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ORIGINAL ARTICLE

Determining cut-off values for neck circumference as a measure of the metabolic syndrome amongst a South African cohort: the SABPA study

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Abstract The aim was to determine receiver operating characteristic (ROC) neck circumference (NC) cut offs best associated with the metabolic syndrome (MetS) in a South African cohort. We included 409 urban Africans and Caucasians and stratified them into gender and age groups (25–45 years; 45–65 years). Measurements included anthropometric, fasting overnight urine and biological markers for the MetS (systolic and diastolic blood pressure, glucose, triglycerides, and high density lipoprotein). ROC analysis determined pathological (NC) cut-points of 39 and 35 cm for young and older African men; 32 and 35 cm for young and old African women; 40 and 41 cm for Caucasian men; 34 and 33 cm for Caucasian women. Pathological NC cut-points significantly predicted MetS in all ethnic–gender–age groups except in African women (ORs 2.3–5.4; 95% CI 1.36–16.5). Multiple regression analyses revealed that MetS prevalence and ROC cut-points were not associated with renal impairment in any groups. ROC NC cut-points demonstrated that NC may be used as an additional anthropometric marker to predict the MetS in a South African cohort but not in African women.

Keywords Metabolic syndrome (MetS) · Neck circumference (NC) · African · Caucasian

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Introduction

Metabolic syndrome (MetS) prevalence is a rising epidemic, and this is no different in Africa as it has increased along with the rapid urbanization of Africans [1]. Recent research demonstrated that Africans have the highest prevalence of MetS compared to Caucasians [2]. This higher prevalence could, however, change with the use of ethnic specific waist circumference (WC) cut-points [3]. The recently renewed definition of the MetS [4] suggested that ethnic specific cut-points for WC should be made to more correctly identify Africans with underlying MetS.

Microalbuminuria was previously a component of the MetS and research revealed the importance of specifically neck circumference (NC) as a parameter with which to identify the presence of microalbuminuria in Africans [5, 6]. NC is known to be associated with sleep apnea in adults and children [7]. Sleep apnea has also been related with the MetS [8] and MetS can be highly prevalent amongst children [9].

However, literature is sparse on the topic of NC and metabolic health in adult Africans. Some findings demonstrated that NC is worthy of further investigation as an identifying measure of health risk [5, 10]. Furthermore, NC shows association with body mass index (BMI) and WC, which indicates central obesity [11, 12]. Onat et al. [12] further demonstrated that associations between NC and physiological risk factors were more profound in men. Nielsen et al. [13], however, concluded that women are more prone to show associations between NC and adverse health-risk factors.

Together with WC, NC might therefore be a good supportive or independent screening tool for MetS [11, 12]. Furthermore, NC has been found to be a more ideal measure than WC because it does not change during the day [11].

Due to a distinct lack of information for NC and especially amongst Sub-Saharan Africans, we will aim to identify possible cut-points for NC amongst an African and Caucasian cohort to predict MetS. This could lead to the development of cost effective screening measures, which would be of great importance to impoverished African communities.

Materials and methods

This sub-study formed part of the prospective cohort study, *S*ympathetic Activity and *A*mbulatory *B*lood *P*ressure in *A*fricans (SABPA) which was conducted during 2008 and 2009.

Study population

The study sample ($N = 409$) comprised urban African and Caucasian teachers from the Dr. Kenneth Kaunda Education district in the North West Province, South Africa. This sample was thus homogenous concerning socio-economic class and included 200 Africans (men, $N = 101$; women, $N = 99$) and 209 Caucasians (men, $N = 101$; women, $N = 108$). Participants were aged 25–65 years. Exclusion criteria for participation included pregnancy, lactation, temperature >37°C, use of alpha and beta blockers and psychotropic substance abuse as well as blood donors and persons vaccinated in the 3 months before participation. Data from HIV-positive participants (13 African men; 6 African women) and clinically diagnosed diabetics (7 African men; 3 African women; 1 Caucasian man; 1 Caucasian woman) were excluded from analysis. Participants were classified with the MetS using the guidelines of Alberti et al. [4] (WC, men ≥94 cm and women ≥80 cm; triglycerides ≥1.7 mmol/l; HdL, men 1.0 mmol/l and women <1.3 mmol/l; glucose ≥5.5 mmol/l; SBP ≥130 mmHg; DBP ≥85 mmHg). The suggested cut-points for WC for Africans as suggested by Prinsloo et al. [3] were used for Africans. All participants signed an informed consent form and the study was approved by The Ethics Review Board of the North-West University (project nr: NWU-00036-07S6). The study conformed to the ethical guidelines for human participants of the World Medical Association Declaration of Helsinki.

