation between predictor variables and dependent variables (physical performance) in men and women in 2015

Physical performance tests	Men (n=220)			Women (n=559)		
	Age (years)	**Physical activity score**	**Body mass index (kg/m^2)**	**Age (years)**	**Physical activity score**	**Body mass index (kg/m^2)**
Chair stand time(s)	*r*=0.20 ***p*=0.007**	*r*=-0.24 ***p*=0.001**	*r*=0.07 *p*=0.33	*r*=0.13 ***p*=0.004**	*r*=-0.16 ***p*=0.001**	*r*=0.06 *p*=0.15
Walk speed (m/s)	*r*=-0.32 ***p*=0.002**	*r*=0.20 ***p***=0.06	*r*=0.10 ***p***=0.34	*r*=-0.44 ***p*<0.0001**	r=0.03 ***p***=0.63	*r*=0.02 *p*=0.78
Handgrip strength (kg)	*r*=-0.28 ***p*<0.0001**	*r*=0.14 ***p*<0.0001**	*r*=0.24 ***p*=<0.0001**	*r*=-0.33 ***p*<0.0001**	*r*=0.11 ***p*=0.015**	*r*=0.19 ***p*<0.0001**

*: Correlation significant at the 0.01 level 2-tailed) using Pearson correlation coefficient.

TABLE 5 Results of physical performance tests by calf circumference tertile groups of men and women measured in 2015

	Men (n=226)					Women (n=501)				
Calf circumference (cm) t*ertile groups*	***1(<30.4 cm)***	***2(30.5-35.5 cm)***	***3(>35.6 cm)***	***P****	***P#***	***1(<32.3 cm)***	***2(32.4-37.2 cm)***	***3(>37.3 cm)***	***P****	***P#***
Chair stand time(s)	17.4±4.32	17.1±3.34	17.4±3.93	0.71	0.90	17.7±3.84	17.9±5.19	18.3±4.70	0.59	0.26
Walk speed (m/s)	1.25±0.33	1.39±0.43	1.44±0.31	0.12	**0.04**	1.22±0.30	1.20±0.27	1.26±0.26	0.46	0.75
Handgrip strength (kg)	29.1±7.6[a]	31.9±9.4[a]	34.8±11.1[b]	**0.002**	**<0.001**	22.0±5.99[a]	24.3±7.26[b]	25.4±6.82[b]	**<0.001**	**<0.001**

a, b variables with different subscript differ significantly (ANOVA, Bonferroni with post hoc test); Data presented as mean and standard deviation; p* difference between tertile groups evaluated by ANOVA; p# p for trend evaluated by linear regression across tertile midpoints

TABLE 6 Cross-sectional association between anthropometric measures and physical performance test measured in men and women in 2015, adjusted for confounding factors

		Standardised coefficient	*p*-value	Standardised coefficient	p-value	Standardised coefficient	*p*-value
Men		***n=209***		***n=92***		***n=266***	
Body mass index (kg/m²)	Crude model	0.08	0.25	0.15	0.15	0.21	**0.001**
	Model 1	0.07	0.27	0.11	0.24	0.21	**0.001**
	Model 2	0.04	0.53	0.15	0.12	0.23	**<0.0001**
	Model 3	0.09	0.18	0.18	0.09	0.21	**0.02**
	Model 4	0.10	0.16	0.18	0.09	0.20	**0.02**
Calf circumference (cm)	Crude model	0.03	0.70	0.26	**0.01**	0.30	**<0.0001**
	Model 1	0.04	0.27	0.20	**0.04**	0.28	**<0.0001**
	Model 2	0.02	0.78	0.25	**0.01**	0.30	**<0.0001**
	Model 3	0.06	0.35	0.29	**0.006**	0.28	**<0.0001**
	Model 4	0.07	0.33	0.31	**0.006**	0.27	**<0.0001**
Women		***n=469***		***n=187***		***n=496***	
Body mass index (kg/m²)	Crude model	0.04	0.37	-0.02	0.20	0.20	**<0.0001**
	Model 1	0.03	0.27	-0.03	0.61	0.20	**<0.0001**
	Model 2	0.04	0.44	-0.03	0.62	0.20	**<0.0001**
	Model 3	0.05	0.24	-0.05	0.45	0.19	**<0.0001**
	Model 4	0.06	0.19	-0.07	0.29	0.18	**<0.0001**
Calf circumference (cm)	Crude model	0.04	0.31	-0.01	0.87	0.22	**<0.0001**
	Model 1	0.05	0.26	-0.04	0.49	0.21	**<0.0001**
	Model 2	0.04	0.28	-0.04	0.50	0.21	**<0.0001**
	Model 3	0.06	0.19	-0.06	0.38	0.20	**<0.0001**
	Model 4	0.07	0.12	-0.07	0.25	0.19	**<0.0001**

Model 1: crude model adjusted for age; Model 2: model 1+physical activity score; Model 3: model2 + smoking (smoking as reference); Model 4: model 3+ education (school education as reference); multiple linear regression method; standardised coefficient.

