Metabolic syndrome and the risk of consuming street food among commercial taxi drivers in South Africa. a cross-sectional study

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Thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy (Public Health) in the School of Public Health, Faculty of Community and Health Sciences, University of the Western Cape

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Abstract

Background: Minibus taxi drivers in South Africa are eminent street food (SF) consumers with these affordable foods easily accessible at taxi ranks. Regular SF consumption, in combination, with unhealthy lifestyles associated with taxi driving, predisposes them to develop metabolic syndrome (MetS). Detecting the early onset of MetS allows for early intervention, which may slow the progression to various health consequences.

Aims: The primary aim of the thesis was to describe the prevalence, extent, and determinants of MetS among male minibus taxi drivers, 20 years and older operating in the Cape Town metropole who rely on SF for their daily calorie and nutrient intake. A secondary aim was to use these outcomes to develop recommendations for targeted interventions to improve their health status and lifestyle.

Methodology: This study was conducted in three phases. *Phase 1* included the secondary data analysis of the 1st South African National Health and Nutrition Examination Survey (SANHANES-1) to compare the ability of anthropometric indices in predicting diabetes mellitus (DM) risk in South African males in general. Phase 2 and 3 formed part of a cross-sectional study where *Phase 2* reviewed commonly recommended algorithms for MetS measurement with the purpose being to identify the most suitable algorithm for male minibus taxi drivers operating in Cape Town Metropole. *Phase 3* determined the prevalence of MetS among this group of taxi drivers identified relevant social determinants of MetS to suggest potential interventions for combating the syndrome.

Results: The mean age and driving experience of taxi drivers were 40.0 years (SD: 10.7) and 9.1 years (SD: 7.4), respectively. The International Diabetes Federation (IDF) algorithm that considered abdominal obesity (WC > 94 cm) in males; FBG ≥5.5 mmol/L; TGs ≥1.7 mmol/L; HDL-C <1.0 mmol/L in males and SBP ≥130 mmHg or DBP ≥85 mmHg was the suitable algorithm for measuring MetS among this group of taxi drivers. Using this algorithm, 41.6% presented with MetS. Older taxi drivers and those with driving experience of ≥8 years were 3 times more likely to exhibit MetS than their younger counterparts with ≤7 years driving experience. The statistical analysis predicted waist circumference (WC), waist-to-hip ratio (WHR), and waist-to-height ratio (WHtR) as excellent predictors ($p<0.001$) for DM risk among most South African men in general with body mass index (BMI) <30kg/m^2. For those taxi drivers with BMI >30kg/m^2, anthropometrical indices that measured overall body adiposity, such as the body mass index

(BMI), percentage body fat (%BF), and the Clínica Universidad de Navarra-body adiposity estimator (CUN-BAE), predicted MetS risk excellently. Over 43% and 54% of taxi drivers smoked cigarettes and drank alcohol, respectively, with those who consumed SF frequently having 4, 8, 3 and 3 times increased likelihood of MetS, low high-density lipoprotein cholesterol (HDL-C), abnormal triglycerides (TG), and high blood pressure (HBP), respectively. Those taxi drivers who avoided consuming takeaway and fried foods had decreased risks for the afore-metabolic disorders. Consuming canned fish daily and 1–3 times a week reduced the risk of MetS and elevated TG levels while low fresh fruit consumption resulted in low HDL-C.

Conclusions: WC, WHR, WHtR, BMI, %BF, and CUN-BAE predicted the risk of DM and MetS excellently in adult South African men in general and minibus taxi drivers. Most minibus taxi drivers had unhealthy lifestyles, while regular SF consumption was associated with undesirable lipid profiles and elevated blood pressure. All these factors predisposed them to MetS development. These findings have a public health implication that calls for South African policymakers to endorse system-level approaches where taxi drivers' lifestyle changes are motivated within the industry to improve their lifestyle and health risk profile.

Key words

Metabolic syndrome, dietary intake, commercial taxi drivers, hypertension, type 2 diabetes mellitus, obesity, cardiovascular diseases, street food, risk factors, receiver operating characteristic curve, macronutrient intake, fatty acids intake, substitution mode, diet, lifestyle, socio-economic status, South African taxi drivers

Declaration

I declare that the ***Metabolic syndrome and the risk of consuming street food among commercial taxi drivers in South Africa. a cross-sectional study*** is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Full name: Machoene Derrick Sekgala

Signed: 

Date: December 2022

Dedication

To my single parent (Germinah Sekgala), and my late grandmother (Green Makgabo Sekgala)

To my uncle Sello and wife Conny Morudi

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List of abbreviations and acronyms

AACE:	American Association of Clinical Endocrinology Criteria
ABSI:	A body shape index
AHA/NHLBI:	American Heart Association/National Heart, Lung, and Blood Institute
AUC:	Areas under the curve
BMI:	Body mass index
BP:	Blood pressure
BRI:	Body Roundness Index
CHO:	Carbohydrates
Cis:	Confidence intervals
CUN-BAE:	Clínica Universidad de Navarra-body adiposity estimator
CVD:	Cardiovascular disease
EGIR:	European Group for the Study of Insulin Resistance
FBG:	Fasting blood glucose
FFRU:	Functional Foods Research Unit
HbA1c:	Glycosylated haemoglobin
HBP:	High blood pressure
HDL-C:	High-density lipoprotein cholesterol
HSRC:	Human Science Research Council
IDF:	International Diabetes Federation
IFG:	Impaired fasting glucose
IGT:	Impaired glucose tolerance
IPAQ:	International Physical Activity Questionnaire

IR:	Insulin resistance
LDL-C:	Low-Density Lipoprotein Cholesterol
MetS:	Metabolic syndrome
MRC:	South African Medical Research Council
MUFA:	Monounsaturated fatty acids
NCDs:	Non-communicable diseases
NCEP:ATPIII:	National Cholesterol Education Program Adult Treatment Panel III
NHANES:	National Health and Nutrition Examination Survey
OR:	Odds ratio
PA:	Physical activity
PUFA:	Poly-unsaturated fatty acids
ROC:	Receiver operating characteristic
SANHANES-1:	The first South African National Health and Nutrition Examination Survey
SD:	Standard deviation
SF:	Street food
SFA:	Saturated fatty acids
SPSS:	Statistical Package of Social Sciences
SSB:	Sugar-sweetened beverages
TG:	Triglycerides
US:	United States
WC:	Waist circumference
WHO:	World Health Organization
WHR:	Waist-to-hip ratio

WHtR:	Waist-to-height ratio
%BF:	Percentage body fat

Glossary and definitions

Body mass index	the body mass index is calculated using the formula, kg/m², i.e. body weight in kilograms divided by the square of the body height in meters.
Cardiovascular disease	is a group of disorders of the heart and blood vessels.
A confidence interval	is a statistical measure defined as a specified probability that the value of a parameter lies within a range of values.
A cross-sectional study	is an observational study design where the investigator measures the outcome and the exposures in the study participants at a single point in time.
Dietary intake	is the daily eating pattern of an individual, including specific foods and calories consumed in relative quantities.
Fast food	is easily prepared, processed food served at snack bars and restaurants as a quick meal or that can be taken away.
Hypertension	is a condition in which the force of the blood against the artery walls is too high.
Male gender	An adult male human being
Obesity	is a condition involving excessive body fat that increases the risk of health problems.
Occupation	A job or profession
Odds ratio	is a statistical measure of the association between an exposure and an outcome.
Overweight	is body weight above what is considered healthy.
Physical activity	is all movement including during leisure time, for transport to get to and from places, or as part of a person's work (WHO, 2020).
Prevalence	is the proportion of all cases, e.g. of a disease/condition or a specific characteristic in the population at a given time.

Public health	is the science and art of preventing disease, prolonging life and promoting health through the organised efforts and informed choices of society, organisations, public and private, communities and individuals.
Reliability	is the degree to which the result of a measurement, calculation, or specification can be depended on to be accurate.
Risk factor	When a person is at a higher risk of getting an illness or condition, it is due to the existence of particular risk factors or elements linked with that disease or condition.
ROC	the receiver operating curve, is a graph that shows how the diagnostic ability of a binary classifier system changes as the threshold for making a distinction is changed.
Street food	is prepared or cooked food sold by vendors on the street or in other public locations to be consumed immediately.
A taxi driver	is a person whose job is to drive people where they want to go and get paid for it.
An unhealthy diet	is any food that not regarded as being conducive to maintaining health.
Validity	how well the results among the study participants represent true findings among similar individuals outside the study.
Variable	a person, location, thing, or phenomenon that you are endeavoring to measure
Waist circumference	is a measurement taken around the abdomen from the top of the hip bone and at the level of the umbilicus (belly button).
Waist-to-height ratio	is a measure of the distribution of body fat.

A preferences

This thesis is written in publication format. The role of the PhD candidate in the study is outlined below.

The roles of a PhD candidate in the study

The roles of the candidate in the study are explained in the step that were undertaken during the process as follows:

Step I

During the process of this thesis, the candidate designed, developed, and wrote the thesis proposal.

Step II

Phase I

In this phase, national secondary data was explored to respond to objective 1. The candidate sourced the secondary data from the Human Sciences Research Council (HSRC), selected the variables, analysed data, conceptualised the study, and interpreted the results, and wrote chapter 4

Step III

Phase II

In this phase, a taxi driver survey was used to achieve objective 2. The candidate conceptualised the study, collected data, assembled, and cleaned data, did literature searches, conducted data analysis and interpretation and wrote chapter 5

Phase III

This phase involves a taxi driver survey collected among taxi drivers to respond to objective 3 and 4. The candidate conceptualised the study, collected data, assembled and cleaned data, did literature searches, conducted data analysis and interpretation and wrote chapters 6-7.

The candidate received academic guidance, financial support (through article processing fees) and socio-moral support from his two supervisors throughout the study.

Publications

Three manuscripts have been published, while the fourth manuscript is currently under review and has arisen from work reported in this thesis.

The manuscripts are presented in Chapters 4 to 7

1. **Sekgala, M.D.**, Sewpaul, R., Opperman, M. & Mchiza, Z.J. (2022). Comparison of the ability of anthropometric indices to predict the risk of diabetes mellitus in South African Males: SANHANES-1. *Int. J. Environ. Res. Public Health*, 19, 3224. https://doi.org/10.3390/ijerph19063224

2. **Sekgala, M.D.**, Opperman, M., Mpahleni, B. & Mchiza, Z.J.-R. (2022). Anthropometric indices and cut-off points for screening of metabolic syndrome among South African taxi drivers. *Front. Nutr*. 9:974749. doi: 10.3389/fnut.2022.974749

3. **Sekgala, M.D.**, Opperman, M., Mpahleni, B. & Mchiza, Z.J.-R. (2022). Socio-demographic and lifestyle factors and the risk of metabolic syndrome in taxi drivers. A focus on street food. *Front. Nutr.* https://www.frontiersin.org/articles/10.3389/fnut.2023.1112975/full.

4. **Sekgala, M.D**., Opperman, M., Mpahleni, B. & Mchiza, Z.J.R. (2022). Association between macronutrient and fatty acid consumption and metabolic syndrome: A South African taxi driver survey. *Int. J. Environ. Res. Public Health*, *19*(23), 15452. https://www.mdpi.com/1660-4601/19/23/15452

Chapter 1: General introduction

This introductory chapter provides a brief background that positions the research within the larger body of knowledge, establishes the national setting, and introduces the problem statement, research questions, aim, and objectives.

1.1 Background information

The metabolic syndrome (MetS) is a group of interconnected clinical and metabolic risk factors, such as abdominal obesity, dyslipidemia, glucose intolerance, and hypertension, linked to an increased risk of cardiovascular disease (CVD) and type 2 diabetes mellitus (T2DM) (Takata, Fujimoto, 2013; Lopez-Candales et al., 2017). When these metabolic abnormalities co-occur in one person, the risk of morbidity and mortality from CVD and T2DM increases (Eckel et al., 2010; Alberti et al., 2006). Individuals with MetS are three times more likely to have a stroke or heart attack and two times more likely to die because of these events than those without the condition. Furthermore, people with MetS are five times more likely to develop T2DM than people who do not have MetS (Alberti et al., 2006).

Environmental risk factors associated with MetS primarily include health-related behaviours, such as physical inactivity, poor diet, stress, and tobacco use (Eckel et al., 2010). Therefore, knowledge regarding the factors driving the increasing prevalence of MetS in different populations is needed to assist CVD and T2DM prevention efforts.

Worldwide, the prevalence of MetS varies between 8% and 43% in males (Faizal et al., 2016), whereas the risk of T2DM has become more prevalent in both genders worldwide (Khanal et al., 2019). The prevalence of T2DM in South Africa increased over the past two decades from 4.5% in 2010 to 12.7% in 2019 (NDoH, 2019; Shisana et al., 2014; Saeedi et al., 2019). T2DM is becoming increasingly common because of modernization and urbanization, placing a significant strain on health-care systems (Khanal et al., 2019; Khanal et al., 2019). South African researchers have projected that the prevalence of T2DM will steadily increase in the future (Stokes et al., 2017; NDoH, 2019). While these South African studies show that the prevalence of uncontrolled T2DM is higher in females (87.4%), there is concern that if not tightly monitored, the proportion of males who are living with DM may surpass females in future.

The recent predictions based on current statistics suggest that more males than females (66% versus 64%) are pre-diabetic in South Africa (NDoH, 2019). Since the 1980s, it has been recognized that MetS is caused by insulin resistance-linked obesity. Evidence are mostly from international studies, and therefore a need to investigate the power of obesity to predict T2DM, especially among South African males, was identified. In most South African studies, a body mass index (BMI) greater than 24.9 kg/m^2 is regarded as the primary anthropometric contributor associated with the increased prevalence of T2DM (Mphasha et al., 2022). However, BMI does not indicate body fat distribution (Müller et al., 2012). Therefore, other indices associated with body fat distribution, such as waist circumference (WC) and waist-to-hip and waist-to-height ratios (WHR, WHtR), are commonly known as the preferred indicators in predicting the development of T2DM. Body fat distribution is a better indicator for the risk of insulin resistance, where insulin resistance is a precursor to T2DM (Du et al., 2014).

Since 1998, the prevalence of overweight and obesity in men, measured by BMI, increased by only 2% (from 29% to 31%), whereas it was more than 12% in women (NDoH, 2019; Shisana et al., 2014). Despite this relatively low increase, more than ten years ago, Joubert et al. (2007) reported that among 87% of adults >30 years who presented with T2DM, the T2DM could be attributed to a BMI above 21kg/m^2. In most parts of the world, including South Africa, men present with ill-defined CVD outcomes compared to women (Lim et al., 2012; Schneider et al., 2009). This outcome might be attributed to the finding that more men actively smoke (Lim et al., 2012; Schneider et al., 2009), together with higher alcohol consumption among them compared to women. Hence, more ambitious NCD risk detection mechanisms may be required for men.

Substantial evidence exists suggesting that metabolic complications associated with obesity are more closely linked to visceral adiposity than overall body adiposity (Tchernof & Després, 2013). As such, other measurements of visceral adiposity, such as WC, WHR and WHtR, are widely advocated (Zyriax et al., 2011; Tchernof & Després, 2013). Visceral adiposity can promote a cascade of secondary risks for cardiometabolic conditions, such as hypertension, insulin resistance, hyperuricaemia and hyperlipidaemia (Zalesin et al., 2008). Some studies have proposed the individual use of WC, WHR or WHtR to measure the disease risks (Chen et al., 2014; Chen et al., 2015; Lee et al., 2016), whereas others advocate their combined use (Guh et al., 2009; Chiang & Koo, 2012). With the preceding international evidence that implicates adiposity in the development of T2DM, it is imperative to assess the sensitivity and specificity of BMI to predict

DM among South African males and to compare the power of BMI to predict the risk of DM against other indices such as WC, WHR, and WHtR.

MetS in Africans vary from 17% to 25% and considerably across the various diagnostic criteria (Okafor, 2012). Several studies on MetS undertaken in South Africa and Africa used the IDF criterion. In Ukegbu et al. (2011), the prevalence of MetS in African men aged 30–50 years living in the United States (US) was 10%. In rural South Africa, the MetS prevalence in men was 7.9% and 10.5% as described by Motala et al. (2011). Peer et al. (2016) reported a 17.9% MetS prevalence in black men living in Cape Town, while Sekgala et al. (2018) found 8.6% among young black South African men aged 18-30 years in the Limpopo province. In these South African studies, high WC, elevated fasting blood glucose (FBG), and triglycerides (TG) were considered the main risk factors for MetS.

1.2 Rationale

Street food (SF) is food sold in the streets of Cape Town and surrounding areas and is a public health concern since it is energy-dense and high in saturated fat, trans fats, salt, and sugar, according to Mchiza et al. (2014) and Hill et al. (2018). Frequent consumption of such food predisposes individuals to the risk of MetS (Okube et al., 2020). Commercial taxi drivers operating around the transport interchange areas seem to be at risk of MetS since they are among the 38% of South Africans who consume street food (SF) frequently, as these foods are easily accessible and affordable (Hill et al., 2016). Moreover, commercial taxi drivers work long hours and only achieve a few hours of sleep. They are also physically inactive and tend to overconsume alcohol and engage in smoking tobacco to overcome stress, a lifestyle leading to weight gain, which is the common risk factor of MetS (Đinđić et al., 2013). Therefore, it is necessary to investigate the prevalence and extent of MetS among taxi drivers and determine the association between MetS and the risk factors with SF intake.

The proposed research provides the first information of its kind in South Africa to determine the extent of MetS and explain the role played by SF consumption, alcohol consumption, tobacco smoking, and physical inactivity in the development of MetS among commercial taxi drivers. This thesis reports on the outcomes from the proposed study to develop workable recommendations to

aid in the prevention of MetS in this neglected group of South Africans. Furthermore, the current research provided the new algorithm of MetS among male commercial taxi drivers.

1.3 Research questions considered for the thesis

a) What are the best anthropometrical indices to predict DM and MetS in South African males and minibus taxi drivers?

b) What is the prevalence of MetS among commercial taxi drivers operating in the Cape Town metropole?

c) What are the significant determinants and predictors for MetS among commercial taxi drivers operating in the Cape Town metropole?

d) What are the recommendations to prevent and manage MetS among minibus taxi drivers operating in the Cape Town metropole?

1.4 Aims of the study

I. The overall aim of the current study sought to describe the prevalence, extent, and determinants of MetS among 20-year and older male minibus taxi drivers operating in the Cape Town metropole who rely on SF for their daily calorie and nutrient intake.

II. The secondary aim was to use the outcomes of this study to develop recommendations for targeted interventions to improve the health status and lifestyle of these taxi drivers.

1.5 Objectives of the study

I. To explore anthropometrical indices suitable for predicting DM among South African males using existing South African national data sets.

II. To examine the MetS and explore anthropometrical indices that are suitable in predicting MetS among minibus taxi drivers operating in the Cape Town metropole.

III. To investigate the social determinants of MetS in minibus taxi drivers operating in the Cape Town metropole.

IV. To examine the association between macronutrient and fatty acid consumption, and the risk of MetS in minibus taxi drivers operating in the Cape Town metropole.