Experimental procedure

Avoiding seasonal changes, collection of data for each participant continued over a 48-h period in the working week from February to May 2008/2009. Each morning Actical® accelerometer (Montréal, Québec) devices were fitted and software programs activated for four participants after which they resumed their daily activities. Participants had to overnight at the Metabolic Unit Research Facility on the NWU campus. The Metabolic Unit consists of bedrooms for each participant, bathrooms, a kitchen and a dining room as well as a living room with a television. Participants were welcomed at 16:30 at the Metabolic Unit and introduced to the experimental setup. A standardized dinner was given and participants fasted from 2200 h. The following day at 0600 h anthropometric measurements were taken in triplicate, followed by blood pressure (BP) and blood sampling.

Assessment of anthropometric variables and physical activity

Anthropometric measurements were performed by level 2 accredited anthropometrists with subjects wearing minimal clothing and without shoes.

Maximum stature was measured with a stadiometer to the nearest 0.1 cm whilst weight was measured to the nearest 0.1 kg on a KRUPS scale with the weight evenly distributed. The above-mentioned measurements were used to calculate BMI by dividing weight (kg) by length $(m)^2$ [14].

Circumferences were measured with the participant in a standing position using a non-extensible and flexible anthropometric tape. NC was taken immediately superior to the thyroid cartilage perpendicular to the long axis of the neck. WC was taken at the midpoint between the lower costal rib and the iliac crest, perpendicular to the long axis of the trunk and not at the narrowest point for standardisation purposes [15].

Physical activity was measured by means of the Actical® physical activity monitor, which was water resistant, lightweight and small. The monitors were initialized and the results downloaded using a serial port computer interface. Acticals were fitted to participants' waists and were worn for 24 h and removed after their overnight stay at NWU.

Assessment of biological variables

Blood pressure measures followed after participants had rested for 5 min in a semi-recumbent position. BP was measured with a sphygmomanometer using the Riva-Rocci/Korotkoff method on the non-dominant arm [16]. Two duplicate measures were taken with a 3–5 min resting period between each measurement and the last measurement was used for screening for the MetS prevalence.

An overnight (8 h) fasting urine sample of 100 ml was obtained after waking. And used to determine albumin:creatinine ratio as a marker of microalbuminuria.

Urine was stored at 4°C after collection and frozen at −80°C.

A fasting resting blood sample was obtained with a winged infusion set from the brachial vein branches from the dominant arm by a registered nurse. Sodium fluoride glucose and serum samples for MetS markers, cotinine and gamma glutamyl transferase (GGT) were handled according to standardized procedures and stored at −80°C. Biochemical analysis for urine which involved a measurement of immunoprecipitation enhanced by polyethylene glycol at 450 nm and blood sampling analyses were done using Sequential Multiple Analyzer Computer, Konelab™ 20i Sequential Multiple Analyzer Computer (ThermoScientific, Vantaa, Finland) and the timed-end-point method (Unicel DXC 800-Beckman and Coulter, Germany) at independent accredited laboratories.

Statistical analyses

Participants were stratified into African and Caucasian gender age groups of 24–45 years (hereafter referred to as the younger group) and 46–65 years (hereafter referred to as the older group).