4 | DISCUSSION

This is the first study to our knowledge that investigated the association between anthropometric measures and physical performance of black adults over a time span of 10-years in SA. Our study showed an increase in BMI and CC in women over 10-years but not in men. BMI and CC were positively associated with HGS in men and women, whereas CC was positively associated with walk speed in men only. The results indicate that CC could be a useful measure of physical performance in black men.

Our results concur with findings of previous studies that the prevalence of obesity is higher in women compared to men (Kruger et al., 2015; Shisana, 2014). The prevalence of obesity increased with time, but more rapidly in women than men. Black women in particular are noted to harbour misperceptions of weight gain and they tend to underestimate their weight (Kruger, Venter, Vorster, & Margetts, 2002). The rising prevalence of obesity could be attributed to the nutrition transition currently taking place in SA and other LMICs (Bourne, Lambert, & Steyn, 2002). Fat accumulation in older persons occur due to hormonal changes and a loss of muscle mass caused by a decrease in physical activity, which reduces the basal metabolic rate and contribute to decreases in total energy expenditure (Stenholm, Alley, Bandinelli, Griswold, Koskinen, Rantanen, Guralnik, & Ferrucci, 2009).

Despite the general increase of overweight and obese participants over time in our study, no inverse associations between BMI and physical performance tests were found. On the contrary, our results differ from other studies suggesting that a higher BMI is associated with poor physical performance (Jensen & Friedmann, 2002; Zoico, Di Francesco, Guralnik, Mazzali, Bortolani, Guariento, Sergi, Bosello, & Zamboni, 2007; Pataky, Armand, Muller-Pinget, & Allet, 2014). The non-significant association of chair stand time with BMI and CC in our participants is similar to findings of a United States study of healthy subjects aged 20-80 years, which found neither height nor body mass was related to chair time test in both men and women (Csuka & McCarty, 1985). On the other hand, low muscle strength, but not low muscle mass was found to be associated with poor physical performance in older men and women in a study in the Netherlands (Visser, Deeg, Lips, Harris, & Bouter, 2000). In epidemiological studies, BMI is generally considered a suitable measure to categorise the status of individuals with regard to being underweight, normal, overweight or obese. However, BMI does not differentiate between body fat and lean mass and different cut-points may be applicable to different ethnic groups (Deurenberg, Deurenberg-Yap, & Schouten, 2002; Kruger et al., 2015). The lack of an association between BMI and chair stand time could be a result of associations in opposite directions between the amount of body fat mass and muscle mass, respectively, and chair stand performance. Excessive body fat may have contributed in a longer time necessary to rise from the chair, as reported in an earlier study (Pataky et al., 2014), while a greater muscle mass may have contributed in a shorter time to rise from the chair due to greater muscle strength (Visser et al., 2000). Both fat mass and muscle mass are higher in individuals with a greater BMI (Kruger et al., 2015).

The walk speed test is a useful measure of mobility (Harada, Chiu, & Stewart, 1999). In the present study, BMI did not show a linear negative association with walk speed among men or women. This may be due to the fact that BMI is a measure of both underweight and overweight, and the prevalence of being underweight in men was relatively high in this study. Underweight individuals present with a low fat mass and low muscle mass and underweight may therefore be associated with a weaker physical performance among the men in the present study.

The total adiposity and associated fat infiltration into muscle were important predictors of a walk speed decline in black and white adults of the Health Aging, and Body Composition (ABC) study in the United States of America (Beavers, Beavers, Houston, Harris, Hue, Koster, Newman, Simonsick, Studenski, & Nicklas, 2013). In a South African study, women with a high BMI presented both a high fat mass and high muscle mass (Kruger et al., 2015). A high BMI may, therefore not be associated with a slower walk speed or a longer chair stand time as reported in other studies where a higher BMI is normally associated with poor physical performance (Jensen & Friedmann, 2002; Zoico et al., 2007; Pataky et al., 2014). A positive association was found between BMI and HGS of both men and women in the present study. In the Finnish population-based Health 2000 Survey, HGS cut-points for mobility increased together with BMI in men (p=0.02) (Sallinen, Stenholm, Rantanen, Heliövaara, Sainio, & Koskinen, 2010). The findings by Sallinen et al. (2010) supports the notion that underweight individuals show both a low fat mass and low muscle mass and, therefore, a low BMI may be associated with a weaker physical performance, particularly concerning men in the present study. A BMI in the underweight range may therefore be a useful predictor of suboptimal physical performance in older adults and could be useful in public health practice to assess the strength of older adults.