V. To explore opportunities to improve MetS among minibus taxi drivers operating in the Cape Town metropole areas and make recommendations.

1.6 Outline of the thesis and chapter descriptions

This thesis, written in manuscript format, comprises nine chapters. ***Chapter 1*** introduces the study's research topic and provides the rationale, aim, and objectives. It introduces the key concepts of the MetS risk factors at a larger scale in South Africa and the stance of the research. ***Chapter 2*** provides findings of the literature review on MetS and the consumption of SF together with the conceptual framework used in the current research. ***Chapter 3*** entails the overall methodology and the study setting. ***Chapters 4 to 7*** comprise the manuscripts that describe the three phases conducted to fulfil the mentioned aims and objectives. ***Chapter 8*** outlines the synthesis of the information generated from *Chapters 2, 4 to 7*. ***Chapter 9*** provides the conclusion, limitation and recommendation sections. In Figure 1.1, the interrelation among the study chapters is shown.

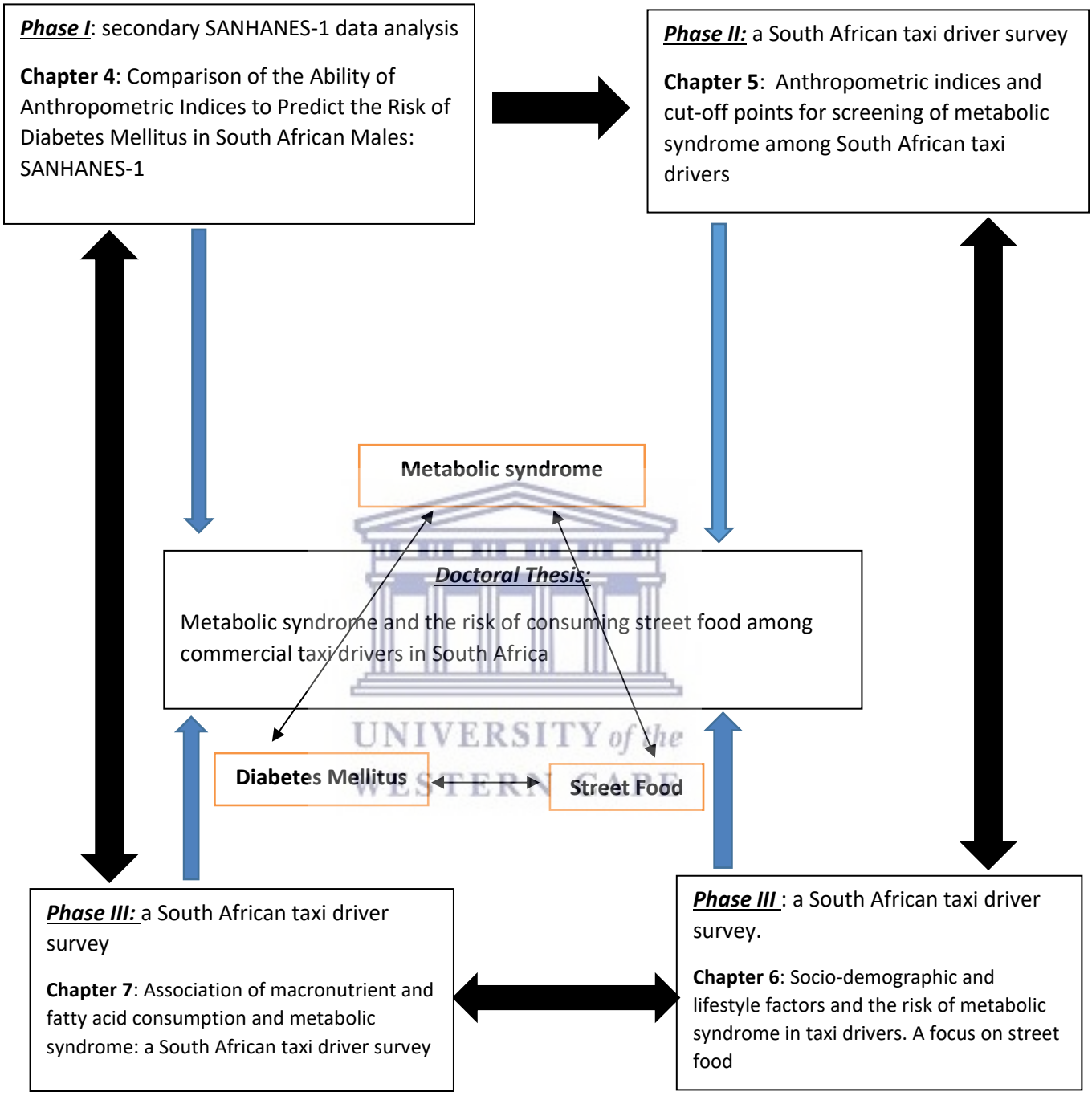

Figure 1.1: Schematic representation of the study depicting the chronological relationships between the study chapters.

Chapter 2: Literature review

This chapter forms the backbone of the current study providing a summary of the prevalence of MetS and DM in the global, African, and national contexts and general lifestyle behaviours, including SF consumption, physical activity, tobacco smoking, and alcohol consumption of taxi drivers. Furthermore, the scope of the problem, criteria for MetS determinants, and the scientific contribution of the study are presented in this chapter.

Chapter 3: Overall methodology

This chapter explains the methodology to achieve the project objectives and includes a discussion on the study setting and design, sampling methods, reliability, and validity of the study instruments.

Chapter 4: Comparison of the ability of anthropometric indices to predict the risk of diabetes mellitus in South African males: SANHANES-1

(*Int. J. Environ. Res. Public Health* 2022, 19, 3224)

In this chapter, we analysed SANHANES-1 (the first South African National Health and Nutrition Examination Survey) secondary data to assess the sensitivity of BMI to predict the risk of DM. Also, to determine whether WC, WHR and WHtR ratios are better predictors of the risk of DM than BMI in South African men aged 20 years and older. Our results suggest that the overall adiposity and abdominal adiposity (indicated by BMI and WC, WHR and WHtR, respectively) play a prominent role in predicting the risk of DM measured by glycosylated haemoglobin (HbA1c) in men. However, not all anthropometric indices have the same performance in predicting the risk for DM.

For instance, indices that consider fat deposition, especially around the waist, such as WC, WHR and WHtR, show excellent performance in predicting DM, with BMI, which is not sensitive to body fat distribution, only offers an acceptable ability to predict DM.

Despite the inferior performance of BMI, our findings show that BMI could still be an acceptable indicator to identify South African men at risk of having DM since there are no significant differences between the performance of BMI and other anthropometrical indices. Our high areas

under the curve (AUC) show that WC, WHR and WHtR could be used independently to predict the risk of DM in South African men.

Chapter 5: Anthropometric indices and cut-off points for screening of metabolic syndrome among South African taxi drivers

(*Front. Nutr*. 9:974749. doi: 10.3389/fnut.2022.974749)

For this chapter, we used primary data from taxi drivers to examine the predictive power of anthropometric indices for MetS. We included BMI, WC, WHtR, a body shape index (ABSI), Body Roundness Index (BRI), percentage body fat (%BF), CI, and CUN-BAE, and the cut-off points to identify male South African taxi drivers with MetS, were determined. The results of this study confirmed the usefulness of BMI, WHtR, %BF, BRI, and CUN-BAE for identifying MetS in male taxi drivers, whereas ABSI was found to be the weakest predictor of the syndrome.

Therefore, the cut-off points proposed in this study showed alternative indices for earlier diagnosis of MetS than the commonly accepted obesity criterion. For people with only one MetS component to be diagnosed, consideration should be given to setting cut-off points for the indicators in question, thereby avoiding a late diagnosis of MetS. These results highlight the usefulness of BMI, WHtR, %BF, BRI, and CUN-BAE for public health purposes, given their potential higher accuracy and low cost for measurement.

Chapter 6: Socio-demographic and lifestyle factors and the risk of metabolic syndrome in taxi drivers. A focus on street food

(Accepted for publication in *Frontiers in Nutrition*)

In this chapter, a cross-sectional study was conducted to investigate the socio-demographic and lifestyle factors predisposing taxi drivers operating around the Cape Town Metropole to MetS development. Overall, their mean age and driving experience was 40.0 years and 9.1 years, with those presenting with MetS being significantly older and having more driving experience than those without MetS. Older participants and those with a driving experience of eight years or more, were 3 and 2.9 times significantly more likely to present with MetS compared to those who were younger and had seven years or less of driving experience.

Most taxi drivers (70%) met the IDF diagnostic criteria for MetS. Smokers (1.96 times), those who spent 100 ZAR (5.90 USD) or more (2.0 times) and those who exercised less than 1.4 MET-minute/week (13.6 times) were significantly more likely to present with MetS compared to their

counterparts who did not smoke, spent less than 100 ZAR (on SF?) and who excercised 1.4 or more MET-minute/week. Consumption of alcohol and sugar-sweetened beverages (SSB), as well as that of take-away and fried foods, snacks and crisps sold by the SF vendors, increased the likelihood of MetS, abnormal HDL-C, TG and hypertension while avoiding takeaway and fried foods decreased this likelihood. Those taxi drivers who also avoided consuming fresh fruits displayed lower HDL-C levels, while those who consumed canned fish daily and 1 to 3 times a week had a reduced likelihood of MetS and TG.

Chapter 7: Association of macronutrient and fatty acid consumption and metabolic syndrome: a South African taxi driver survey

(*Int. J. Environ. Res. Public Health*, *19*(23), 15452)

Dietary variables receive the most attention among modifiable lifestyle factors of non-communicable diseases (NCDs). As a result, it has been demonstrated that comprehensive lifestyle intervention can improve all aspects of MetS. Multivariable nutrient density substitution models were applied to investigate the association between macronutrient and fatty acid intake with MetS and its components in South African male taxi drivers. In short, the presence of MetS was entered as the dependent variable in the logistic regression models, while linear regression was used to analyse the continuous variables. All models were adjusted for total energy intake to allow studying the effects of dietary composition. In each model, one macronutrient was included as a variable of interest, while another was excluded. Then all the other macronutrients were included as cofactors. Results indicated that that when one or more macronutrients were added to or removed from the model, an increase or decrease, respectively, occured in the outcome variable, to account for the iso-energetic substitution of those nutrients.

In the present study, it was indicated that South African male taxi drivers, who operated in the urban areas and consumde a total dietary energy above the recommended dietary allowances were at risk of MetS. In an iso-energetic state, the taxi drivers' diets were high in protein, carbohydrates (CHO) and poly-unsaturated fatty acids (PUFA) reduced TG and blood pressure (BP), respectively. Whereas when their diets were high in total fat and saturated fatty acids (SFA), the opposite effects were observed with an added disadvantage of elevated FBG. However, it should be noted that these outcomes were produced using mathematical models. Therefore, we

recommend further prospective studies in real-life situations that will reveal the actual associations between consuming macronutrients and fatty acids with MetS and its components.

Chapter 8: The discussion and synthesis of the thesis outcome from chapters 4 to 7

In this chapter, a final summary of the results of this thesis is presented and integrated. The results are discussed regarding what is known about the area of study and what this thesis could add to the body of literature.

Chapter 9: Conclusions, limitations, and the recommendations

In this chapter, the conclusion of the overall thesis is presented, followed by the limitations that were not covered in the individual publications. At the end of this chapter, there are some recommendations for future research, policies, and interventions at an individual level.

1.7 References

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Chapter 2: Literature review and the conceptual framework

This chapter draws on existing literature surrounding the risk factors of MetS, which will encompass the socio-economic and lifestyle risk factors along with the SF consumption patterns among the South African population.

2.1 Socio-economic status? and lifestyle of commercial taxi drivers

Worldwide, taxi drivers play a vital part in the socio-economic functioning of communities by transporting commuters working in various sectors e.g. business, tourism, and commerce. Drivers are vulnerable to various health problems, including work stress, irregular and long working hours, shift work, poor posture, poor eating patterns, and lack of relaxation and sleep as a direct result of the occupational environment (Lim & Chia, 2015). Consequently, to reduce or minimise stress, some commercial drivers resort to using psychoactive drugs such as alcohol and cigarettes (Makanjuola et al., 2014). Hence a study by Ding et al. (2014) suggested that taxi driving increases the odds of smoking, physical inactivity, short sleep duration, and obesity, along with poor? physical and mental health. Most of these risk factors are modifiable at an individual level through habit and lifestyle change (Mendis et al., 2011; Lalor, 2012). However, Afanuh et al. (2015) argue that the most effective way of improving the health risk profile of individuals is through a system-level approach, where individuals' lifestyle changes are motivated within the workplace or the community.

2.2 Scope of the problem

According to the National Health and Nutrition Examination Survey (NHANES) conducted between 1999 and 2006, the prevalence of MetS increased from 29.2 to 34.2% in the US (Mozumdar & Liguori, 2011). The increased prevalence of MetS was initially attributed to increased abdominal obesity and high BP (HBP). From the mentioned survey, it can be assumed that an increase in MetS prevalence is expected to be followed by an increase in diabetes prevalence; however, in a smaller magnitude. Therefore, the persistent increase of MetS is a critical public health concern as it raises the likelihood of an increased prevalence of T2DM (Mozumdar & Liguori, 2011).

In the last two decades, the subject of MetS has received much attention in Africa because of increasing awareness of its association with CVD-related deaths (Kruger, 2011; Bruno et al., 2004; Isezuo & Ezunu, 2005). In the past, infectious diseases accounted for the majority of the disease burden among Africans. However, new reports indicate that Africa is undergoing an epidemiological transition characterized by an increase in cardiovascular illnesses, resulting in a twofold disease burden on the continent (Okafor, 2012). The confluence of undernutrition and obesity or diet-related, chronic NCDs constitutes a double burden. The association between MetS and diabetes is supported by the fact that the prevalence of MetS is much higher in diabetic patients than in healthy people (Ogbera, 2010).

The prevalence of MetS is on the rise in South Africa (Motala et al., 2011; Erasmus et al., 2012). Patients with MetS components have a higher risk of CVD and T2DM, whereas obesity, particularly abdominal obesity, contributes to the development of MetS and subsequently increases the risk of morbidity and mortality (Erasmus et al., 2012). In previous research, taxi drivers in South Africa were found to have a high prevalence of T2DM (16%) (FBG ≥100 mg/dl) (Adedokun et al., 2019), hypertension (57.0%) (Adedokun et al., 2017), obesity (24.5–75.5%), and abdominal obesity (29–71%) (Ramukumba & Mathikhi, 2016). These cardiometabolic risk factors diminish life quality while the health-care system remains overburdened.

2.3 Criteria for determining the MetS

The prevalence of the MetS varies according to population. The different algorithms used to predict MetS are presented in **Table 2.1**. These include the World Health Organization (WHO) (Alberti et al., 1998), the European Group for the Study of Insulin Resistance (EGIR) (Balkau & Charles, 1999), the National Cholesterol Education Program Adult Treatment Panel III (NCEPATP, 2001), the American Association of Clinical Endocrinology (AACE) (Einhorn et al., 2003), the IDF (Alberti et al., 2005), and American Heart Association/National Heart, Lung, and Blood Institute (AHA/NHLBI) (Grundy et al., 2004). These algorithms are based on the risk factors considered clinically realistic assessment measures for MetS among the specific populations under study. Researchers prefer to use anthropometrical measures showing adipose tissue distribution and differentiate central or abdominal obesity when classifying MetS (Cheong et al., 2015; Matsha et al., 2019).

Table 2.1: Criteria for the diagnosis of MetS

WHO, 1998. (Alberti *at al*., 1998)	EGIR (1999) (Balkau & Charles, 1999)	NCEP: ATPIII, 2001 (NCEP, 2001)	AACE, 2003 (Einhorn *et al*., 2003)	IDF (2005) (Alberti *et al*., 2005)	AHA/NHLBI, 2004 (Grundy *et al*., 2004)
Insulin resistance is defined as T2DM or (IFG) (>100 mg/dl) or (IGT), plus two of the following are present:	Insulin resistance is defined as insulin levels >75th percentile of non-diabetic patients, plus two of the following are present:	MetS is diagnosed if any three of the following are present:	MetS is diagnosed if IGT plus two or more of the following are present:	MetS is diagnosed if central obesity (defined as WC but can be assumed if BMI >30 kg/m^2) with ethnicity-specific values, WC must be of Europeans, >94 cm in males and >80 cm in females plus two of the following are present:	MetS is diagnosed if any three of the following are present:
Abdominal obesity (BMI) >30 kg/m^2	WC ≥94 cm in males, ≥80 cm in females.	WC >102 cm in males, >88 cm in females.	BMI ≥25 kg/m^2	TG ≥150 mg/dl.	WC ≥102 cm in males, ≥88 cm in females.
TG ≥150 mg/dl HDL-C <40 mg/dl in males and <50 mg/dl in females.	TG ≥150 mg/dl, HDL-C <39 mg/dl in males or females.	TG ≥150 mg/dl.	TG ≥150 mg/dl, HDL-C <40 mg/dl in males and <50 mg/dl in females.	HDL-C <40 mg/dl in males and <50 mg/dl in females.	TG ≥150 mg/dl.
BP ≥140/90 mmHg.	BP ≥140/90 mmHg or taking antihypertensive drugs.	HDL-C <40 mg/dl in males and <50 mg/dl in females.	BP ≥130/85 mmHg.	BP ≥130/85 mmHg.	HDL-C <40 mg/dl in males and <50 mg/dl in females.
Microalbuminuria (urinary albumin secretion rate >20 μg/min or albumin-to-creatinine ratio >30 mg/g	Fasting glucose >110 mg/dl.	BP ≥130/85 mmHg.	.	Fasting glucose ≥100 mg/dl.	BP ≥130/85 mmHg.
		Fasting glucose ≥110 mg/dl.			

WHO, World Health Organization; EGIR, European Group for the Study of Insulin Resistance; NCEP: ATPIII, National Cholesterol Education Program Adult Treatment Panel III; AACE, American Association of Clinical Endocrinology criteria; IDF, International Diabetes Federation; AHA/NHLBI, American Heart Association/National Heart, Lung, and Blood Institute; T2DM, type 2 diabetes mellitus; IFG, impaired fasting glucose; IGT, impaired glucose tolerance; MetS, metabolic syndrome; WC, waist circumference; BMI, body mass index; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; BP, blood pressure.

There is limited data on the central obesity status of South African male taxi drivers, despite the substantiated international evidence presented by Saberi et al. (2011) and Hirata et al. (2012) that suggest that 50% of male occupational drivers display significantly higher depositions of visceral adipose tissue than the general male population. Even though multiple articles on the link between adiposity and the risk of MetS have been published, it is still difficult to determine unambiguously the best measure to be applied in an algorithm to identify individuals with MetS, especially in the South African male population. Therefore, it is essential to assess the ability of different anthropometric indices to detect MetS and determine their cut-off points to screen for MetS among male taxi drivers.