Statistical analyses were performed with Statistica 9 computer program (StatSoft Inc. 2009). Normality was tested and GGT was log transformed. Results were expressed as mean ± standard deviation (SD). Independent *t* tests compared different age groups within African and Caucasian men and women. Comparisons were made with Chi-square analysis. Partial correlations determined associations between NC and WC in each ethnic age group, adjusting for cotinine and log GGT. Thereafter, non-parametric receiver operating characteristic (ROC) curves were computed to examine the ability of NC to suggest population specific cut-off points (SPSS, v17 for Windows). The optimal cut-off was obtained from the Youden index [maximum (sensitivity + specificity − 1)]. For all logistic and linear stepwise regression analyses, cotinine and log GGT were included as covariates.

Results

African men and women

Table 1 depicts the basic characteristics of the African groups. Concerning lifestyle factors, there were no differences between age groups for BMI, physical activity and GGT levels. Both older groups have higher cotinine levels, 58.1 and 30.6 ng/ml for men and women, respectively, compared to the 23.2 and 7.5 ng/ml of their younger counterparts. GGT levels amongst the African groups indicate alcohol abuse [17].

In both male groups, the MetS components (glucose, triglycerides, BP and WC) were above the recommended cut-points. It was, however, only SBP that was significantly higher in the older men, 149 mmHg, compared to the younger men, 136 mmHg. MetS was prevalent in 39 of the young men and 26 of the older men. ACR mean levels above cut-point were evident only in the young African men.

In the older African women, the MetS components indicated more risk as their glucose (5.6 mmol/l), SBP (134 mmHg) and DBP (86 mmHg) were above, whilst HdL levels (1.2 mmol/l) were below recommended cut-points. Younger African women only revealed risk with lower than recommended HdL (1.2 mmol/l) levels. A similar trend pertaining to SBP in older men was evident in the older women.

Amongst the women it was however the older group that presented with a greater prevalence of MetS, 32, compared to the much lower 21 participants in the younger group.

Significantly, strong partial associations existed between NC and WC within all African age groups (young African men: $r = 0.8$; older African men: $r = 0.8$; young African women: $r = 0.7$; older African women: $r = 0.7$) (not shown).

ROC analysis was used to determine the suggested cut-off values for NC for the MetS. Figure 1 visually illustrates where the AUC was most optimal for the MetS and what the cut-points were according to the Youden index.

The respective ROC cut-off values, yielding maximum sensitivity and specificity were found at a cut-point of 39 cm (AUC: 0.8) for younger and at 35 cm (AUC: 0.7) for older African men whilst the younger African women revealed a cut-point at 32 cm (AUC: 0.7) and the older women at 35 cm (AUC: 0.6) for older women (Fig. 1).

Odds ratios (Table 2) revealed that increased risk for MetS was evident in young (OR 5.4, $P = 0.0$) and old (OR 4.0, $P = 0.0$) African men above the suggested NC cut-points. This risk was most prominent for young African males. On the contrary, NC was not associated with risk for MetS in older and younger African women (OR 1.7, $P = 0.1$; OR 1.8, $P = 0.2$).

Forward stepwise linear regression analysis demonstrated that no associations existed between ACR and NC in any of the ethnic–gender–age groups.

Caucasian men and women

Table 3 depicts basic characteristics for Caucasians. Lifestyle factors did not differ within age groups. In both Caucasian male groups, glucose and WC exceeded cut-points. In older men, BP exceeded cut-points probably contributing to being identified with MetS ($n = 43$) compared to the young men ($n = 33$).