CC provides a relatively accurate estimation of lower limb muscle mass and it has therefore been suggested to be used as proxy for muscle mass, although it measures the muscle area and subcutaneous fat (Landi et al., 2014; Rolland, Lauwers-Cances, Cournot, Nourhashémi, Reynish, Rivière, Vellas, & Grandjean, 2003). The predictive power of CC to assess lean body mass can also be influenced by leg oedema (Kawakami, Murakami, Sanada, Tanaka, Sawada, Tabata, Higuchi, & Miyachi, 2015). A CC of <31 cm was associated with disabilities in a study of older adults in Turkey (Landi et al., 2014). The relationship between CC and lean body mass was stronger in men than in women and may possibly be due to the fact that women distribute more fat mass on their lower extremities (Kawakami et al., 2015). This may be the reason why CC increased significantly over the period of ten years in the women of the present study, but not in the men. The results of this study are in contrast with another study from Ireland (Corish & Kennedy, 2003), where the CC of women decreased over time with aging. This may be due to the fact that most women in the present study were between the ages of 45 to 65 years, while all of the women in the Irish study were older than 65 years (Corish & Kennedy, 2003). In this study, the CC of women increased in line with their general increase in body mass and BMI over the time span of ten years.

CC was positively associated with HGS across CC tertile groups in men and women. This is an indication that CC can be a useful predictor of physical performance in black men and women. A HGS test is a useful tool to identify individuals at risk for mobility limitations and is a good measure of muscle strength, with a positive correlation with leg strength (Cruz-Jentoft et al., 2010). Low HGS is a clinical indicator of poor mobility and a better predictor of clinical outcomes than low muscle mass. In the present study, CC was associated with both HGS and walk speed in men. CC has been reported as more effective in predicting long-term mortality risks, and is more accessible and time efficient to measure than BMI, or physical performance (Tsai & Chang, 2011). This study confirmed that increased age is associated with a weaker performance in physical performance tests, indicating declining muscle strength (Eremenko, Pink, Biffar, Schmidt, Ittermann, Kocher, & Meisel, 2016). This study also found that age has a negative association with walk speed and HGS, while the chair stand time had a positive association with age. This can be viewed as an indication that physical performance in all three tests declined during aging.

The strength of this study lies in the repeated anthropometric measurements in apparently healthy men and women over time and statistical adjustments for a wide range of potential confounders. A limitation of this study is the fact that the PURE-SA study was composed exclusively of adult black men and women from four communities in the North West Province, thus limiting generalisability of the results. Some of the participants were lost to follow up, resulting in 926 participants returning for a follow up in 2015. The physical performance tests were only performed at the end of the study in 2015 as an outcome of longitudinal exposures. No changes in anthropometric measures were found in men and therefore only cross-sectional associations between anthropometric measures and physical performance were assessed at the end of the study. Use of self-reported physical activity contribute to possible errors and bias. Although BMI is widely used as a measure of obesity, it is not sensitive to differences in body fat and muscle mass. It is possible that changes in BMI do not fully capture adiposity-related and muscle-related changes with aging. Anthropometric measures are not high resolution measures, but these measures are often the only measurements available and affordable in epidemiological studies, as well as public health practice in LMICs. Further interventions and longitudinal research will be needed to understand these relationships better. Additional measures, such as DXA or bioelectric impedance analysis (BIA), can be useful in future investigations to more precisely understand the nature of the observed associations found in the present study.

Conclusion

BMI and CC in men and women were associated with HGS, but CC was associated with walk speed in men only. We partly accept the hypothesis that a non-invasive, simple anthropometric measurement, in particular CC, and to some extent BMI in the underweight range may be useful predictors of physical performance in adults and could be useful in public health practice to assess the strength of older adults. CC may be a useful predictor of physical performance in black men and to a more limited extent in black women. In conclusion, there was a stronger association among CC, HGS and walk speed in men than in women, but no associations were found with chair stand performance. Intervention and longitudinal research are needed to gain a better understanding of these relationships between anthropometric measures and physical performance.

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CONFLICT OF INTEREST

The authors report none.

AUTHOR CONTRIBUTIONS

PM and HSK conceptualised the study, drafted the manuscript and conducted all of the statistical analyses with input from MC and CR. SJM, IMK, POU and HSK made substantial contributions to the drafts and were involved in critically reviewing the manuscript and interpreted the results. PM, HSK and IMK contributed to data collection. All of the authors have reviewed and approved the final version for publication.

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