2.4 Receiver operating characteristics curve (ROC AUC)

The Receiver operating characteristics (ROC) curve is a depiction of the test's true-positive rate vs its false-positive rate, or sensitivity versus 1-specificity. The various points on the curve represent the different cut off points used to decide if the test results are positive. A ROC curve can be thought of as the average value of a test's sensitivity, overall potential specificity values, or vice versa. Given the test results, a more general interpretation is that the probability that a randomly chosen pair of patients with and without the disease/condition, or the patient with the disease/condition, will have a result indicating greater suspicion proportional to the test results. (Hanley & McNeil, 1982; Boyer et a., 2013).

In the early phases of evaluating a novel diagnostic test, an overall ROC curve is most beneficial. Once the diagnostic capacity of a test has been determined, often just a subset of the ROC curve is of interest, for instance, only regions with high specificity and not the average specificity over all sensitivity levels. Like sensitivity and specificity, ROC curves are independent of an illness's prevalence but depending on patient characteristics and disease spectrum. A ROC curve is independent of the scale of the test results and can be used to visually compare two or more test results on the same scale. This is not conceivable with sensitivity and specificity measures, as a change in the cut point used to designate test findings as positive or negative could have distinct effects on the two tests (Turner, 1978).

Area under the curve (AUC) is an efficient approach to summarize the diagnostic accuracy of a test as a whole. It accepts values between 0 and 1, where 0 denotes a perfectly inaccurate test and

1 suggests a perfectly accurate test. In general, an AUC of 0.5 indicates no discrimination (i.e., the inability to distinguish between patients with and without the disease or condition based on the test), 0.7 to 0.8 is regarded as acceptable, 0.8 to 0.9 as excellent, and greater than 0.9 as remarkable (Zhou et al., 2009; Jiménez-Valverde, 2012). There are some disadvantages highlighted in Halligan et al (2015), aimed to describe the disadvantages of the area under the ROC AUC to measure diagnostic test performance. Authors noted the following: The ROC AUC measures diagnostic accuracy, Confidence scores used to build ROC curves may be difficult to assign, False-positive and false-negative diagnoses have different misclassification costs and Excessive ROC curve extrapolation is undesirable.

2.5 Dietary intake and the risk of MetS

The prevalence of MetS is known to be rising in low middle-income countries because of increased physical inactivity, consumption of energy-dense foods, increased use of alcohol and high levels of obesity (Dalal et al., 2011). This increase is reflected in the rising rates of NCDs in sub-Saharan Africa. The estimated prevalence of MetS in the general population ranges between 17% and 25%. However, in subjects with pre-existing cardiovascular risk factors, such as hypertension or diabetes, the prevalence rises (Longo-Mbenza et al., 2011), as demonstrated in Caucasians with T2DM, where the MetS prevalence was 75.6% (Tran et al., 2011).

Several international epidemiological studies found the prevalence of metabolic diseases to be high among occupational drivers compared to other professionals such as industrial and office workers (Chen et al., 2010; Đinđić et al., 2013, Gany et al., 2013). For example, most professional drivers are at excessive risk of hypertension (Lakshman et al., 2014), myocardial infarction, and haemorrhagic stroke (Shin et al., 2013; Inamasu et al., 2018).

Furthermore, most drivers are in the habit of consuming fried foods and snacks that are sold by street vendors during working hours. On the other hand, many taxi drivers resort to alcohol and smoking to overcome stress (Useche et al., 2017). Therefore, they may have an additional risk of developing metabolic diseases. According to Poó et al. (2018), the working environment of commercial taxi drivers is characterized by bad eating habits, continuous tension caused by driving and exposure to various environmental hazards such as air pollution (Baba et al., 2020), as well a lack of exercise (Turner & Reed, 2011). In South Africa, taxi drivers and commuters are eminent

consumers of SF since it is relatively cheap and easily accessible at taxi ranks and bus stations (Hill et al., 2016; Steyn et al., 2014).

Adaption of unhealthy eating behaviour such as overconsumption of sweets, biscuits, snacks, and SSB, as well as refined carbohydrates, added sugar, saturated fat, and trans-fat, may lead to abdominal obesity (Zulet et al., 2017). Abdominal obesity is the most common cause of insulin resistance (McLaughlin et al., 2011), which is also associated with dyslipidaemia (Franssen et al., 2011), T2DM (Van Greevenbroek et al., 2013), and long-term vascular complications (Carlsson et al., 2017) which are all components of the MetS. Therefore, lifestyle modification intervention that includes targeting diet is instrumental and necessary for reducing abdominal fat and the prevalence of MetS (Ebrahimof & Mirmiran, 2013).

To our knowledge, no research has been dedicated to investigating SF intake among commercial taxi drivers in South Africa, particularly concerning the risk of MetS. Although most commercial taxi drivers suffer from other occupation-related diseases, MetS may be one of the leading conditions that need closer attention. A high prevalence of unhealthy food intake, physical inactivity, excessive alcohol use, cigarette smoking and other substance abuse is found among the general South African male population (Peer et al., 2013; Owolabi et al., 2017). Hence, there is no reason to believe that the mentioned behaviour will be different among taxi drivers.

2.6 The risk factors associated with MetS among taxi drivers

Metabolic syndrome is a global public health issue associated with a cluster of risk factors co-existing in an individual (Kaur, 2014; Eckel et al., 2010). These risk factors can be manageable (modifiable) and unmanageable (nonmodifiable).

2.6.1 Modifiable risk factors of MetS

a) Increased waist circumference

The prevalence of high WC was reported among vehicle drivers compared to non-drivers (Zahedi et al., 2015). Other similar studies (Hirata et al., 2012; Saberi et al., 2011) also showed that 50% of the Brazian male drivers had a WC higher than normal (WC > 102 cm). Overconsumption of specific foods, especially food high in carbohydrates, saturated fats, salt, sugar, and SSB, and a sedentary lifestyle (Sekgala et al., 2022 (Chapter 6)) and lack of awareness were significant determinants for abdominal obesity among taxi drivers. Consequently, researching the prevalence

of cardiovascular risk factors among various social groups, especially high-risk groups, is one of the primary and predominant steps for the health systems of all nations. (Alberti et al., 2009).

b) Lipid profile

Cholesterol can be described as a fat-like substance found in the bloodstream, the body organs and nerve fibres (Santos-Gallego et al., 2014). There are two types of cholesterol namely low-density lipoprotein cholesterol (LDL-C) and HDL-C. The LDL-C is referred to as 'bad' because it is a protein that carries cholesterol but deposits it on the walls of the arteries (Santos-Gallego et al., 2014). The HDL-C, in contrast, is considered 'good' because it is a protein bound firmly onto the cholesterol and carries it through the bloodstream without allowing it attach to the arterial walls (Santos-Gallego et al., 2014). Triglycerides are lipid fractions mainly used for energy storage. Elevated blood TG levels are an independent risk factor for CVC.. A study among 429 bus and truck drivers in Kashan, a city in Iran by Saberi et al. (2011) reported that 35.4%, 53.4%, and 48.7% drivers had elevated total cholesterol, high TG, and low HDL-C, respectively compared to those of general male population. Additionally, Casmir et al. (2018) indicated a 56.3% prevalence of dyslipidaemia among professional male long-distance bus drivers in Lagos, South-West Nigeria. Therefore, the coexistence of these fat components contributes to the development of MetS among drivers.

c) Fasting blood glucose and insulin resistance

Elevated FBG can be described as a state of higher-than-average fasting glucose concentration frequently caused by insulin resistance (Zhou et al., 2022). Insulin resistance inhibits the ability of the cells to transport glucose from the bloodstream to the muscle tissue, adipose tissue, and liver cells (Zhou et al., 2022). Association between elevated FBG, insulin resistance and T2DM? + Reference. The prevalence of T2DM in taxi drivers investigated by Saberi et al. (2011) and Marcinkiewicz and Szosland (2010) were 7% and 3.5%, respectively. These prevalences were lower than the 22.2% reported by Feli 2018. These findings may, to some extent, be attributed to the correlation between T2DM and individuals' social duties (driving experience) and psychological reasons (sleeping duration). The studies mentioned above by Saberi et al. (2011) and Marcinkiewicz and Szosland (2010) have examined bus or truck drivers, while Feli (2018) focused on taxi drivers. Therefore, differences in work-related conditions, such as driving duration

and shift working hours, can justify differences in the prevalence of T2DM among taxi drivers (Virtanen and Kivimäki, 2018; Lunde et al., 2020).

d) High blood pressure

Blood pressure is the force exerted by the blood against by the body's blood vessels (Nobrega et al., 2014). The prevalence of hypertension and other coronary heart diseases was high among taxi drivers who were employed for at least four years (Nasri & Moazenzadeh, 2010; Saberi et al., 2011). The prevalence of HBP among transport drivers was reported to be 36.9% and 35.8% in Mazandaran (Saberi et al., 2011) and Yazd (Feli, 2018), respectively. Taxi drivers are exposed to unhealthy working environments, which include inadequate physical activity and stress leading to elevated levels of BP (Elshatarat & Burgel, 2016). Consequently, the identification of these individuals' risk factors is crucial for the prevention of CVD.

e) Physical inactivity

According to the literature, lifestyle-related diseases are customary among professional drivers (Czerwińska et al., 2016; Wong et al., 2012). Some of the lifestyle habits adopted by these drivers are tobacco smoking, and overconsumption of stimulants such as coffee, energy drinks, SSB, and alcohol (Ramukumba, & Mathikhi, 2016). Sedentary behaviour is defined as 'any waking behaviour characterized by an energy expenditure ≤1.5 (metabolic equivalent) METs while in a sitting or reclining posture' (Bames et al., 2012), which is common among working adults, especially those in driving industries (Varela-Mato et al., 2016). The study by Varela-Mato et al. (2017) demonstrated a high prevalence of sedentary lifestyles and physical inactivity among lorry drivers. A greater prevalence of smoking, inactivity, and bad eating habits has been demonstrated in studies on taxi drivers (Chan et al., 2019; Murray et al., 2019). These have been shown as independent risk factors for an increased likelihood of Mets. While South African occupational/commercial drivers do not receive regular health assessments (Ramukumba & Mathikhi, 2016) to detect the risk factors for MetS and other CVDs, they may be equally at risk of developing these diseases.

f) Dietary intake

Professional drivers have a high prevalence of overweight, obesity, inactivity, and bad eating practices (Varela-Mato et al., 2017). This behaviour may be because the working conditions of

professional drivers make it difficult to adopt healthy lifestyles and make healthy food choices (Bschaden et al., 2019). This evidence supports that of commercial drivers who are susceptible to lifestyle-related MetS risk factors. Because of the nature of their profession, they tend to rise early, work long hours, and have irregular dietary habits (Siu et al., 2012). McCullagh (2005) reported low levels of fruit and vegetable intake and physical activity, followed by high levels of smoking and obesity among occupational drivers, in conjunction with high fat and total calorie consumption (Jacobson et al., 2007). As a result of frequent breaks and long hours on the road, drivers often eat snacks or meals while driving or at taxi stops, which limits their food options. Asif et al. (2018) showed similar results in that daily food intake of professional drivers was associated with central obesity, a vital component of MetS. No similar studies on SF intake regarding MetS have been undertaken on drivers in South Africa.

g) Tobacco smoking and alcohol abuse

Many psychotropic drugs (including tobacco and alcohol) have been associated with various detrimental outcomes in the driving industry (Carrell et al., 2011). These outcomes include health complications, interpersonal problems, and a reduction in driving ability (Drummer et al., 2004; Sobngwi-Tambekou et al., 2016). Useche et al. (2017) reported a prevalence of 20.3% tobacco smoking and 27.9% alcohol drinking among professional drivers. Similarly, alcohol overconsumption and substance use of about 18% and 24% have been reported among drivers in Colombia (Buitrago Cubidesal et al., 2015). These habits have also been reported among commercial taxi drivers in South Africa (Ramukumba & Mathikhi, 2016). Although the aetiology of MetS is still debated, smoking has been identified as a significant modifiable risk factor for MetS (Wang et al., 2022). Tobacco use is linked to lipid abnormalities, endothelial dysfunction, and a prothrombotic state (Slagter et al., 2013; Golbidi et al., 2020), all of which are MetS components.

h) Sleep duration

There is a general association between sleeping duration and the risk of MetS (Shayestefar et al., 2019) reported among transport drivers. A study among truck drivers reported frequent sleep disturbances, back discomfort, and other physical health concerns (Guglielmi et al., 2018; Garbarino et al., 2018). MetS was prevalent and severe among long-distance truck drivers. Additionally, driving experience and workday sleep quality were also associated with MetS

prevalence (Lemke et al., 2017). Not only does sleeping duration affect MetS, but 49 (15.3%) of the 320 public drivers in a study by Özer et al. (2014) reported that they had at least one sleep-related motor vehicle accident or near-missed accident during occupational hours. The hours of driving have both short- and long-term consequences on the health of professional drivers, including weariness and acute or chronic sleep deprivation (Hege et al., 2015). Research by Jean-Louis et al. (2014) also revealed that persons who did not get enough sleep had a 20% higher likelihood of being overweight and a 57% greater likelihood of being obese. Obesity and MetS are highly related to obstructive sleep apnea (Malhotra & White, 2002), a significant cause of excessive daytime sleepiness among drivers and a critical public health problem (Ward et al., 2013).

2.6.2 Non-modifiable risk factors of MetS

a) Age and Gender

Traditionally, ageing has been regarded as a natural process determining the development of NCDs (Donmez & Guarente, 2010). Tobin et al. (2013) assessed the prevalence of elevated BP among long-distance drivers in Nigeria and demonstrated that age was significantly associated with increased hypertension. Therefore, considering age as a critical risk factor for MetS is important, not only for the health and safety of the drivers but also for their commuters. Metabolic syndrome is a complex condition with different components that change with age and gender, which could be important for understanding the link between MetS and mortality risk. It has been reported that each risk factor for MetS is different across gender (Ford et al., 2002; Ervin, 2009). Thus, it means that males and females may have diverse MetS risk factor combinations. Substantiated evidence suggests biological and behavioural differences between males and females predispose these genders differently to a wide range of diseases (Regitz-Zagrosek, 2012). Until now, it is not evident whether these differences remain the same over the course of a person's life or if the different MetS combinations affect the mortality risk correspondingly among younger and older males and females.

Ageing is linked to chronic diseases, disability, and dependence, leading to higher health-care costs and other economic effects. Also, the syndrome is more common as people age. Less than 10% of people in their 20s have MetS, but 40% of people in their 60s have the syndrome.

b) Race and ethnicity

Different diseases tend to be more prevalent in certain ethnic groups (Mathur et al., 2011). For instance, while the Asian and mixed ancestry populations have a higher prevalence of MetS than the Caucasian population (Krishnadath et al., 2016), black South Africans and females are at an increased risk of developing T2DM (Peer et al., 2016); Sekgala et al., 2018); Shisana et al., 2015). Peer et al. (2016) also have shown that more than 17% of black males in the Western Cape presented with MetS. MetS is more common in some racial or ethnic groups than in others. Hispanics, Amerindians, and people of Indian descent have been found to have higher rates of MetS, while In Whites, black Africans, and Chinese have been found to have lower MetS (Krishnadath et al., 2016). It has been shown that the racial and ethnic makeup of a population affects the differences in MetS prevalence between men and women. One study (Liaw et al., 2016) found that MetS was more common in non-Hispanic whites than blacks, while others found that Hispanics are more likely to get MetS than non-Hispanic whites. Multiple research point to genetic differences, environmental variables, and socioeconomic status as potential causes of racial and ethnic disparities in CVD and MetS (Nazroo & Genetic, 1998; McKeigue, 1997).

c) Predominant abdominal obesity in the MetS

Abdominal obesity appears to be the most prevalent of the five clinical risk factors used as diagnostic criteria for MetS (Grundy, 2016). The pathophysiology of abdominal obesity in developing insulin resistance and the MetS is described in detail by McCracken et al. (2018). Irrespective of other fat deposits, abdominal obesity is a significant risk factor for systemic inflammation, hyperlipidaemia, and CVDs (Bastien et al., 2014). Evidence suggests that changes in body composition, namely abdominal fat reduction, are more important in treating MetS (Paley & Johnson, 2018).

2.7 Scientific contribution of this PhD

Growing evidence exists suggesting commercial taxi drivers are exposed to stressful environments, impacting their health and quality of life (Yang et al., 2014; Lim & Chia, 2015). These drivers are less likely to use health facilities (Ramukumba & Mathikhi, 2016), although they have a right to regular health surveillance to ensure their optimum health and safety. Despite the relevance of the taxi business in the country's economy, studies on the health status of commercial

taxi drivers are limited in South Africa. The lack of evidence of health information on commercial taxi drivers makes it difficult to plan for health and wellness interventions.

Commercial taxi drivers contribute to MetS prevalence because of their stressful working conditions, sedentary lifestyle, and exposure to less healthy SF (Saberi et al., 2011; Mchiza et al., 2014; Hill et al., 2016). Moreover, their remuneration statuses make it problematic to secure decent foodstuffs and engage in health behaviours such as recreational physical activities when off duty (Murray et al., 2019; Mmadi, 2012). As such, they tend to be obese and suffer from heart diseases and T2DM, which are all preventable. If successful, the outcome of this study will bridge the gap in the literature regarding the health status of commercial taxi drivers operating in the streets the Cape Town metropole. This information will be beneficial in informing the interventions required to prevent and treat MetS and its risk factors among commercial taxi drivers. These interventions will benefit commercial taxi drivers and help improve the health of other long-duration drivers.

2.8 Theoretical framework for the thesis

For the current study, the socio-ecological model (SEM) on the environmental influence of taxi drivers' SF intake and MetS will be applied (Townsend and Foster, 2011) (**Figure 2.1**). Workplaces are well-known settings to influence dietary intake, given the amount of time workers spend at work, and offer a suitable venue for reaching many workers to provide ongoing education as well as healthy food options. Furthermore, changes to the foods available at work, and consideration of other work-related factors associated with workers' dietary patterns support via the workplace could be possible for long-term behaviour changes (Story et al., 2008; Sparling, 2010).

Some evidence supports the effectiveness of these workplace approaches in promoting healthy diets (Matson-Koffman et al., 2005; Pelletier, 2009; Benedict & Arterburn, 2008). Pertaining taxi drivers transport, interchanges (workplace) are prominent sources for promoting healthy nutrition. Due to the variety of food and beverage supplies at the taxi rank stations, this setting is considered as a highly complex culinary environment (Hill, 2016).

According to the SEM's basic assumptions, individual health and health behaviour patterns are related to the environment, and health cannot be described without an awareness of the environment in which individuals exist. If effective health change is desired, the individual's context must be considered (Davison & Birch, 2001; Richard et al., 2011).

Basically, the socio-ecological perspective broadly looks at the factors influencing what taxi drivers eat at taxi rank stations and their overall health. The smallest or centre sphere symbolizes the individual or taxi driver level, then progresses outward to embrace a greater, more complicated variety of influences and factors within and around taxi ranks stations. The development and application of the SEM to promote healthy eating at the workplace by investigating the influence on dietary choices workers make at workplaces was originally developed by Townsend & Foster (2011). Their concept consists of six levels of impact, including *demographic, intrapersonal, interpersonal, organizational, community, and macro-level organization*. With adjustments, their model served as the foundation for this study.