Table 1 Baseline characteristics of African men and women

	African men (25–45 years) ($n = 66$)	African men (45–65 years) ($n = 34$)	*P* value	African women (25–45 years) ($n = 51$)	African women (45–65 years) ($n = 50$)	*P* value
MetS *n* (%)	40 (59.7)	26 (76.5)	0.1	21 (42.0)	32 (68.0)	0.0
Lifestyle factors						
Age	38.6 ± 5.1	52.2 ± 4.3	0.0	39.1 ± 4.3	52.1 ± 4.4	0.0
BMI, kg/m^2	27.6 ± 5.7	27.6 ± 6.0	1.0	32.0 ± 7.6	33.6 ± 6.8	0.3
PA kcal/h	2818 ± 851.4	2509.7 ± 668.5	0.1	2608.5 ± 758.5	2686.2 ± 827.6	0.6
GGT, U/l	75.7 ± 72.5	102.9 ± 120.2	0.2	43.5 ± 36	50.8 ± 88.6	0.6
Cotinine, ng/ml	23.2 ± 47.5	58.1 ± 86.5	0.0	7.5 ± 27.0	30.6 ± 73.2	0.0
MetS components						
Glucose, mmol/l	5.8 ± 1.9	6.4 ± 2.2	0.1	5.0 ± 1.4	5.6 ± 2.6	0.2
HdL, mmol/l	1.0 ± 0.4	1.1 ± 0.3	0.1	1.2 ± 0.3	1.2 ± 0.3	0.2
TRIG, mmol/l	1.8 ± 1.8	1.8 ± 1.2	0.9	0.9 ± 0.5	1.2 ± 0.7	0.0
SBP, mmHg	136 ± 18	149 ± 22	0.0	125 ± 15	135 ± 18	0.0
DBP, mmHg	92 ± 14	97 ± 14	0.1	82.5 ± 9.6	86 ± 10	0.1
WC, cm	92.6 ± 15.2	95.5 ± 16.2	0.4	91.0	96.3 ± 14.7	0.1
NC as possible Mets predictor						
NC, cm	37.8 ± 3.2	37.4 ± 3.4	0.5	33.6 ± 2.8	33.6 ± 2.6	1.0
Target organ damage						
ACR	3.5 ± 19.1	2.7 ± 5.1	0.8	2.1 ± 4.9	1.4 ± 1.2	0.3

Values are arithmetic mean ± SD

BMI body mass index, *PA* physical activity, *GGT* gamma glutamyl transferase, *HdL* high density lipoprotein; *TRIG* triglyceride, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *NC* neck circumference, *WC* waist circumference, *ACR* creatinine ratio

The younger Caucasian women had significantly higher cotinine levels (27.7 ng/mg) when compared to their older counterparts (4.1 ng/ml). No other lifestyle factor differences existed. Older Caucasian women revealed risk with glucose (5.5 mmol/l) and WC (87.2 cm), whilst the younger group only revealed risk according to their WC (82.4 cm). Despite triglycerides, SBP, DBP being significantly higher amongst the older women when compared to the young group, these levels did not constitute health risk. On the contrary, ACR was significantly higher in the young women but also did not constitute health risk. Significantly, more of the older Caucasian women ($n = 30$) presented with MetS compared to the 12 younger women.

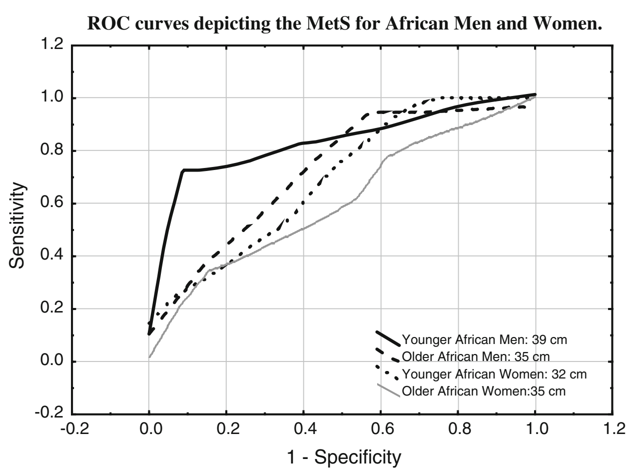

Fig. 1 ROC curves depicting the MetS for the African men and women predicting pathological NC. The area under the curve (AUC) (95% CI) was 0.8 (0.7; 0.9) for young African men, 0.7 (0.5; 1.0) for older African men, 0.7 (0.5; 0.8) for young African women and 0.6 (0.4; 0.8) for older African women

Significantly, strong associations existed between NC and WC within all Caucasian age and gender groups (young Caucasian men: $r = 0.8$; older Caucasian men: $r = 0.8$; young Caucasian women: $r = 0.8$; older Caucasian women: $r = 0.8$).