In this study, the model contains four ecological layers of influence – including individual factors (e.g., demographics, behaviours, cognitions), social environment (e.g. family, co-workers, friends), physical and organizational environment settings (e.g. workplace), and macro-level environments (e.g. societal values, food marketing) (Story et al., 2008).

Descriptions of each layer of influence

Individual factors – At the first level of influence, taxi drivers are placed in the innermost sphere, surrounded by the several levels of influence at a taxi rank station setting (Townsend & Foster, 2011). Researchers have found that lifestyle (diet, physical activity), sociodemography (age, gender, and self-efficacy), and food preference are individual factors that are positively associated with SF intake (AlGhanim & Alkazemi, 2020).

Social environment – The second level of influence immediately surrounds the taxi drivers and often includes peers, family members and co-workers at the taxi ranks stations (Townsend & Foster, 2011). An important attribute of this level of influence is the role of social relationships as a type of influence on behaviour (McLeroy et al., 1988). At the taxi rank station environment setting, peer influences can have a crucial bearing on the choices of the types of SF and beverages consumed. Studies have documented that family, co-workers, friends, peers and role models can be factors related to the environment that correlate with SF consumption (Adzovie & Jibril, 2020; Higgs & Ruddock, 2020).

Physical and organizational environment settings –The taxi rank station has a direct and indirect effect on the availability of nutritious foods (Suarez-Balcazar et al., 2007). Workplace including

the nature of work, neighbourhoods, and community resources are correlated to the SF intake (Boone-Heinonen et al., 2011; Diez Roux & Mair, 2010).

Macro-level environments – The agencies and institutions in the outermost circle are responsible for developing and implementing regulatory policies. This is a policy domain that refers to the legislation or policy-making actions that have the potential to affect the SF consumption in the population (Townsend & Foster, 2011). It could include, for example, a policy to reduce salt and saturated fats and increase fruit and vegetable intake at the transport interchange (Khatun, 2019).

This study will use the SEM in the context of taxi rank stations. Using the SEM in a taxi rank station setting will aid in understanding the various levels of influence over the SF and nutrition environment.

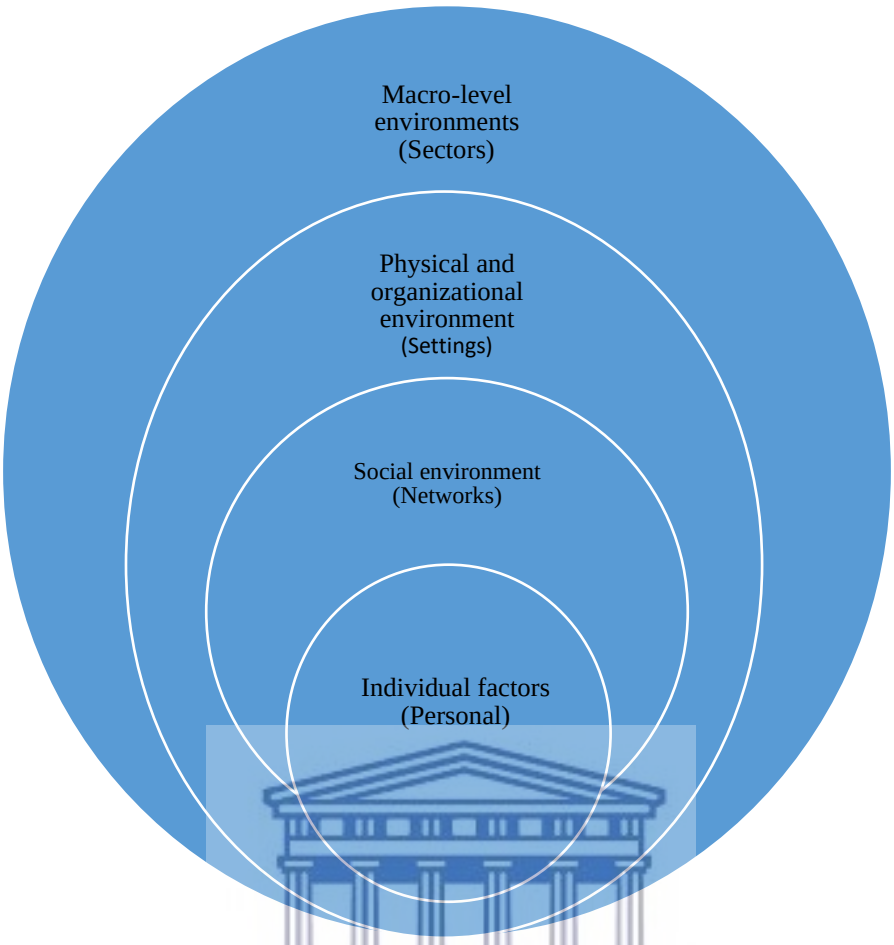

Figure 2.1: Socio-ecological model of 4 domains for health promotion

An adapted version of the SEM (Townsend & Foster, 2011).

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Chapter 3: Overall methodology

3.1 Introduction

The methodology to achieve the project objectives is explained in this section, which includes a discussion on the study setting and design, sampling methods, reliability, and validity of the study instruments. A comprehensive description of the research settings applied in the study is also provided. Furthermore, a concise description of the setting is defined in each manuscript, while the study design and methods of data collection are highlighted in subsequent chapters. Additional details of the study design, sample size calculation, sampling and data collection procedures, data analysis, study permit, ethics statements and confidentiality are described in the subsequent chapters.

3.2 Study design and procedures

This study formed phase five of a bigger project which aimed to develop a business model to promote healthy and safer SF in Cape Town and its suburbs (Hill et al., 2016). The current study was a descriptive, cross-sectional study focussing on commercial taxi drivers who regularly (three days or more per week) consumed SF. The study employed quantitative techniques and instruments used for data collection.

Details of the procedures used in performing the statistical analysis are outlined for each investigation in the respective chapters (i.e., Chapters 4 to 7).

To summarise, at baseline, questionnaires were administered to collect data on socio-demographic and lifestyle factors such as physical activity, cigarette smoking, alcohol consumption, and dietary intake. The anthropometry measurements, laboratory analysis, and techniques were conducted in phases 1–3. *Phase 1 (Chapter 4)* included the secondary SANHANES-1 data analysis to conduct a test to compare the ability of anthropometric indices to predict the risk of diabetes mellitus in South African males. One of the primary aims of SANHANES was to provide information beneficial for studying the relationship between diet, nutritional status, and health of the South African population. *Phase 2 (Chapter 5)* included performing similar analyses to identify a suitable algorithm to identify those presenting with MetS among a group of male minibus taxi drivers who operated in the Cape Town Metropole area. *Phase 3 (Chapters 6 and 7)* included determining the prevalence and extent of MetS among this group of minibus taxi drivers using selected IDF MetS

criteria and identifying the essential social determinants of MetS among this group to identify interventions for action in curbing the syndrome among them.

3.3 Study setting and sample

For this study, we applied convenience sampling to target most of the taxi drivers operating in the busiest transport interchange areas (i.e., Cape Town and Bellville taxi ranks) previously shown to have many SF vendors operating (Hill et al., 2016). All taxi drivers were invited to attend the briefing meeting about the study. The aims, objectives and the procedures that were included in the proposed study, was explained in simple language. Those taxi drivers who indicated their willingness to participate in the study were then asked to attend an information session, where all objectives and procedures of the trial were explained in detail and provided in writing. All questions that the participants had were addressed by the research team at the meeting.

Before data collection, an information sheet was presented to the taxi drivers and explained in the language of their choice (either English or IsiXhosa). They were also informed that their blood samples will only be used for the measurements indicated in the study protocol. Upon agreeing and understanding, the taxi drivers were requested to sign an informed consent form to give their permission to participate in the study and have their blood drawn. All taxi drivers were advised that participation is on a voluntary basis and that they could choose not to participate in the study at any time. Even if they initially gave consent to participate, they were advised that they were free to withdraw from the study at any time or to not answer any question they were not comfortable with, without any negative consequences.

3.3.1 Cape Town Metropolitan Municipality

A metropolitan municipality in the only subcategory in the province of Western Cape. The Atlantic Ocean is to the south and west of Cape Town, and the city's coastline is 294 km long. The diagram (**Figure 3.1**) shows it is next to the West Coast district to the north, the Cape Winelands district to the north-east, and the Overberg to the south-east (Stats SA, 2016).

After Johannesburg, Cape Town is South Africa's second-largest economic centre and second-most populous city. National Parliament is situated in Cape Town, making it the legislative centre of South Africa. Cape Town is also the capital of the Western Cape province, covering an area of 2,441 km^2. The City of Cape Town is still the most strategic place in the Western Cape regarding

population, transportation, and jobs. It also forms a larger part of the regional network of economic and spatial connections, including the towns of Stellenbosch, Malmesbury, Paarl, Saldanha, and Grabouw (Stats SA, 2016).

Cape Town has a population of approximately 4.4 million, making it the second most populated city in South Africa. The metro is also proud of being the country's tourism hub. Since 2011, the rate of population growth has been decreasing. According to the 2016 Community Survey (Stats SA, 2016), 43% of the population was black African, 40% was Coloured, and only 16% was white.

Using the upper poverty line of R1227 per person, 2.016.021 million people were living in poverty in 2019, which is 45.9% more than in 2009. This increase of 2.9% (520,420) occurred over ten years. Using the upper poverty line as a guide, the population group with the most people living in poverty is the African population group, with 61.4% of people living in poverty. The number of Africans living in poverty dropped by 7.16 percentage points, from 61.40% in 2008 to 54.24% in 2018. In 2018, 9.9% of all jobs in the country were in the City of Cape Town, making it the second largest employer. The number of unemployed people in Cape Town has decreased from 454 278 in 2017 to 445 080 in 2018 (Census 2011). **Figure 3.1** illustrates the bordering districts of the City of Cape Town metropole.

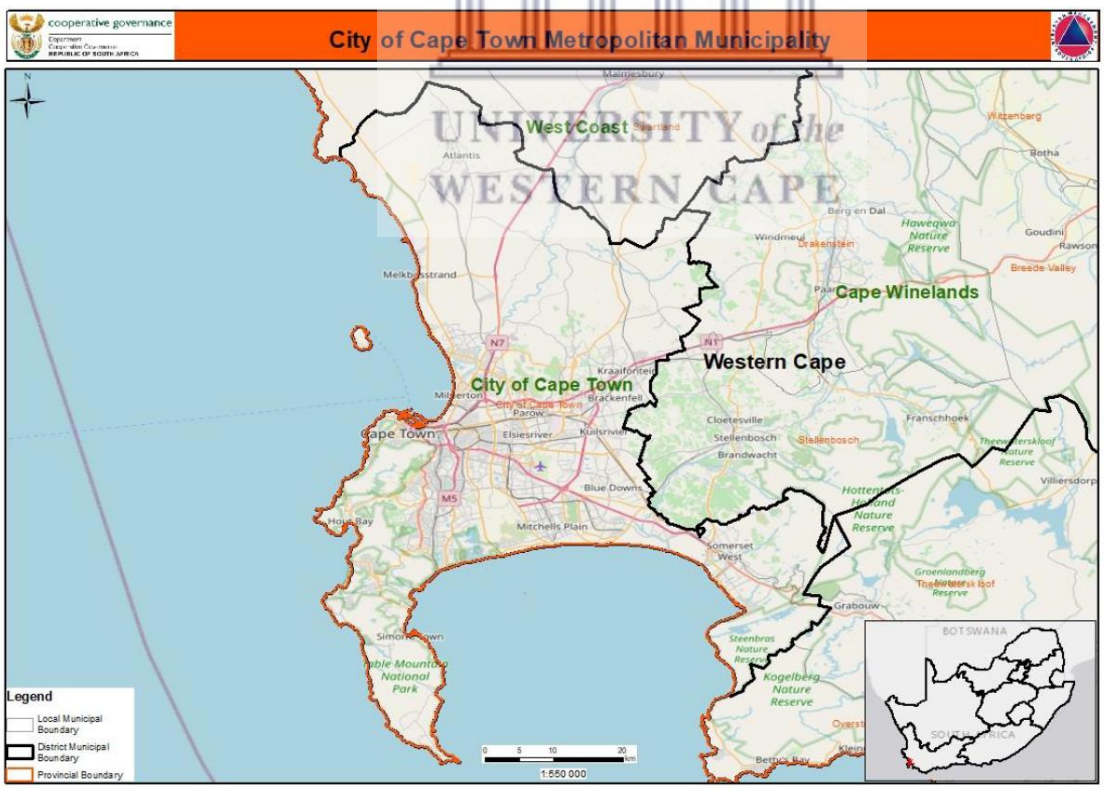

Figure 3.1: Borders of the City of Cape Town. (GIS/IT Department of the Board, 2011)

Three national roads, the N1, N2, and N7, connect Cape Town with the rest of South Africa. The N1 starts in the city centre, passes Goodwood and Bellville on its way to the northern suburbs, and ends in Beitbridge at the Zimbabwe border. The N2 also starts in the city centre and follows the coastal route to Cape Town International Airport and Somerset West, eastwards along the Indian Ocean past Durban and ending in Ermelo, Mpumalanga. The N7 goes north from Cape Town along the West Coast to Malmesbury and then to the Namibian border (Stats SA, 2016).

Taxis are the most popular and easiest way to get around Cape Town. During the time of Apartheid, when public transportation for people living in the townships was limited, the taxi service was created. Now that they are regulated, they are fast, cheap, and easy to use (Africa Check, 2021). This informal way of travelling does not follow strict schedules; thus, one can hop on a taxi almost any time of the day. Taxis go practically everywhere in the city. The taxi system uses 120 official public transportation stops. Of these, 63 are inside public transportation hubs, and 57 are on their own. Sixty-five unofficial public transportation facilities are part of the system, of which 11 facilities are part of public transportation hubs, and the other 54 are on their own (The Greater Tygerberg Partnership website, n.d.). **Figure 3.2** is a City of Cape Town map showing the Bellville taxi rank and surrounding areas used by taxi drivers to commute passengers.

3.3.2 Bellville, a suburb of City of Cape Town

The Bellville taxi rank is east of Cape Town City in the urban area of the Cape Peninsula. When founded, this area became a place for farmers to stop on their way to Cape Town with their goods and was called *12 Mile Post*. Today, the *12 Mile Stone* and oil lamp are national monuments to commemorate the 12-mile distance (20 km) from the centre of Cape Town. The name changed to Bellville in 1861 to honour Charles Bell, the surveyor general (Britannica, 2015). In 1979 Bellville became a city.

Bellville is ideally located near the Cape Town International Airport, prime award-winning golf courses, wine routes, world-class shopping malls, and leading medical facilities like Tygerberg Hospital, Karl Bremer Hospital, and Louis Leipoldt Hospital. The University of the Western Cape, several satellite campuses of the University of Stellenbosch, and other tertiary education facilities

are close by, as are the towns of Durbanville, Stellenbosch, Paarl and Kuilsriver, and Cape Town city.

Figure 3.2: City of Cape Town destinations served by the Bellville taxi rank

3.4 Reliability and validity

Several measures were used to ensure the study's reliability and validity. Research assistants were trained on the study protocol and standard operating procedures (SOPs) were designed for data collecting processes. These included participant enrolment, questionnaire administration, as well as anthropometrical and blood pressure measurements. The training highlighted the significance of accurate coding of questionnaires and samples, also how to complete the questionnaire and measure body weight, height, skin folds and waist circumference. Laboratory technicians and professional field nurses received training regarding blood sample collection and storage. Moreover, the primary investigator was in the field to supervise data collection processes and ensured that no deviations from SOPs occurred through directly reviewing data collection procedures and randomly reviewing the completed questionnaires. The Correctness of data entry forms were verified, and incomplete or missing information was rectified in the field.

The data collection instruments selected for this study were applicable and usable in the South African context (Mouton, 2007). In this case, all the measurement instruments used have been previously validated and used successfully in adult South Africans in other South African national surveys (SANHANES-1 and SADHS) (Shisana et al., 2015; NDoH, 2019). However, before use, all the instruments were calibrated and pilot tested in a subsample of 10% of participants with similar characteristics as the current sample. Joubert et al, (2007) suggested that a valid instrument should produce the same results when used repeatedly.

Reliability refers to the consistency of the measurement or the extent to which an instrument measures the same way each time it is used under identical conditions with the same participants. In short, it is the repeatability of the measurement (Mouton, 2007). The Global Neuberg Laboratories, Durban, South Africa, analyzed the blood samples using standard laboratory techniques that ensured the reliability of the blood sampling procedures. The interviews, physical investigations, and blood-related measurements were conducted by trained fieldworkers (i.e., a qualified dietician, laboratory assistants, and qualified and experienced field nurses). All interviews were conducted in English and isiXhosa, depending on the participants' preferences.

3.5 Ethical considerations

The Biomedical Science Research Ethics Committee of the University of the Western Cape (Reference number: BM18/9/25), the City of Cape Town (CCT), and the Western Cape Department of Health approved this study. Permission to collect data from the participants was granted by the taxi rank coordinators affiliated with the Western Cape Taxi Drivers' associations. Taxi drivers were informed about the details of the study, what would be expected of them, and that they could withdraw from the study at any time with no punitive measures taken against them if they chose to do so. Willing participants received information sheets with details of the research and the contacts they could use in case of further information or to lodge disputes. They were then invited to provide written consent before the commencement of this study. Their rights to data confidentiality and anonymity were ensured throughout the study.

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Chapter 4: Comparison of the ability of anthropometric indices to predict the risk of diabetes mellitus in South African males: SANHANES-1

Machoene Derrick Sekgala, Ronel Sewpaul, Maretha Opperman, Zandile June-Rose Mchiza

Abstract:

This study aimed to assess the sensitivity of body mass index (BMI) to predict the risk of diabetes mellitus (DM) and whether waist circumference (WC), waist-to-hip (WHR) and waist-to-height (WHtR) ratios are better predictors of the risk of DM than BMI in South African men aged 20 years and older. Data from the first South African National Health and Nutrition Examination Survey (SANHANES-1) were used. Overall, 1405 men who had valid HbA1c outcomes were included. The sensitivity, specificity, and optimal cut-off points for predicting DM were determined using the receiver operating characteristic (ROC) curve analysis. A total of 34.6% percent of the study participants were overweight/obese, while 10.5%, 10.4%, 36.6% and 61.0% had HbA1c, WC, WHR and WHtR above the normal reference ranges, respectively. Based on age-adjusted logistic regression analysis, the highest likelihood of DM was observed for those participants who had increased WC and WHtR (odds ratios [OR] were 6.285 (95% CI: 4.136–9.550; $p < 0.001$) and 8.108 (95% CI: 3.721–17.667; $p < 0.001$)). The ROC curve analyses for WC, WHR, and WHtR displayed excellent ability to predict the risk of DM, with their areas under the curve (AUC) being 80.4%, 80.2% and 80.8%, respectively. The overall cut-off points to predict the risk of DM for WC, WHR, and WHtR were ≥88.95 cm, ≥0.92, and >0.54, respectively. The ROC analysis for BMI, on the other hand, showed acceptable ability to predict the risk of DM (AUC = 75.6%), with its cut-off point being ≥24.64 kg/m^2. Even after stratifying the data by two age groups, WHtR remained a superior index to predict DM, especially in the younger age group. To conclude, no significant differences were observed between the AUC for BMI the AUCs for other indices. However, the AUCs for these indices showed significant excellent ability as opposed to the significant acceptable ability of BMI to predict DM in adult South African men.

Keywords: diabetes mellitus; body mass index; waist-to-hip ratio; waist circumference; waist-to-height ratio; South Africa

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Comparison of the Ability of Anthropometric Indices to Predict the Risk of Diabetes Mellitus in South African Males: SANHANES-1

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Abstract: This study aimed to assess the sensitivity of body mass index (BMI) to predict the risk of diabetes mellitus (DM) and whether waist circumference (WC), waist-to-hip (WHR) and waist-to-height (WHtR) ratios are better predictors of the risk of DM than BMI in South African men aged 20 years and older. Data from the first South African National Health and Nutrition Examination Survey (SANHANES-1) were used. Overall, 1405 men who had valid HbA1c outcomes were included. The sensitivity, specificity, and optimal cut-off points for predicting DM were determined using the receiver operating characteristic (ROC) curve analysis. A total of 34.6% percent of the study participants were overweight/obese, while 10.5%, 10.4%, 36.6% and 61.0% had HbA1c, WC, WHR and WHtR above the normal reference ranges, respectively. Based on age-adjusted logistic regression analysis, the highest likelihood of DM was observed for those participants who had increased WC and WHtR (odds ratios [OR] were 6.285 (95% CI: 4.136–9.550; $p < 0.001$) and 8.108 (95% CI: 3.721–17.667; $p < 0.001$)). The ROC curve analyses for WC, WHR, and WHtR displayed excellent ability to predict the risk of DM, with their areas under the curve (AUC) being 80.4%, 80.2% and 80.8%, respectively. The overall cut-off points to predict the risk of DM for WC, WHR, and WHtR were ≥88.95 cm, ≥0.92, and >0.54, respectively. The ROC analysis for BMI, on the other hand, showed acceptable ability to predict the risk of DM (AUC = 75.6%), with its cut-off point being ≥24.64 kg/m^2. Even after stratifying the data by two age groups, WHtR remained a superior index to predict DM, especially in the younger age group. To conclude, no significant differences were observed between the AUC for BMI the AUCs for other indices. However, the AUCs for these indices showed significant excellent ability as opposed to the significant acceptable ability of BMI to predict DM in adult South African men.

Keywords: diabetes mellitus; body mass index; waist-to-hip ratio; waist circumference; waist-to-height ratio; South Africa

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1. Introduction

The prevalence of DM ($HbA1_c$ higher than 6.5%) in South Africa increased in the past two decades [1–3]. A body mass index higher than 24.9 kg/m^2 is often regarded as the main anthropometric contributor to the increase in the prevalence of DM in most South African studies [4–6]. However, BMI does not indicate body fat distribution [4]. Body fat distribution is a better indicator for the risk of insulin resistance, where insulin resistance is a precursor to DM [7]. Hence, other indices that show body fat distribution such as

WC, WHR and WHtR are commonly known as the preferred indicators to predict the development of DM [8–10].

In South Africa, the age-standardized prevalence of DM among adults in 2012 was shown to be 10.1% [11]. More recent estimations by the International Diabetes Federation [12] indicated that approximately 4.6 million people between 20 and 79 years old are living with DM in South Africa, representing almost 13% of the total adult population. South African researchers have projected that the prevalence of DM will steadily increase in the near future [3,9,11–14]. While the aforementioned South African studies show that the prevalence of uncontrolled DM is higher in females, there is concern that if not tightly monitored, the proportion of males who are living with DM may surpass females in future. These predictions are based on current statistics that suggest that there are more males than females (66% versus 64%) who are pre-diabetic in South Africa [1].

Alongside the projected increase in DM in South Africa is the escalating prevalence of individuals with a BMI higher than 24.9 kg/m^2 [1,2]. In fact, the increase in overweight and obesity in South Africa raises concern, given that elevated BMI is an important risk factor for many of non-communicable diseases (NCDs) including DM [15–17]. According to Patel et al. [18], BMI was significantly associated with DM status for all United States cohorts in the National Health and Nutrition Examination Surveys.

There is also growing evidence to suggest that the prevalence of adiposity among South African men may be underestimated by only utilizing BMI [2]. For instance, unlike in women where the prevalence of overweight and obesity, as measured by BMI, has increased by more than 12% since 1998, the prevalence of overweight and obese men has increased by just 2% (from 29% to 31%) during the same period [1,2,14,19]. Despite this low increase, Joubert et al. (2007) [17] reported more than 10 years ago that 87% of South African men older than 30 years, who were not classified as overweight or obese, presented with DM [17]. In most parts of the world, including South Africa, men present with poor ill-defined cardiovascular disease outcomes compared to women [20,21]. This might be attributed to the finding that more men actively smoke [20,21] as well as higher alcohol consumption among men compared to women. Hence, more ambitious NCD risk detection mechanisms may be required for men.

Current international evidence shows that although BMI has been widely used as a measure of obesity [4,22], this index has a significant limitation in that it does not reflect body fat distribution. Moreover, while BMI is a simple and convenient measure for adiposity in many epidemiological studies, its validity and ability to accurately measure adiposity have been questioned as it does not directly measure the amount of adipose tissue and cannot differentiate between body fat and lean mass [23]. There is substantial evidence to suggest that metabolic complications associated with obesity are more closely associated with visceral adiposity than overall body adiposity [24]. As such, other measurements of visceral adiposity, such as WC, WHR and WHtR are widely advocated [10,24]. Visceral adiposity can promote a cascade of secondary risks for cardiometabolic conditions such as hypertension, insulin resistance, hyperuricemia and hyperlipidemia [25]. Some studies have proposed the individual use of WC, WHR or WHtR to measure the aforementioned disease risks [5,26,27] whereas others advocate their combined use [23,28].

With the preceding international evidence that implicates adiposity in the development of DM, to our understanding, no South African study has previously investigated the specificity and sensitivity of BMI to predict DM. In fact, no South African study considered identifying better-performing anthropometric indices to predict the risk of DM. Hence, this study aimed to assess the sensitivity and specificity of BMI to predict DM among South African males aged 20 years and older. Furthermore, this study compared the power of BMI to predict the risk of DM against other indices such as WC, WHR, and WHtR.

2. Materials and Methods

2.1. Sampling Procedure

This research forms part of a larger analyses of data from individuals who participated in the SANHANES-1 study. The SANHANES-1 was a cross-sectional survey undertaken in 2012 to determine the nutrition and health status of the South African population. The sample size was determined by the requirement of an acceptable precision of estimates per reporting domain; that is, to be able to estimate the prevalence of a given health or nutrition variable as well as societal risk factor(s) in each of the main reporting domains with an absolute precision level of less than 5%, which is equivalent to the expected width of the 95 percent confidence interval (z-score $Z_{1-\alpha/2}$ at the 95% level). A design effect of 2 was assumed to account for possible intra-class correlation. The total sample size of 10,000 households was determined using the minimum sample sizes required for each reporting domain, as well as the multistage cluster sampling design and expected response rates. Assuming that 75% of the 10,000 households in the sampling frame agree to participate, the survey would yield 7500 valid contactable households with eligible survey participants. The average household size demonstrated in the 2008 national HIV household survey [29] was 3.9 people per household, and this figure was used to calculate the expected sample size of eligible individuals by age group for the total sample.

The survey used a stratified cluster sampling approach with multiple stages. A total of 1000 census enumeration areas (EAs) mapped using aerial photography in 2007 were used to produce the Master Sample. The EAs were chosen based on their province and locality type. From the Master Sample, 500 EAs were chosen to represent the socio-demographic profile of South Africa. Random samples of 20 visiting points (VPs) were chosen at random from each EA, providing a total sample of 10,000 homes. As shown in Figure 1, the final sample consisted of 8166 valid and occupied households, with 27,580 eligible individuals of all ages. Of the eligible individuals, 92.6% (25,532) participated in the interviews, 43.6% (12,025) volunteered to undergo a physical examination where anthropometric measures were obtained and 29.3% (8078) donated a blood sample for biomarker analysis.

Of these individuals 17% had missing data on HbA1c and therefore were excluded. A further screening of completeness of data on weight, height, waist and hip circumferences was undertaken. Additional exclusion of those with missing data on the aforementioned indicators was undertaken, resulting in a total sample of 4083 males and females. Of these individuals, because the focus of this research was on males, females were excluded and all males aged 20 years and older (41.5% [N = 1405]) were included in the current analyses. A summary flow diagram of participant selection for this study is presented in Figure 1. Additional information about the SANHANES-1 methodology, content, and laboratory procedures can be found elsewhere [2,11].

2.2. Anthropometric Measurements

2.2.1. Weight

A bench scale was used to weigh all of the participants (Model A1ZE, East Rand; maximum weight limit 300 kg calibrated electronic scales). The scale was leveled with the help of its inbuilt spirit level on an even, uncarpeted surface (if a zero (0) appeared in the top left side of the display window, the scale was level). All participants were weighed in the clinics and were instructed to remove shoes and be dressed in light clothing when their weights were recorded. Participants were instructed to step onto the scale, stand still and upright in the center of the platform, face the clinic assistant, and look straight ahead with their feet flat and slightly apart until the reading was taken. The reading was then entered into the section provided on the clinical assessment form by the clinic assistant. Weight was measured to the closest hundredth of a gram. The individual was asked to take a step back from the scale. The clinic assistant waited for the zero reading to appear on the digital display after the participant stepped down from the scale before repeating the procedure. The difference between the 2 values had to be less than 100 g. If not, the scale was examined for accuracy, and the process had to be repeated until the two readings

were within 100 g. Both measures were recorded on the clinical examination form. A third measurement was conducted if the two measures differed by more than 100 g. For inspection, the two measurements that were closest to each other were chosen.

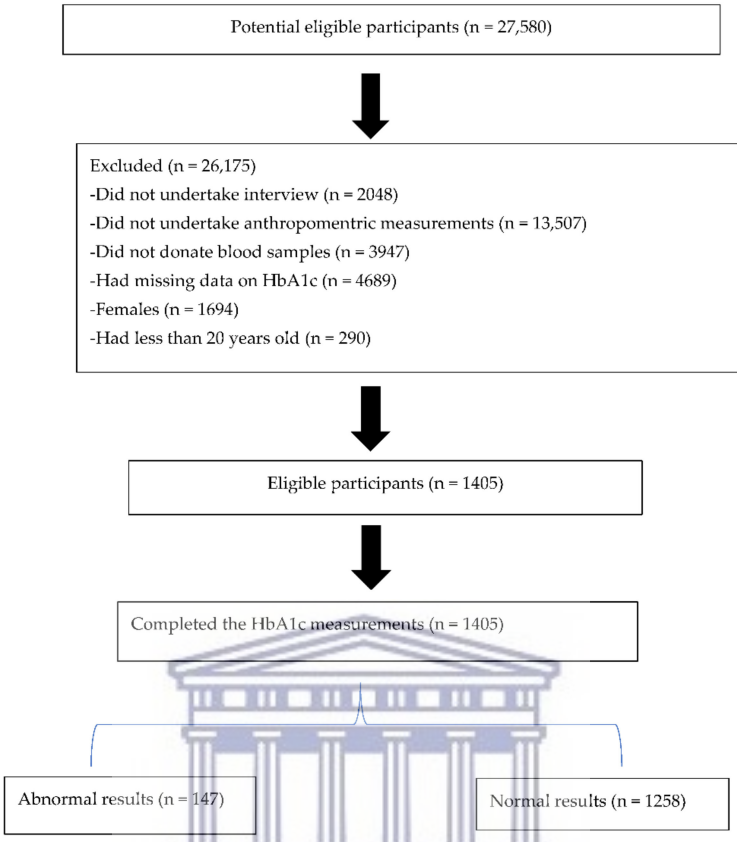

Figure 1. Flow diagram of subject selection for this study.

2.2.2. Height

The standing height was taken using a stadiometer (Seca Model 213; Medical Scales and Measuring Systems). The participant's shoes were removed and the stadiometer was placed on an even, uncarpeted surface. If the participant had his hair tied on top of his head, it was untied, and he was aligned in front of the clinic assistant, facing directly ahead with his head in the Frankfort plane. Shoulder blades, buttocks, and heels lightly touched the stadiometer's stand, arms comfortable at sides, legs straight with knees together, and feet flat with heels touching. The measurement was recorded on the clinical examination, and the procedure was repeated once more. A total of two readings were recorded. If the two readings differed by more than 0.1 cm, a third measurement was taken. For further examination, the two measurements that were closest to each other were utilized.

2.2.3. Body Mass Index

BMI was calculated for all participants using the equation: weight (kg)/height (m^2) and the recommended WHO cut-off points were used to determine normal weight (BMI = 18.5–24.9) and overweight/obesity (BMI $\geq$ 25) [30].

2.2.4. Waist Circumference

The individual stood upright/erect, abdominal relaxed, arms at sides, feet together, and weight evenly distributed between both legs. In the mid-axillary line, the lowest rib-margin and the iliac crest were located. The midpoint between the two anatomical landmarks was used to determine the waist circumference level, which was measured by wrapping a non-stretch fiberglass tape (Seca Model 203) horizontally around the abdomen.

To avoid clenching their muscles or holding their breath, participants were instructed to breathe normally and lightly while the measurement was taken. The measurement was taken without squeezing the skin with the tape and was taken down to the nearest 0.1 cm. Two measures were obtained and entered on the clinical examination form. A third measurement was taken if the two measures differed by more than 0.1 cm. For inspection, the two measurements that were closest to each other were chosen [31,32]. A waist circumference ≥94 cm in men indicated central obesity [33].

2.2.5. Hip Circumference

Participants stood erect and aligned themselves similarly to how they did for the waist circumference measurement, with arms at their sides and feet slightly apart. The measurement was obtained at the place where the circumference of the buttocks reached its maximum [32] with the non-stretch tape held in a horizontal plane, touching the skin but not indenting the soft tissue [31]. Measurement was obtained to the nearest 0.1 cm. Two measures were obtained and entered on the clinical examination form. A third measurement was taken if the two measures differed by more than 0.1 cm. For additional investigation, the two measurements that were closest to each other were chosen.

2.2.6. Waist-to-Hip Ratio

By dividing the waist circumference by the hip circumference, the waist-to-hip ratio was calculated. A value > 0.91 for men was regarded as indicative of central obesity [33].

2.2.7. Waist-to-Height Ratio

The waist-to-height ratio was calculated as the ratio of waist-to-height by dividing the waist circumference by the height. Central obesity was computed as WHtR > 0.5 [33].

Training was led by a certified anthropometrist, who was assisted along other personnel who had prior experience in taking anthropometric measurements. Trained survey staff conducted the actual measurements.

2.3. Biomarkers

Glycated Hemoglobin

Nurses and doctors in the clinic took a blood sample from the antecubital fossa. In adults, approximately 15–20 mL of blood was collected. Only consenting household members' blood samples were collected, aliquoted into appropriate blood specimen collection tubes, mixed as needed, kept in a cooler box with ice packs, and couriered daily to the designated laboratories within 24 h of the time a blood sample was collected. The appointed laboratories were Pathcare and Lancet Laboratories. Both entities are South African National Accreditation System (SANAS) accredited. The biomarker studies were carried out using automated techniques such as high-performance liquid chromatography (HPLC) (HbA1c). Deviations from specified internal and external quality control methods have to be notified in accordance with the standard. There were none reported. The coefficient of variation for the analyses ranged from 0.5 to 3.75%, according to the analytical quality control documentation.

A threshold of 6.5% for HbA1c was used for the diagnosis of DM in the current analysis [34,35]. Participants were considered to have DM if they had HbA1c levels greater than or equal to 6.5% or were currently taking either oral glycemic medication or insulin.

2.4. Statistical Analysis

Data for males aged 20 years and older who had completed anthropometric assessments and had their HbA1c measured (N = 1 405) were analyzed. Continuous variables were presented as the means and standard deviations (M ± SD). The t-test was used to compare the means of the groups. The Chi-square and trend tests were used to analyze categorical variables, which were reported as numbers and percentages. The data were stratified by age group categories as follows: 20–44 (n = 695) and over 45 years (n = 710).

The screening ability of anthropometric indices (BMI, WC, WHR and WHtR) to identify individuals with DM was explored using the ROC analysis. Plots of sensitivity versus 1 minus specificity were constructed for each of the indices. The AUC of the ROC and 95% confidence intervals (CIs) were used to identify which indicator had the best DM screening accuracy. The AUC is a measure of discrimination, and an AUC of 0.5, $0.6 \leq$ AUC < 0.7, $0.7 \leq$ AUC < 0.8, $0.8 \leq$ AUC < 0.9, and ≥ 0.9 corresponds to no discrimination, poor, acceptable, excellent, and outstanding discrimination, respectively [36]. The maximum value of Youden's index, calculated as sensitivity + specificity $- 1$, was used to determine the optimal cut-off point for each index to identify individuals with DM [37]. A logistic regression analysis, fitted by age group, race, employment, province, locality, education, triglycerides, LDL-C and total cholesterol using multivariable fractional polynomials (MFP) and reporting odds ratios (OR) was used to measure the association of each of the indices (WHR, WHtR, WC and BMI) with the odds of having DM. Three logistic regression models were applied: model 1, adjusted for age group; model 2, adjusted for age group, race, employment, province, locality, and education; and model 3, further adjusted for age group, race, employment, province, locality, education, triglycerides, LDL-C and total cholesterol. Data were analyzed using Statistical Program for Social Sciences (SPSS, version 25.0, Chicago, IL, USA). All statistical tests were two sided, and differences were considered statistically significant at p-values < 0.05. Because of SANHANES-1's multistage cluster sampling design, some individuals had a higher or lower probability of selection than others. Estimates may be skewed as a result of the unequal sampling. Sample weights were introduced to correct for bias at the EA, household, and individual levels, as well as to adjust for non-response. EA sampling weights were calculated when drawing the 500 EAs. These EA sampling weights were calculated to account for unequal size measurements during sampling. However, not all 500 EAs were carried out. As a result, the sampling weights for these EAs were adjusted for non-response at the EA level. Furthermore, because not all targeted VPs were realized, VP sampling weights were calculated based on realized and valid households. Demographic, physical examination, and clinical examination data on all individuals in all households in all responding EAs were then compiled in order to calculate individual sample weights at each responding level (questionnaire, physical and clinical examination). This weight was calculated by multiplying the final VP sampling weights by the selected person's sampling weight per VP and age group. This procedure yields a final sample that is representative of the South African population in terms of gender, age, race, locality type, and province. The survey was intended to be generalizable to the entire South African household population. The weighting procedure described here was carried out with SAS version 9.3 and the CALMAR macro for benchmarking.

3. Results

Descriptive Analysis

Table 1 presents the socio-demographic characteristics, anthropometrical indices as well as the HbA1c levels of the participants. There was almost an equal spread of participants in both age groups (i.e., 49.5% and 50.5% in age groups 20 to 44 and >45 years, respectively). The majority (63.5%) of the participants were of Black African descent and only 36.5% were non-Black. The majority (53.0%) of the participants resided in urban formal settlements. A total of 34.6%, 10.5%, 10.4%, 36.6% and 61.0% of the participants were overweight and obese based on their BMI levels and had abnormal HbA1c, WC, WHR and WHtR, respectively.