ROC analysis was used to determine the suggested cut-off values for NC for the MetS. Figure 2 visually illustrates where the AUC is most optimal for the MetS and what the cut-points were according to the Youden index. The respective ROC cut-off values, yielding maximum sensitivity and specificity were found at a cut-point of 40 cm (AUC: 0.9) and 41 cm (AUC: 0.7) for the young and older men, respectively. NC cut-points for young women were found at 34 cm (AUC: 0.7) and 33 cm (AUC: 0.8) for the older group.

We commenced with logistic regression and odds ratios in Table 4. The pathological NC, as determined with ROC

Table 2 Logistic regression and odds ratios are demonstrated to indicate if NC cut-points predict MetS in Africans

MetS	Young African men		Older African men		Younger African Women		Older African women	
	OR	(± 95 CI)	OR	(± 95 CI)	OR	(± 95 CI)	OR	(± 95 CI)
NC	5.4	1.8, 16.1 $P = 0.0$	4.0	1.2, 12.6 $P = 0.0$	1.7	0.8, 3.6 $P = 0.1$	1.8	0.7, 4.3 $P = 0.2$

Data presented as odds ratio (OR) with (% confidence interval and *P* values for significance of OR. Co-variates included cotinine and log GGT

analysis, determined risk for MetS in all Caucasian groups. Odds ratios revealed that increased risk for MetS was evident in young and old Caucasian men (OR 3.2, $P = 0.0$; OR 2.3, $P = 0.0$). High risk was also prevalent for young (OR 2.8, $P = 0.0$) and older women (OR 4.6, $P = 0.0$).

Multiple regression analysis revealed no associations between NC cut-point and ACR in any of the ethnic–gender–age groups.

Discussion

The aim of this study was to determine the best NC cut-off points for the MetS. Our main finding demonstrated that ROC developed NC cut-points can be used to determine risk for MetS.

Africans: lifestyle factors

Urbanization or acculturation [18] and accompanying poor lifestyle factors, such as alcohol abuse, smoking and low physical activity could affect cardiometabolic health in African populations [19]. These risk behaviours have been found to be utilized as coping strategies in stressful environments with subsequent increase in hypertension prevalence [20] and WCs [21], both of which are MetS indicators. Further research is needed to indicate whether these factors are also linked to NC.

High BP has been found to be a concern amongst urban Africans [18, 22, 23] and also apparent in our groups. A contributing factor namely high GGT concentration (>65 U/l) in both age groups may act as a surrogate marker of oxidative stress accompanying MetS but which can also

Table 3 Baseline characteristics of Caucasian men and women

	Caucasian men (25–45 years) ($n = 46$)	Caucasian men (45–65 years) ($n = 55$)	*P* value	Caucasian women (25–45 years) ($n = 50$)	Caucasian women (45–65 years) ($n = 58$)	*P* value
MetS	33 (71.7)	43 (78.2)	0.6	12 (24)	30 (51.7)	0.0
Lifestyle factors						
Age	35.2 ± 8.4	53.1 ± 4.3	0.0	35.7 ± 7.7	52.8 ± 5.0	0.0
BMI, kg/m^2	28.9 ± 6.2	29.1 ± 4.2	0.8	25.9 ± 7.0	26.6 ± 6.0	0.6
PA kcal/h	3482.3 ± 636.2	3481 ± 814.1	1.0	2602 ± 690.2	2574 ± 609.0	0.8
GGT, U/l	32.2 ± 33.1	36.8 ± 26.2	0.4	15.4	23.3 ± 47.7	0.3
Cotinine, ng/ml	33.6 ± 94.4	28.6 ± 99.4	0.8	27.7 ± 71.9	4.1 ± 23.6	0.0
MetS components						
Glucose, mmol/l	5.8 ± 1.0	6.1 ± 0.8	0.2	5.2 ± 0.4	5.5 ± 0.7	0.0
HdL, mmol/l	0.9 ± 0.2	1.0 ± 0.3	0.1	1.3 ± 0.4	1.5 ± 0.4	0.1
TRIG, mmol/l	1.5 ± 1.0	1.5 ± 0.8	0.9	0.8 ± 0.3	1.0 ± 0.5	0.0
SBP mmHg	126 ± 12	133 ± 14	0.0	116 ± 11	128 ± 16	0.0
DBP mmHg	84 ± 10	86 ± 9	0.3	76 ± 8	83 ± 9	0.0
WC, cm	99.0 ± 16.0	103.7 ± 12.7	0.1	82.4 ± 13.6	87.2 ± 12.8	0.1
NC as possible Mets predictor						
NC, cm	40.8 ± 3.3	41.0 ± 2.7	0.7	33.5 ± 2.3	34.2 ± 2.7	0.1
Target organ damage						
ACR	0.3 ± 0.4	0.5 ± 1.3	0.3	1.2 ± 2.1	0.4 ± 0.4	0.0