Table 1. Socio-demographic characteristics, anthropometric indices and HbA1c outcome of South African males aged 20 years and older: SANHANES-1.

	***n* (%)**
Age Group (Years)	
20–44	695 (49.5)
>45	710 (50.5)
Race ***	
Black *	888 (63.2)
Non-Black **	510 (36.3)
Locality	
Urban formal	744 (53.0)
Urban informal	147 (10.5)
Rural formal (farms)	260 (18.5)
Rural informal (tribal)	254 (18.1)
Body mass index (kg/m^2)	
Normal BMI, 18.5–24.9	878 (65.4)
Overweight/obesity, >25	465 (34.6)
Diabetes mellitus (%)	
Normal, HbA1c < 6.5	1258 (89.5)
Abnormal, HbA1c ≥ 6.5	147 (10.5)
Waist circumference (cm)	
Normal, WC < 94	1203 (89.2)
Abnormal, WC ≥ 94	146 (10.4)
Waist-to-hip ratio	
Normal, WHR < 0.91	850 (63.4)
Abnormal, WHR > 0.91	491 (36.6)
Waist-to-height ratio	
Normal, WHtR < 0.5	470 (35.4)
Abnormal, WHtR > 0.5	857 (61.0)

* Black African Descent; ** Mixed Race, European Descent and Asian; Race *** = data have 7 missing values on race variable, and total percentage does not add up to 100%. BMI = body mass index, WC = waist circumference, WHR = waist-to-hip and WHtR = waist-to-height ratio.

Table 2, on the other hand, shows that the mean values for BMI, WC, WHR, WHtR and HbA1c were 24.1 kg/m^2, 83.0 cm, 0.9, 0.5 and 5.9%, respectively.

Table 2. The physiological characteristics of South African males aged 20 years and older.

Anthropometric Indices and HbA1c	**Mean ± SD**
Weight (kg)	67.3 ± 16.4
Height (cm)	167.9 ± 8.2
Body mass index (kg/m^2)	24.1 ± 5.9
Waist circumference (cm)	83.0 ± 14.2
Hip circumference (cm)	93.9 ± 11.8
Waist-to-hip ratio	0.9 ± 0.1
Waist-to-height ratio	0.5 ± 0.1
HbA1c (%)	5.9 ± 1.0

Table 3 shows the risk (as shown by ORs) for DM as predicted by BMI, WC, WHtR and WHR of the participants. Overall, there were significant associations (all p values were < 0.05) between all anthropometric indices and DM before and after the data were adjusted. Before adjusting, it was shown that participants who had higher than normal BMI and abnormal WC, WHR and WHtR were 5-, 7-, 7- and 12-fold more likely to have

higher than normal levels of HbA1c. In this case, the ORs were 5.06 at 95% CI: 3.47–7.37, 7.13 at 95% CI: 4.78–10.65, 7.06 at 95% CI: 4.70–10.62, and 12.15 at 95% CI: 5.63–26.22, respectively, with all p values < 0.001. After removing the confounding effects of age group, ORs decreased slightly for BMI and WC to 4.14 at 95% CI: 2.81–6.10 and 6.29 at 95% CI: 4.14–9.55, respectively; and decreased substantially for WHR and WHtR to 4.80 at 95% CI: 3.14–7.33 and 8.11 at 95% CI: 3.72–17.67), while all the p values remained < 0.001. On further removal of the confounding effects of age, race, employment, province, locality, education, triglycerides, LDL-C and total cholesterol, ORs decreased for all indices to 2.445 at 95% CI:1.213–4.929; p = 0.012 for BMI, 4.950 at 95% CI: 2.243–10.926; p < 0.001 for WC, 2.926 at 95% CI: 1.503–5.697; p = 0.002 for WHR, and 4.590 at 95% CI: 1.603–13.141; p = 0.005 for WHtR. It is also important to note that ORs for BMI were the lowest both before and after adjusted ORs.

Table 3. The risk for diabetes mellitus among South African males aged 20 years and older by anthropometric indices: SANHANES-1.

	Unadjusted			Adjusted OR Model 1			Adjusted OR Model 2			Adjusted OR Model 3		
	Crude OR	95% CI	*p*-Value	AOR	95% CI	*p*-Value	AOR	95%CI	*p*-Value	AOR	95% CI	*p*-Value
BMI	5.061	3.474–7.374	<0.001	4.142	2.814–6.097	<0.001	3.687	2.260–6.016	<0.001	2.445	1.213–4.929	0.012
WC	7.133	4.779–10.647	<0.001	6.285	4.136–9.550	<0.001	6.533	3.746–11.394	<0.001	4.950	2.243–10.926	<0.001
WHR	7.064	4.698–10.623	<0.001	4.800	3.141–7.334	<0.001	4.836	2.881–8.118	<0.001	2.926	1.503–5.697	0.002
WHtR	12.151	5.632–26.215	<0.001	8.108	3.721–17.667	<0.001	8.406	3.235–21.840	<0.001	4.590	1.603–13.141	0.005

Model 1 = adjusted OR for age group. Model 2 = adjusted OR for age, race, employment, province, locality, and education. Model 3 = adjusted OR for age, race, employment, province, locality, and education, triglycerides, LDL-C and total cholesterol. BMI = body mass index, WC = waist circumference, WHR = waist-to-hip ratio, WHtR = waist-to-height ratio, and OR = odds ratio.

The ROC analysis outcomes for WC, WHR and WHtR exhibited excellent abilities to predict DM (i.e., as all outcomes were above 80%). For instance, the AUC for WC was 80.4%, 80.2% for WHR and 80.6% for WHtR (Figure 2a and Table 4). The cut-off points to predict DM for WC, WHR and WHtR were calculated to be ≥88.95 cm; >0.92 and >0.54, respectively. The sensitivity and 1-specificity for WC were 71.0% and 26.2%, 70.3% and 25.7% for WHR, and 70.3% and 21.1% for WHtR, respectively. The ROC analysis outcome for BMI, on the other hand, only exhibited an acceptable ability to predict DM. The AUC for BMI in this case was less than 80% (i.e., it was equal to 75.6%), with the cut-off point calculated to be ≥24.64 kg/m^2 and the sensitivity and 1-specificity being 70.3% and 31.9%. Despite the AUC for BMI being less than the AUCs for WC, WHR and WHtR, based on the overlapping CIs, no significant differences were observed.

Table 4. Outcomes that show the power of the anthropometric indices to predict diabetes mellitus: the area under the curve, sensitivity, 1-specificity and 95% confidence intervals.

Anthropometric Index	AUC	*p*-Value	95% CI	Cut-Off Point	Sensitivity	1-Specificity
BMI kg/m^2	0.756	<0.001	0.714–0.798	24.64	0.703	0.319
WC cm	0.804	<0.001	0.754–0.833	88.95	0.710	0.262
WHR	0.802	<0.001	0.757–0.827	0.921	0.703	0.257
WHtR	0.806	<0.001	0.769–0.842	0.543	0.703	0.211

AUC = area under curve, BMI = body mass index, WHR = waist-to-hip ratio, WHtR = waist-to-height ratio, and WC = waist circumference.

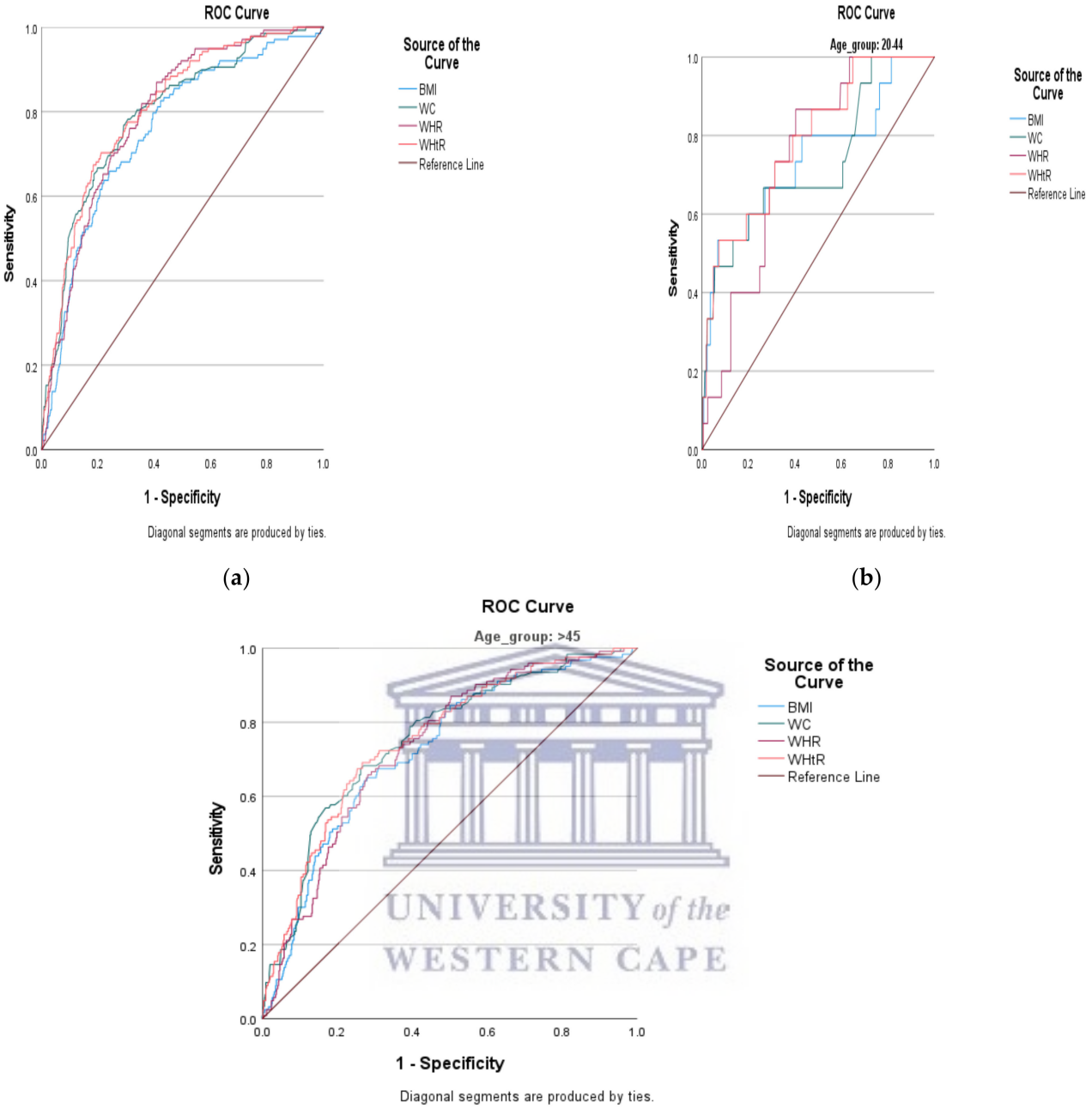

Figure 2. (**a**) ROC curves and optimal cut-off values for anthropometric indices in the prediction of diabetes mellitus in South African males aged 20 years and older. (**b**) ROC curves and optimal cut-off values for anthropometric indices in the prediction of diabetes mellitus in South African males who are 20–44 years old. (**c**) ROC curves and optimal cut-off values for anthropometric indices in the prediction of diabetes mellitus in South African males who are >45 years old.

Because our findings in Table 3 showed that age influenced the interaction between the anthropometric indices and the DM, we decided to stratify the ROC curve analysis by age group (Figure 2b,c and Table 5) to determine which indices predicted the risk of DM better in the younger (20–44 years) or the older (>45 years) groups of South African men. In this case, the AUCs for all indices became lower than 80%, showing an only acceptable ability to predict the risk of DM. Of note is that, while no significant differences were observed based in the overlapping CIs, the AUCs showed that WC and WHtR performed better in predicting the risk of DM in the older age group (with AUCs of 75.4% and 75.3%), with

WHtR being the only index that performed better in the younger age group (AUC of 78.8%). On the other hand, all the cut-off points to predict DM were higher in the older age group compared to the younger group (i.e., were ≥24.7 kg/m^2, ≥89.8 cm, >0.93 and >0.54 versus ≥24.2 kg/m^2, ≥87.5 cm >0.88 and >0.48 for BMI, WC, WHR and WHtR, respectively). As for the sensitivity values, BMI and WC values were higher in the older age group (i.e., were 70.7% and 71.5%) and WHR and WHtR values were higher in the younger age group (i.e., both were equal to 73.3%).

Table 5. Area under the curve and optimal cut-off points for anthropometric indices to predict diabetic mellitus: stratified by age group.

	Age 20–44 Years (n = 695)						Age > 45 years (n = 710)					
Anthropometric Index	AUC	95% CI	p-Value	Cut-Off Point	Sensitivity	1-Specificity	AUC	95% CI	p-Value	Cut-Off Point	Sensitivity	1-Specificity
BMI kg/m^2	0.742	0.593–0.890	0.001	24.23	0.667	0.271	0.724	0.676–0.772	<0.001	24.65	0.707	0.400
WC cm	0.729	0.583–0.874	0.002	87.45	0.600	0.201	0.754	0.707–0.801	<0.001	89.75	0.715	0.330
WHR	0.740	0.645–0.836	0.001	0.875	0.733	0.314	0.733	0.688–0.779	<0.001	0.926	0.707	0.358
WHtR	0.788	0.674–0.903	<0.001	0.483	0.733	0.314	0.753	0.707–0.800	<0.001	0.544	0.707	0.300

4. Discussion

The current study sought to assess the sensitivity and specificity of BMI to predict DM as measured by HbA1c in South African males aged 20 years and older, and compare the performance of BMI against the performance of other anthropometric indices (i.e., WC, WHR and WHtR). The notable outcomes were that, based on the AUCs, BMI showed acceptable ability to predict the risk of DM in South African males aged 20 years and older. Moreover, no significant differences were observed between the AUC for BMI and the AUCs for WC, WHR, and WHtR. However, the AUCs for WC, WHR, and WHtR were above 80%, an indication that they were stronger predictors of DM. We can explain the inferior performance of BMI to predict DM by the fact that BMI is not sensitive to body fat distribution, especially central obesity, a condition that is observed in the majority of older South African men [38,39]. On the other hand, we can attribute the excellent performance of WC, WHR and WHtR to the fact that they measured central adiposity [7–10], hence they performed better in the current group of participants.

Moreover, our current outcome that suggested age to be a confounder when using anthropometric indices to predict the risk of DM is also corroborated by other similar international studies [26,27,40,41]. For instance, Chen et al. [27] and Cheng et al. [42] have shown that age mediates the ability of these anthropometric indices to predict metabolic syndrome (MetS), and its components such as DM and hypertension. For this reason, in the current study, participants were stratified into two age groups. Despite AUCs lower than the outcomes of the overall analysis, the AUCs showed that WC and WHtR still performed better in predicting the risk of DM in older men (the AUCs were both above 75%), while WHtR even performed close to excellent in predicting the risk of DM in younger men (AUC = 79%). These outcomes are in contrast to those reported in other international studies, where anthropometric indices such as WHtR are shown to have stronger associations with cardiometabolic risk factors including DM in middle- to older-adult population groups, compared to the younger adults [43,44]. In these studies, such differences were attributed to fat mass gain and lean mass loss at old age [45,46]. However, we acknowledge that participants in these studies were stratified into three and more age groups, while we only stratified the participants into two age groups in our study.

Our outcomes also magnified the mediocre performance of WHR to predict diabetes in men, when compared to WC and WHtR. We can interpret these outcomes using other international studies that suggest WC to be an accurate and simple measure of abdominal obesity as compared to WHR [47], while WHtR is regarded as a measure that takes height into account when predicting central adiposity [46,48]. According to the aforementioned studies, height is a more sensitive indicator to muscle mass distribution throughout the

entire body than the hip circumference used in WHR. Generally, men do not have big hips [49]; and in South Africa, evidence suggests that younger men are taller and leaner (i.e., masculine) than older men [39]. In fact, muscle mass is replaced by fat mass especially around the waist in older adult men [39]. Moreover, shorter stature and higher waist circumference translate to higher WHtR outcomes [50]. According to the outcomes of the current study, WHtR increased with an increase in the HbA1c, where older men had higher HbA1c than younger men (data shown elsewhere [2,11]). However, we cannot discount other risky behaviors (i.e., smoking or drinking) that men engage in, that have been shown to contribute to the increase in HbA1c outcomes especially in the majority of older South African men [51].

The outcomes from the current study and other recent systematic reviews [44,52] also highlighted that WHtR is a better predictor for cardiometabolic risk factors, including DM when compared to BMI and WC alone. Based on the outcomes of the current analysis, it is also shown that WC, WHR and WHtR can excellently and individually predict the risk of DM. This outcome is consistent with other international literature that advocate the individual use of WC, WHR or WHtR [5,26,27]. However, pairing BMI with WHtR, on the other hand, could leverage its performance, especially in South African surveillance studies of men to predict DM. This is because, in addition to determining the overall adiposity (as measured by BMI), WHtR will also give an indication of where fat is stored in the body, whether in the visceral or abdominal region relative to the gluteal region [53]. WHtR will also give an added indication of the role played by the height of an individual in specifying central obesity, especially in a country such as South Africa that grapples with stunting even in adult men [1,2].

Finally, while the World Health Organization (WHO) [33] and the International Diabetes Federation (IDF) [12] recommend the use of pre-specified cut-off points for BMI, WC, WHR and WHtR to standardize comparisons within and between populations [33,54,55], such cut-off points are based on research centering European, Asian, Chinese and Japanese people, and may not apply to other ethnic groups, especially those of African descent—there is substantiated evidence to suggests that the current WHO [33,55] and IDF [12] cut-off points slightly underestimate the screening of DM among other ethnicities, especially in men. Our current outcomes may therefore mitigate this shortfall in that it may be necessary to lower all the cut-off points to those obtained for younger men (i.e., $\geq$24.23 kg/m^2, $\geq$87.45 cm, >0.88 and 0.48 for BMI, WC, WHR, and WHtR, respectively). Doing this may improve the predictability of DM in adult South African men regardless of age. These outcomes could also be applied to other adult men of African descent in the southern region of Africa, who have similar characteristics as those in South Africa.

While the current study have many strengths, there are limitations that need to be taken into consideration when interpreting the outcomes. Firstly, we could not demonstrate the causal relationship between anthropometric indices and DM because of the cross-sectional nature of our study design. As such, only associations were measured and reported. Secondly, this study focused only on male participants, thus limiting gender difference comparisons. Our focus was on men because there is substantiated evidence from South African to suggest that the prevalence of uncontrolled DM is higher in females and is mediated by their large body size as measured by BMI. Based on this background, we became concerned that uncontrolled DM may be underestimated in South African men. This could be partly due to the existing evidence that unlike South African women who are obviously obese, the mean BMI for South African men is still regarded to be within the normal range of weight (between 22.5 and 24.5 kg/m^2), because few of them present with overweight and obesity [56]. Normal-weight individuals are often assumed to be free of diseases if they do not present with symptoms for these diseases, hence they are often overlooked when implementing targeted interventions to mitigate metabolic diseases such as DM. Moreover, unlike women, South African men are reluctant to attend health services/or participate in health screening/surveillance activities [11]. Hence, the majority of them only present to health service centers when their DM condition has progressed.

This therefore results in them having a poor prognosis for this disease. We have also already highlighted our concern in the introduction that, if not tightly monitored, the proportion of South African men who are living with DM may surpass that of South African women in the future, since current predictions suggest that there are already more males than females (66% versus 64%) who are pre-diabetic in South Africa [1]. Further, we are conducting similar research in South African women, and this analysis is ongoing. Finally, we did not differentiate between type 1 or type 2 DM as this was beyond the scope of the current research.

5. Conclusions

To conclude, we packaged the notable outcomes from this research in Box 1 below. These suggest that both overall adiposity (as shown by BMI) and abdominal adiposity (as shown by WC, WHR and WHtR) play an important role in predicting the risk of uncontrolled DM (as measured by HbA1c) in men. However, not all anthropometric indices have the same performance in predicting the risk for DM. For instance, indices that consider fat deposition, especially around the waist, such as WC, WHR and WHtR, show excellent performance in predicting DM, while BMI, which is not sensitive to body fat distribution, only shows acceptable ability to predict DM. Despite the inferior performance of BMI, our findings show that BMI could still be an acceptable indicator to identify South African men who are at risk of having DM since there are no significant differences between the performance of BMI and other anthropometrical indices. Our high AUCs, show that WC, WHR and WHtR could be used independently to predict the risk of uncontrolled DM in South African men. However, if researchers are interested in predicting the maximum number of South African men at risk of this disease, regardless of age, BMI could be paired with WHtR. Waist-to-height ratio outcomes will also identify stunted men with a bigger waist circumference who may be missed by BMI cut-off points. Finally, because we showed that the interaction between the anthropometric measurements included in the current research and DM was mediated by age, we recommend the use of lower cut-off points than those pre-specified by the WHO and the IDF in order to improve the predictability of DM in all age groups of adult South African men. These cut-off points are for younger men and are presented in Table 5 (i.e., $\geq$24.23 kg/m^2, $\geq$87.45 cm, >0.88 and 0.48 for BMI, WC, WHR, and WHtR, respectively). We therefore think these current outcomes are of importance as they may aid in health promotion directed at improving the nutritional status of South African men. They can also be used to improve DM surveillance in the country, more especially in screening adult men of all age groups who may have uncontrolled DM, as well as support targeted interventions to control DM in a country such as South Africa that grapples with metabolic disorders.

Box 1. Take-home messages from the current research.

- Based on the current research, 34.6%, 10.5%, 10.4%, 36.6% and 61.0% of South African males aged 20 years and older had BMI $\geq$ 25 kg/m^2, HbA1c $\geq$ 6.5, WC $\geq$ 94, WHR > 0.91 and WHtR > 0.5, respectively.
- After adjusting for age group, South African men with abnormal BMI, WC, WHR and WHtR were 4-, 6-, 5-, and 8-fold more likely to present with higher abnormal levels of HbA1c.
- Further adjusted for age group, race, employment, province, locality, education, triglycerides, LDL-C and total cholesterol, ORs decreased for all indices to 2 for BMI, 5 for WC, 3 for WHR, and 5 for WHtR to pre-sent participants with higher abnormal levels of HbA1c.
- Based on the area under the curve (AUC) outcomes, WC, WHR and WHtR excellently predicted the risk of DM (with corresponding AUCs of 80.4%, 80.2% and 80.6%, respectively).
    - This means that these indices could be used independently to predict the risk of DM.
- Body mass index (BMI) shows acceptable ability to predict the risk of DM (i.e., AUC of 75.6%).
    - This means that BMI could still be used independently to predict the risk of DM.
    - However, we recommend pairing it with another strong index (especially a high-performing index such as WHtR) that considers central adiposity to supplement its ability to predict the risk of DM.
- Based on confidence interval (CI) levels that do not overlap, the AUC for BMI was not significantly differ-ent from those of WC, WHR and WHtR.
- Because age is a confounder when using anthropometric indices to predict the risk of DM, we recommend the use of lower cut-off points than those pre-specified by the WHO and the IDF, in order to improve the predictability of DM in all age groups of adult South African men.
    - The following cut-off points are for younger men and are presented in Table 5 (i.e., $\geq$24.23 kg/m^2, $\geq$87.45 cm, >0.88 and 0.48 for BMI, WC, WHR, and WHtR, respectively)

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Informed Consent Statement: The SANHANES-1 survey received clearance from the Research Ethics Committee (REC) of the HSRC (REC 6/16/11/11). Each respondent provided written consent before the interview. The interviews were conducted by trained interviewers in the respondents' homes and the respondents' preferred language.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The SANHANES data are available on request from http://datacuration.hsrc.ac.za/ (accessed on 15 June 2019).

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Chapter 5: Anthropometric indices and cut-off points for screening of metabolic syndrome among South African taxi drivers

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Abstract:

Detecting the early onset of metabolic syndrome (MetS) allows for quick intervention which may slow progression to a variety of health consequences, hence, determining the best measurement to detect MetS is essential. This research aimed at examining the MetS predictive power of anthropometric indices, such as body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR), a body shape index (ABSI), body roundness index (BRI), percentage body fat (%BF), conicity index (CI), and Clínica Universidad de Navarra-body adiposity estimator (CUN-BAE) to determine the cut-off points to identify male South African taxi drivers with MetS. A cross-sectional study was conducted among 185 male taxi drivers. Their weight, height, WC, blood lipid profile were measured. International Diabetes Federation (IDF) definition was used to define MetS. Receiver Operating Characteristic (ROC) curves were used to compare the predictive ability of Anthropometric indices to detect MetS. The mean age of the participants was 39.84 years. Overall, 41.6% (N = 77) of the participants presented with MetS. The mean values for BMI, WC, WHtR, %BF, BRI, CUN-BAE, ABSI and CI were 28.60 ± 6.20 kg/m^2, 99.13 ± 17.59 cm, 0.58 ± 0.10, 27.28 ± 8.28%, 5.09 ± 2.33, 27.78 ± 8.34, 0.08 ± 0.01 and 1.70 ± 0.19, respectively. The mean values for these indices were significantly (p<0.001) higher in participants with MetS. The highest area under the curve (AUC) outcomes for screening MetS were for the %BF and CUN-BAE, followed by the BMI and WHtR, and lastly the BRI. All these anthropometric indices had outstanding discriminatory powers for predicting MetS with AUCs and sensitivity values above 80%. The BMI, WHtR, %BF, BRI, and CUN-BAE, had cut-off points for detection of metS in South African men at 28.25 kg/m^2, 0.55, 25.29%, 4.55, and 27.10, respectively. Based on the logistic regression models abnormal BMI, WHtR, %BF, BRI, CUN-BAE, TG, FBG, systolic BP, diastolic BP and WC showed increased risk of MetS. While the %BF, CUN-BAE, BMI, WC, WHtR, BRI, CI and CUN-BAE could predict MetS among South African male taxi drivers, these indices were less effective in predicting the individual MetS risk factors such as TG, BP, and FBG.

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Anthropometric indices and cut-off points for screening of metabolic syndrome among South African taxi drivers

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Background: Detecting the early onset of metabolic syndrome (MetS) allows for quick intervention which may slow progression to a variety of health consequences, hence, determining the best measurement to detect MetS is essential.

Aim: This research aimed at examining the MetS predictive power of anthropometric indices, such as body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR), body shape index (ABSI), body roundness index (BRI), percentage body fat (%BF), conicity index (CI), and Clínica Universidad de Navarra-body adiposity estimator (CUN-BAE) to determine the cut-off points to identify male South African taxi drivers with MetS.

Method: A cross-sectional study was conducted among 185 male taxi drivers. Their weight, height, WC, blood lipid profile were measured. International Diabetes Federation (IDF) definition was used to define MetS. Receiver Operating Characteristic (ROC) curves were used to compare the predictive ability of Anthropometric indices to detect MetS.

Results: The mean age of the participants was 39.84 years. Overall, 41.6% (N = 77) of the participants presented with MetS. The mean values for BMI, WC, WHtR, %BF, BRI, CUN-BAE, ABSI and CI were 28.60 ± 6.20 kg/m^2, 99.13 ± 17.59 cm, 0.58 ± 0.10, 27.28 ± 8.28%, 5.09 ± 2.33, 27.78 ± 8.34, 0.08 ± 0.01 and 1.70 ± 0.19, respectively. The mean values for these indices were significantly ($p < 0.001$) higher in participants with MetS. The highest area under the curve (AUC) outcomes for screening MetS were for the %BF and CUN-BAE, followed by the BMI and WHtR, and lastly the BRI. All these anthropometric indices had outstanding discriminatory powers for predicting MetS with AUCs and sensitivity values above 80%. The BMI, WHtR, %BF, BRI, and CUN-BAE, had cut-off points for detection of metS in South African men at 28.25 kg/m^2, 0.55, 25.29%, 4.55, and 27.10, respectively. Based on the logistic regression models abnormal BMI, WHtR, %BF, BRI, CUN-BAE, TG, FBG, systolic BP, diastolic BP and WC showed increased risk of MetS.

Conclusion: While the %BF, CUN-BAE, BMI, WC, WHtR, BRI, CI and CUN-BAE could predict MetS among South African male taxi drivers, these indices were less effective in predicting the individual MetS risk factors such as TG, BP, and FBG.

KEYWORDS

metabolic syndrome, anthropometric indices, a body shape index (ABSI), body roundness index (BRI), waist circumference, body mass index (BMI), waist-to-height ratio (WHtR), receiver operating characteristic curve

Introduction

Metabolic syndrome (MetS) is a cluster of multiple, interconnected metabolic risk factors that promote the development of non-communication diseases (NCDs) such as diabetes, abdominal obesity, high cholesterol, low high-density lipoprotein cholesterol (HDL-c), and high blood pressure (1). Several international studies report an increased prevalence of MetS among occupational drivers when compared to other professionals such as industrial and office workers (2–4). International evidence further suggests that occupational drivers are at increased risk of cardiovascular diseases (5, 6). In South Africa there is dearth of data on the prevalence of MetS among occupational drivers and more specifically minibus taxi drivers (hereafter referred to as taxi drivers). Ramukumba and Mathikhi (7) state that taxi drivers' working environment is characterized by poor eating habits, elevated stress levels caused by long hours of driving, exposure to various environmental hazards such as air pollution as well as a lack of exercise. Their poor eating habits are aggravated by regular consumption of fried foods and snacks high in sugar and salt since these foods are relatively cheap and easily accessible at taxi ranks and bus stations where they operate (8, 9). Additionally, a recent study in Cape Town reported a notable prevalence of central obesity among taxi drivers as they overconsume alcohol and smoke to overcome stress (10).

Metabolic syndrome is regarded as a public health issue that is associated with the clustering of a wide variety of risk factors that co-exist in an individual (11, 12). The World Health Organization (13), the European Group for the Study of Insulin Resistance (EGIR) (14), the National Cholesterol Education Program Adult Treatment Panel III (15), the American Association of Clinical Endocrinology (AACE) (16, 17), International Diabetes Federation (IDF) (18) and American Heart Association/National Heart, Lung, and Blood Institute (AHA/NHLBI) (19) use different algorithms to determine MetS. These algorithms are based on the risk factors considered to be clinically realistic assessment measures for MetS for the specific populations that are under study (20). In general, any MetS algorithm includes a combination of three or more risk factors, namely: body mass index (BMI), central obesity, insulin resistance, glucose intolerance and diabetes, elevated triglycerides (TG), low levels of HDL-c, and hypertension.

In rural South Africa, the MetS prevalence in men ranges from 7.9 to 17.9% of which 7.9 and 10.5% was reported by Motala et al. (21) and Motala et al. (22), respectively among individuals aged >15 years, in a rural African (black) community of Zulu descent in the Ubombo district of the province of KwaZulu-Natal. Peer et al. (23) on the other hand reported a 17.9% prevalence among black men living in Cape Town, while Sekgala et al. (24) reported it to be 8.6% in young black South African men aged 18–30 years living in Limpopo, a rural province of South Africa.

Obesity and overweight are two important risk factors for MetS (25). According to Suliga et al. (26) and Kabała and Wilczyński (27), the BMI is the most common metric for determining obesity as it is simple to calculate and has well-defined cut-off points. This index is utilized in research all around the world as it is non-invasive. This makes it the best index that allows for possible comparisons of nutritional statuses in different populations globally. However, its inability to portray sex dimorphism, including ethnic differences in adiposity, adipose tissue distribution, and age-related body composition limits the BMI for measuring MetS in different populations (28). Hence, researchers prefer to use anthropometrical measures that show adipose tissue distribution, differentiate central or abdominal obesity when classifying MetS, WC and percentage body fat (%BF), to be specific.

There is limited data on the central obesity status of South African men in the taxi driving industry. This is despite the substantiated international evidence (4, 29) suggesting that 50% of male occupational drivers display significantly higher depositions of visceral adipose tissue compared to the general male population. Visceral adipose tissue (also known as central/abdominal obesity) is a hormonally active component of total body fat, which possesses unique biochemical characteristics that influence several pathological

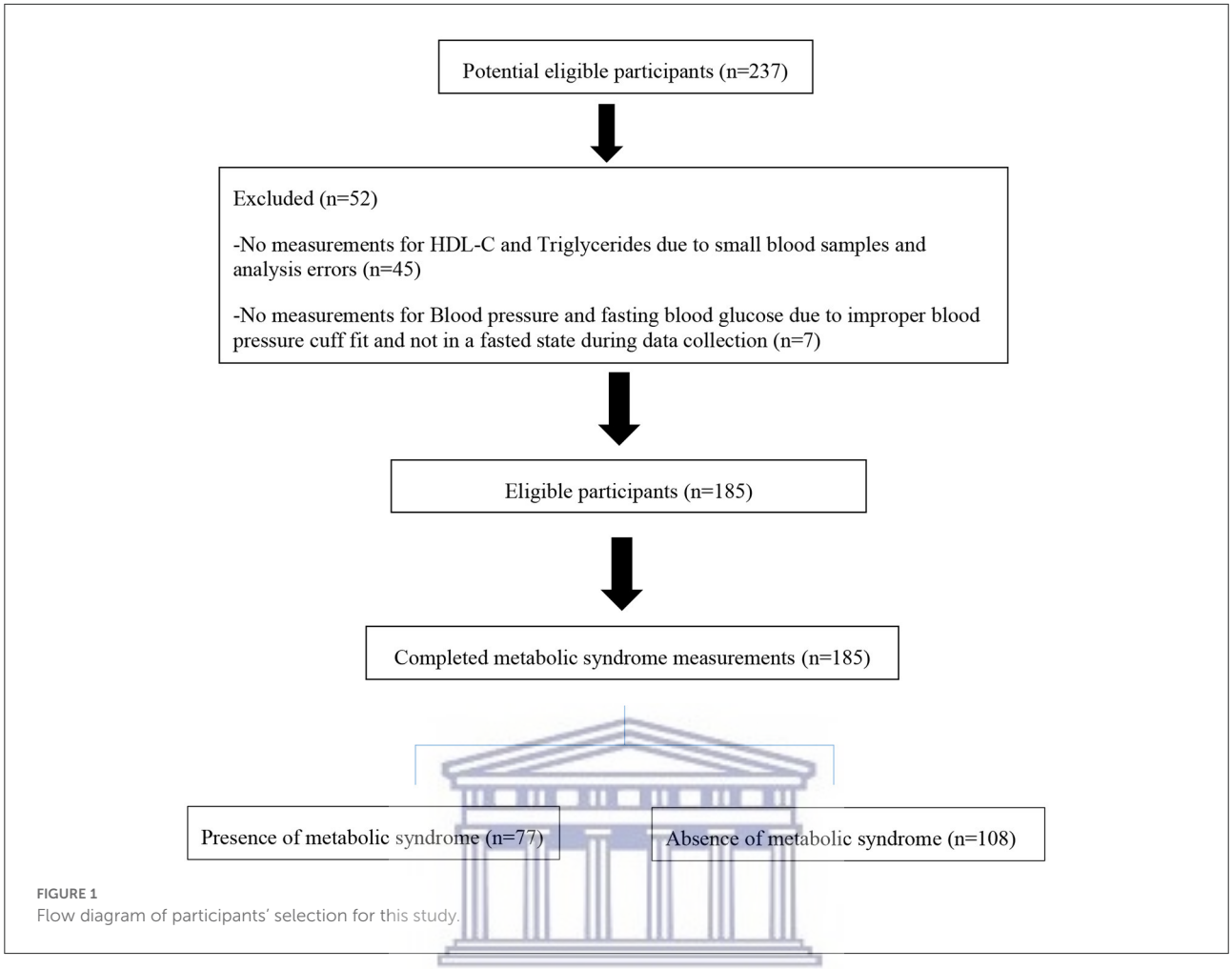

FIGURE 1
Flow diagram of participants' selection for this study.

processes in the human body (30) including the development of non-communicable diseases (NCDs) (31).

The deposition of visceral adipose tissue is measured using both invasive (32) and non-invasive anthropometrical measurements (33). Among the most common, non-invasive, and acceptable anthropometrical measurements undertaken to measure central/abdominal obesity and adipose tissue composition are the WC (34) and the %BF (35). Aside from using solely the WC to determine abdominal obesity, researchers often apply WC in the algorithms to measure its relationship with height (WHtR) (34, 36), as well as the BMI to measure the conicity index (CI) (37), body roundness index (BRI) (36) and a body shape index (ABSI) (38). International studies further suggest that the results of central obesity assessments measured by WC show the strongest connections with metabolic risk variables (39, 40).

There are four skin fold measurements (biceps, triceps, subscapular and suprailiac) that are commonly used in clinical interventions to measure %BF which, according to Rodriguez-Escudero et al. (35) is a good indicator for body composition. Aside from using solely the skinfold measurements to measure %BF, the Clínica Universidad de Navarra-Body Adiposity Estimator (CUN-BAE) is a measure that applies the outcome of %BF to an algorithm that compares it to the individual's BMI (28). The CUN-BAE is based on the BMI, but it has the added benefit of accounting for age and gender body composition differences, hence it is regarded as the best index for determining the %BF. The CUN-BAE has also been significantly associated with the actual adipose tissue composition (28) and is therefore a useful tool for identifying the risk of MetS.

Even though multiple articles on the link between adiposity and the risk of MetS have been published, it is still difficult to determine unambiguously the best measure to be applied in an algorithm to identify individuals with MetS, especially in South Africa. To our knowledge, there has never been a study conducted in South Africa to assess the ability of different anthropometric indices to detect MetS, as well as determine their cut-off point to screen for MetS among male taxi drivers. Hence, the current study was long overdue. This study aimed to examine the MetS predictive power of anthropometric indices such as the BMI, WC, WHtR, ABSI, BRI, %BF, CI, and CUN-BAE, and determine the cut-off points to identify male South African taxi

drivers at risk of MetS. The outcomes of this research will inform policies directed at improving the health status of South African taxi drivers.