Values are arithmetic mean ± SD. *BMI* body mass index, *PA* physical activity, *GGT* gamma glutamyl transferase, *HdL* high density lipoprotein, *TRIG* triglyceride, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *NC* neck circumference, *WC* waist circumference, *ACR* creatinine ratio

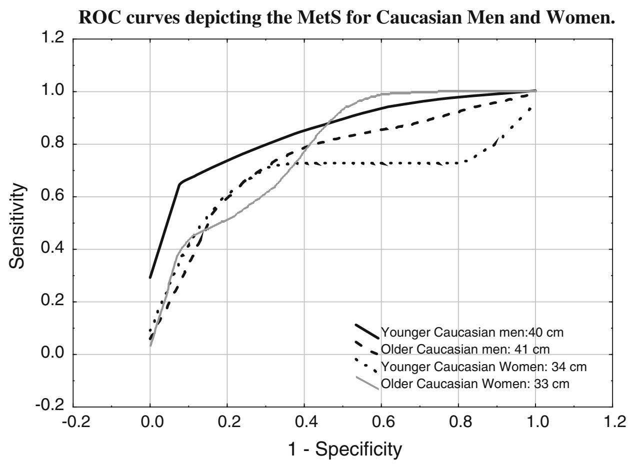

Fig. 2 ROC curves depicting the MetS for the Caucasian men and women predicting pathological NC. The area under the curve (AUC) (95% CI) 0.9 (0.8; 1.0) for young Caucasian men, 0.7 (0.6; 0.9) for older Caucasian men, 0.7 (0.4; 0.9) for younger Caucasian women and 0.8 (0.7; 0.9) for older Caucasian women

Table 4 Logistic regression and odds ratios are demonstrated to indicate if NC cut-points predict MetS in Caucasians

MetS	Young Caucasian men		Older Caucasian men		Younger Caucasian women		Older Caucasian women	
	OR	(± 95 CI)	OR	(± 95 CI)	OR	(± 95 CI)	OR	(± 95 CI)
NC	3.2	1.2, 8.7 $P = 0.0$	2.3	1.0, 5.4 $P = 0.0$	2.8	1.2, 6.3 $P = 0.0$	4.6	1.8, 11.5 $P = 0.0$

Data presented as odds ratio (OR) with (% confidence interval and *P* values for significance of OR. Co-variates included cotinine and log GGT

be indicative of alcohol abuse [17]. Other possible underlying mechanisms for increased GGT values may exist such as hepatic steatoses, insulin resistance and increased oxidative stress [24]. Their increased BP as well as carotid intima media thickness (CIMT) [19] could add to cardio-metabolic and atherogenic risk as Hamer et al. [19] showed that the odds of early structural vascular changes (≥0.9 mm CIMT) based on high GGT levels were 3.1 (95% CI; 0.6–15.5) in the African men, independent of confounders.

Our African women groups revealed a mean value of obesity. African women believe that fatness reflects health and the absence of HIV [25–27]. Although obesity is considered a major health risk factor, our African women seemed to be healthier than their male counterparts with their lower BMI. This could imply that psychological wellbeing possibly has a positive effect on physical wellbeing. This phenomenon has been termed ‘healthy obesity’ and it states that although African women are overweight, they present with good health [25–27]. Although both women age groups revealed obese levels, older African women presented with more risk factors which may be attributed to age. Ageing women have less estrogen protecting them against cardiovascular diseases [28]. Fat distribution changes with ageing and women develop an android build which has been associated with glucose intolerance, lipid and BP irregularities because of the metabolically active nature of visceral fat [29]. The aforementioned were more obvious for glucose, BP and HdL in our older African women. The younger women also revealed low levels of the protective factor HdL. Healthy HdL levels are more easily obtained when BMI is below 28 kg/m^2 [30] which was not the case amongst our obese African women. Triglycerides were favourable in both women age groups suggesting high levels of lipoprotein lipase (LPL) which were demonstrated in Africans, especially in women [31]. This factor can lead to the under diagnosis of MetS in Africans and adjustments for this specific measure for Africans have been suggested [32, 33].

Africans: NC as a predictor of MetS

Concerning the NC the cut-points indicated that pathology for MetS may occur at a higher cut-point than the mean for the younger men and at a cut-point lower that the mean value for older men. Considering ageing, pathology can occur at a lower NC value than in younger persons. Cut-points for African women did however, not predict MetS as opposed to the men where NC predicted risk to develop MetS. This finding could support the notion of healthy obesity.

Finally, regarding the target organ damage resulting from MetS, it can be seen amongst the young African men which could be a result of their high BP or the findings that Africans have a greater prevalence of end stage renal disease and tend to have higher albumin levels than Caucasians [34, 35]. Our results support these findings in the young African men who revealed increased albumin:creatinine ratios. NC, however, did not predict ACR in any ethnic–gender–age groups.

Caucasians: lifestyle factors

Our Caucasian groups seem to be healthier than their African counterparts, as they present with less risk. Caucasians may be acculturated [18] longer that the Africans and as such, urbanization may have less of an effect on overall health of Caucasians. Lifestyle risk factors revealed more alcohol abuse amongst the men whilst younger groups smoked more. All groups revealed overweight

BMIs, increased glucose levels and elevated WC. Even though BP was higher in older gender groups it did not constitute health risk.

Caucasians: NC as predictor of MetS

NC in the Caucasian groups revealed a mean value of 41 cm for all Caucasian men which were the cut-point for older Caucasian men. Young Caucasian men revealed a cut-point of 40 cm. Women revealed a mean value of 34 cm which is in accordance to the cut-point for younger women whilst older women presented with a cut-point of 33 cm.

Ethnic NC recommendations

When comparing our cut-points with those of Onat et al. [12], it is apparent that a Turkish population presented with a 39 cm cut-point which only coincide with the cut-point for young African men. A higher cut-point (35 cm) has been suggested for Turkish women compared to our cut-points for women except in older Africans. Dixon and O'Brien [10] found that an NC of more than 42 cm in women revealed insulin resistance. As we have not measured insulin resistance, we cannot comment on this cut-point but it should be mentioned that these findings were demonstrated in severely obese subjects. In our study, MetS is present in NC cut-points much lower than Dixon and O'Brien [10] has suggested for women. These different findings demonstrate the importance of developing ethnic, gender and age specific cut-points. It is important though that persons of a more muscular build would have a higher mean NC [36] when compared with more sedentary participants.

A limitation of our sub-study is the cross-sectional design which cannot infer causality and no surrogate markers of insulin resistance has been documented. A follow-up study is in progress and future data dissemination should address other laboratory markers such as increased mean red cell volume in order to better indicate alcohol abuse. The strengths of this study include the inclusion of a unique, representative group of urban black Africans as well as Caucasians within a highly standardized experimental protocol.

To conclude, we carefully propose NC cut-offs for young and older African men at 39 and 35 cm, respectively, whilst African women did not pose risk for MetS with NC cut-points. For Caucasian men, we want to propose cut-points of 40 and 41 cm, and 34 and 33 cm for the Caucasian women. This could be useful in future to more easily identify persons at risk of having MetS especially in impoverished African communities. However, prospective cohort studies are needed in larger sample groups to strengthen our findings and to develop race and ethnic specific cut-points.

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Conflict of interest No conflict of interest.

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