Materials and methods

Study design

This cross-sectional study was conducted among 185 conveniently sampled commercial taxi drivers aged 20 years and older who were recruited from the Bellville and Cape Town taxi ranks. These taxi ranks were chosen because they are the two busiest transport interchange areas in the Cape metropole area in the Western Cape Province of South Africa (8).

Study participants and sample size

All taxi drivers who were available, willing to participate and those who met the inclusion criteria were included in the study. Eligible participants had to be 20 years and older, fluent in English and/or Afrikaans and/or IsiXhosa (the most spoken languages in Cape Town and surrounding areas), able to provide informed consent, and willing to donate a blood sample for metabolic assessments. Taxi drivers who have at least 1-year experience as a driver around the targeted interchange areas in the Western Cape Province and also being a members of a recognized taxi association. Only men were included in the study given that more than 99% of taxi drivers operating in these transport interchange areas were men. Participants who were on any form of chronic medication and/or with chronic diseases history were excluded.

Since no similar studies on MetS prevalence among taxi drivers in Cape Town could be located and the fact that the proposed study focused on taxi drivers (>80% black men), the sample size was based on the findings of Peer et al. (23) who indicated a 17.9% MetS prevalence among black men in Cape Town. As such, the sample size was obtained using the formula by Daniel and Cross (41) for cross-sectional studies.

$$\text{Sample Size (N)}: Z^{2*}\,(p)^{*}\,(1-p)/c^{2}$$

Where: Z = Z value (e.g., 1.96 for 95% confidence level); p = expected proportion of the population, expressed as decimal=0.179; c = confidence interval, expressed as decimal = 0.05.

Therefore, the estimated sample size was N = 226 and after adjusting for 5% non-response the sample size increased to N = 237.

Of the 237 participants who agreed to participate, only 185 agreed to complete all the measurements and donate blood specimens for the metabolic parameters (see Figure 1).

Socio-demographic data

Socio-demographic data and information on the participants' lifestyles (duration of sleep, physical activity, alcohol consumption and cigarette smoking) were collected *via* face-to-face interviews using a structured and previously validated questionnaire (30). Collected socio-demographic variables included age, socio-economic status (defined based on the household income, marital status, and education level).

Measurements

Anthropometric indicators

Weight, height and WC were measured to calculate the anthropometric indices using standard procedures (42). All measurements were conducted by a qualified dietitian, with the help of qualified and trained field nurses.

Skinfold thickness was measured on both sides of the body using a Lange Skinfold Caliper at four locations: biceps, triceps, subscapular, and suprailiac. The biceps skinfold thickness was measured at the midpoint of the arm while the individual sat in a supine position with arms relaxed and resting on the thighs. Triceps skinfold thickness was measured in the sitting position with arms crossed at a 90° bend and resting on thighs at the midpoint between the acromion and the olecranon process. The subscapular skinfold was measured while standing with arms to the side. The shoulder blade was located and followed down to the point where it began to curve. The skin was pinched and the calipers were used to measure the skinfold. Still in the standing position the suprailiac skinfold was also measured. The skin above the right hipbone was measured along the midaxillary line (43).

Waist circumference was measured in cm above the iliac crest and below the lowest rib margin at minimum respiration by the use of a non-stretch tape measure (44). Height was measured in meters to the nearest cm using a SECA stadiometer with a right-angle headboard wide enough to rest across the top of the head. The participants were measured without shoes and standing up-right, feet together, knees straight, and heels, buttocks, and shoulder blades in contact with the stadiometer (45). Weight was measured to the closest hundredth of a gram using an electronic scale that was calibrated before use with a total calibration weight of 200 kg. Weight was measured while the participants were standing in the center of the scale and looking straight ahead with minimal clothing (46).

Based on the afore-mentioned measurements, the following indicators were calculated:

a. BMI = weight (kg) / height^2 (m^2): <18 kg/m^2, 18–24.9 kg/m^2, 25–29.9 kg/m^2, and ≥ 30 kg/m^2 considered as underweight, normal weight, overweight and obese, respectively (38).

TABLE 1 Sociodemographic and anthropometric characteristics by the presence/absence of MetS among the taxi drivers in Western Cape, South Africa.

	Total $N = 185$ mean ± SD	MetS present $n = 77$ mean ± SD	MetS absent $n = 108$ mean ± SD	*P*-value
Age (years)	39.84 ± 10.46	43.73 ± 10.34	37.27 ± 10.21	<0.001
Race *n* (%)				0.932
Black	146 (78.9)	33 (42.9)	85 (78.7)	
Non-black	39 (21.1)	44 (57.1)	23 (21.3)	
Merital status *n* (%)				0.279
Single, divorced, separated or widowed	88 (47.3)	33 (42.9)	55 (50.9)	
Married, or living as married	97 (52.7)	44 (57.1)	53 (49.1)	
Driving experience (years) *n* (%)				<0.001
1–7	103 (55.7)	31 (40.3)	72 (66.7)	
8>	82 (44.3)	46 (59.7)	36 (33.3)	
Educational level *n* (%)				0.714
No schooling or primary	58 (31.4)	23 (29.9)	35 (32.4)	
Some high school and higher education	127 (68.6)	54 (70.1)	73 (67.6)	
BMI (kg/m^2)	28.60 ± 6.20	32.71 ± 5.88	25.65 ± 5.21	<0.001
WC (cm)	99.13 ± 17.59	110.83 ± 16.72	90.72 ± 14.50	<0.001
WHtR	0.58 ± 0.10	0.64 ± 0.09	0.53 ± 0.09	<0.001
Weight (kg)	84.74 ± 19.67	97.35 ± 18.66	75.52 ± 16.41	<0.001
Height (cm)	172.03 ± 7.93	172.59 ± 9.33	171.44 ± 7.23	0.387
%BF	27.28 ± 8.28	33.11 ± 7.63	23.16 ± 6.85	<0.001
ABSI	0.0812 ± 0.0840	0.0829 ± 0.0901	0.0800 ± 0.00775	<0.001
BRI	5.09 ± 2.33	6.68 ± 2.50	4.06 ± 1.81	<0.001
CUN-BAE	27.78 ± 8.34	33.55 ± 6.61	23.53 ± 7.52	<0.001
CI	1.70 ± 0.19	1.78 ± 0.21	1.65 ± 0.17	<0.001
Biceps	10.66 ± 6.73	12.84 ± 6.06	8.53 ± 3.31	<0.001
Triceps	17.41 ± 8.75	20.56 ± 9.53	14.95 ± 7.40	<0.001
Subscapular	26.16 ± 13.58	32.14 ± 13.76	21.21 ± 10.87	<0.001
Suprailiac	24.20 ± 13.08	29.40 ± 11.07	19.40 ± 10.90	<0.001

BMI, Body Mass index; WC, Waist circumference; WHtR, waist-to-height Ratio; %B, percentage body fat; ABSI, a body shape index; BRI, body roundness index; CUN-BAE, Clínica Universidad de Navarra-Body Adiposity Estimator; CI, Conicity index; MetS, metabolic syndrome. The numerical values are presented as mean ± standard deviation and intergroup compared using the Mann-Whitney U test.

b. WHtR = WC (cm)/height (cm), The WHtR of > 0.5 was considered abnormal (47).

c. ABSI = WC (m)/[BMI$^{2/3}$(kg/m^2) * height$^{1/2}$ (m)] (38). The ABSI of >0.07 was considered abnormal.

d. CI = 0.109^{-1} WC (m) [weight (kg)/height (m)]$^{-1/2}$. The CI of >1.25 was considered abnormal (37).

e. $BRI = 364.2 - 365.5\,x\sqrt{(1 - \frac{(\frac{WC}{2\pi})2}{(0.5Xheight)2})}$

BRI of >3.5 was considered abnormal (35).

f. %BF= (495/Body Density) - 450 (35). The %BF of >25.00 is considered abnormal (48). %BF was calculated based on the average skinfold thickness measurement from each of the four sites.

g. CUN-BAE was calculated using the equation %BF = -44.988 + (0.503 x age) + (10.689 x sex) + (3.172 x BMI) - (0.026 x BMI^2) + (0.181 x BMI x sex) - (0.02 x BMI x age) - (0.005 x BMI^2 x sex) + (0.00021 x BMI^2 x age), where age is measured in years, and sex was codified as 0 for men. A CUN-BAE of >20.00 is considered abnormal (28).

Blood pressure and blood biochemical parameters

Blood pressure was measured using an Omron BP monitor (Model M3 Intellisense, Mannheim, Germany). Blood pressure was measured on the artery of the right upper limb when the individual was seated and rested at ground level. Following

TABLE 2 Mean non-communicable disease risk factors by the presence/absence of MetS.

Risk factors of MetS	Total	MetS present $n = 77$	MetS absent $n = 108$	Intergroup comparison *p*-value
	mean ± SD	mean ± SD	mean ± SD	
Triglycerides (mmol/L)	1.35 ± 1.12	1.88 ± 1.49	0.96 ± 0.45	<0.001
HDL-c (mmol/L)	1.11 ± 0.34	1.00 ± 0.28	1.20 ± 0.36	<0.001
FBG (mmol/L)	6.50 ± 3.44	7.87 ± 4.82	5.33 ± 1.13	<0.001
SBP (mmHg)	133.44 ± 17.17	141.47 ± 18.79	127.40 ± 13.33	<0.001
DBP (mmHg)	84.71 ± 13.08	92.73 ± 13.94	79.07 ± 9.12	<0.001
WC (cm)	99.13 ± 17.59	110.83 ± 16.72	90.72 ± 14.50	<0.001

HDL-c, high-density lipoprotein cholesterol; FBG, fasting blood glucose; SBP, systolic blood pressure; DBP, diastolic blood pressure; WC, waist circumference; MetS, metabolic syndrome. Values are reported as the mean ± standard deviation.

TABLE 3 Risk factors of MetS grouped by the presence and absence of MetS.

Components of MetS		Total	MetS present $n = 77$	MetS absent $n = 108$	Intergroup comparison
		N (%)	N (%)	N (%)	*p*-value
Triglycerides (mmol/L)	Normal	152 (79.2)	46 (59.7)	101 (93.5)	<0.001
	Abnormal	40 (20.8)	31 (40.3)	7 (6.5)	
HDL-c (mmol/L)	Normal	93 (48.4)	19 (24.7)	71 (65.7)	<0.001
	Abnormal	99 (51.6)	58 (75.3)	37 (34.3)	
FBG (mmol/L)	Normal	111 (48.3)	18 (23.4)	75 (69.4)	<0.001
	Abnormal	119 (51.7)	59 (76.6)	33 (30.6)	
SBP (mmHg)	Normal	93 (40.3)	22 (28.6)	55 (50.9)	0.003
	Abnormal	138 (59.7)	55 (71.4)	53 (49.1)	
DBP (mmHg)	Normal	131 (56.7)	23 (29.9)	82 (75.9)	<0.001
	Abnormal	100 (43.3)	54 (70.1)	24.1 (26.0)	
Hypertension	Normal	149 (64.5)	28 (29.9)	92 (85.2)	<0.001
	Abnormal	82 (35.5)	54 (70.1)	16 (14.8)	
WC (cm)	Normal	95 (40.1)	6 (7.8)	69 (63.9)	<0.001
	Abnormal	142 (59.9)	71 (92.2)	39 (36.1)	

HDL-c, high-density lipoprotein cholesterol; FBG, fasting blood glucose; SBP, systolic blood pressure; DBP, diastolic blood pressure; WC, waist circumference; MetS, metabolic syndrome. Values are reported as the mean ± standard deviation.

a 5-min rest period in a sitting position BP was measured twice with at least a 5-min interval apart. The average of the 2 measurements was considered for data analysis. Hypertension was defined as systolic blood pressure (SBP) > 130 mm Hg or diastolic blood pressure (DBP) > 85 mmHg (49).

Metabolic parameters

Blood was sampled from participants by qualified field nurses in the morning after a 12-h overnight fast and was kept on dry ice and transported to the laboratory for processing. On arrival at the lab, the blood specimens were centrifuged for 5 min at 2,500 rpm at room temperature to separate the plasma and red blood cells. The concentration of TGs was assessed using the phosphoglycerides oxidase peroxidase method while HDC-C was obtained using the colorimetric non-precipitation method. Plasma was used for analysis. The glucose concentration was estimated by the capillary method using a glucometer (One Touch®).

Definition of metabolic syndrome

Following the criteria established by the International Diabetes Federation (IDF) Task Force on Epidemiology and Prevention (joint interim statement in 2009) (49), MetS was defined as the presence of three or more of the following five NCDs: abdominal obesity (WC > 94 cm) in males; FBG ≥ 5.5 mmol/L; TGs ≥1.7 mmol/L; HDL-c <1.0 mmol/L in males and SBP ≥130 mmHg or DBP ≥85 mmHg.

TABLE 4 Area under the curves (AUC) and cut-off points for the anthropometric indices for the prediction of MetS and its risk factors.

Anthropometric indices	MetS and risk factors	AUC	95% CI	*P*-value	Cut-off point	Sensitivity	Specificity
BMI (kg/m^2)	MetS (IDF criterion)	83.8%	0.782–0.895	<0.001	28.25	80.5%	25.0%
WHtR		83.2%	0.775–0.889	<0.001	0.55	87.0%	36.1%
%BF		84.8%	0.794–0.902	<0.001	25.29	85.7%	29.6%
ABSI		67.7%	0.599–0.756	<0.001	0.08	70.1%	38.9%
BRI		83.2%	0.775–0.889	<0.001	4.55	80.5%	36.1%
CUN-BAE		84.6%	0.791–0.901	<0.001	27.10	84.4%	27.8%
CI		76.2%	0.694–0.831	<0.001	1.70	74.0%	36.1%
BMI (kg/m^2)	Triglycerides (mmol/L)	67.8%	0.588–0.768	0.001	28.69	63.2%	39.5%
WHtR		69.3%	0.606–0.780	<0.001	0.57	71.1%	44.2%
%BF		60.5%	0.577–0.761	0.001	25.57	71.1%	46.2%
ABSI		69.3%	0.506–0.705	0.046	0.08	60.5%	40.8%
BRI		69.3%	0.606–0.780	<0.001	5.25	60.5%	34.0%
CUN-BAE		67.6%	0.586–0.767	0.001	29.19	60.5%	36.7%
CI		63.4%	0.535–0.732	0.011	1.71	60.5%	38.8%
BMI (kg/m^2)	HDL-C (mmol/L)	70.9%	0.634–0.784	<0.001	27.74	70.5%	34.4%
WHtR		65.0%	0.582–0.738	<0.001	0.57	60.0%	37.8%
%BF		69.0%	0.614–0.766	<0.001	25.35	67.4%	36.7%
ABSI		53.7%	0.453–0.621	0.384	0.081	50.5%	43.3%
BRI		66.0%	0.582–0.738	<0.001	4.77	60.0%	37.8%
CUN-BAE		70.2%	0.627–0.777	<0.001	26.85	70.5%	35.6%
CI		60.3%	0.521–0.685	0.015	1.71	60.0%	36.7%
BMI (kg/m^2)	Fasting glucose (mmol/L)	62.5%	0.544–0.706	0.003	27.74	60.9%	46.2%
WHtR		61.3%	0.532–0.694	0.008	0.57	57.6%	44.1%
%BF		64.5%	0.566–0.725	0.001	25.68	60.9%	40.9%
ABSI		55.3%	0.470–0.636	0.214	0.081	52.2%	45.2%
BRI		61.3%	0.532–0.694	0.008	4.88	54.3%	39.8%
CUN-BAE		63.5%	0.555–0.716	0.001	27.25	60.9%	40.9%
CI		57.3%	0.491–0.656	0.085	1.72	42.4%	37.6%
BMI (kg/m^2)	BP (mmHg)	64.0%	0.558–0.722	0.002	27.44	64.6%	49.2%
WHtR		63.3%	0.551–0.716	0.003	0.58	60.0%	36.7%
%BF		66.0%	0.578–0.741	<0.001	26.23	64.6%	39.2%
ABSI		59.6%	0.511–0.682	0.031	0.08	61.5%	39.2%
BRI		63.4%	0.551–0.716	0.003	4.92	60.0%	36.7%
CUN-BAE		64.8%	0.565–0.731	0.001	28.31	60.0%	37.5%
CI		63.4%	0.550–0.719	0.003	1.70	60.0%	43.3%
BMI (kg/m^2)	WC (cm)	91.8%	0.876–0.961	<0.001	25.52	91.8%	25.3%
WHtR		96.2%	0.933–0.991	<0.001	0.52	99.1%	29.3%
%BF		92.9%	0.887–0.970	<0.001	23.84	92.7%	17.3%
ABSI		78.3%	0.714–0.852	<0.001	0.08	77.3%	29.3%
BRI		96.2%	0.933–0.991	<0.001	4.14	94.5%	12.0%
CUN-BAE		92.8%	0.887–0.970	<0.001	25.12	92.7%	16.0%
CI		93.5%	0.899–0.971	<0.001	1.66	90.9%	14.7%

BMI, Body Mass index; WC, Waist circumference; WHtR, waist-to-height Ratio; %B, percentage body fat; ABSI, a body shape index; BRI, body roundness index; CUN-BAE, Clínica Universidad de Navarra-Body Adiposity Estimator; CI, Conicity index; MetS, metabolic syndrome; HDL-C, high-density lipoprotein cholesterol; FBG, fasting blood glucose; SBP, systolic blood pressure; DBP, diastolic blood pressure; WC, waist circumference.

TABLE 5 Optimal cut-off point for components of MetS.

Variable	The area under the curve ROC	(95% CI)	*P*-value	Optimal cut-off point	Sensitivity	Specificity
Triglycerides (mmol/L)	76.7%	0.697–0.837	<0.000	1.11	70.1%	29.6%
HDL-c (mmol/L)	71.2%	0.635–0.789	<0.000	1.03	70.4%	32.5%
Fasting blood glucose (mmol/L)	77.0%	0.703–0.838	<0.000	5.35	79.2%	37.0%
SBP (mmHg)	72.5%	0.650–0.800	<0.000	130.50	70.1%	44.4%
DBP (mmHg)	80.5%	0.739–0.870	<0.000	85.5	70.1%	23.1%
Waist circumference (cm)	83.6%	0.780–0.837	<0.000	99.00	81.8%	29.6%

SBP, systolic blood pressure; DBP, diastolic blood pressure; HDL-C, high density lipo-protein- cholesterol.

Ethical approval

This study was approved by the Biomedical Science Research Ethics Committee of the University of the Western Cape (Reference number: BM18/9/25), the City of Cape Town (CCT), and the Western Cape Department of Health. Permission to collect data from the participants was granted by the taxi rank coordinators affiliated with the Western Cape Taxi Drivers' associations. Taxi drivers were informed about the details of the study, what would be expected of them, and that they could withdraw from the study at any time and no punitive measures will be taken against them if they chose to do so. Those who were willing to participate were provided information sheets with details of the research and the contacts they could use in case of further information or to lodge disputes. They were then invited to provided written consent before the commencement of this study. Their rights for data confidentiality and anonymity were ensured throughout the study.

Statistical analysis

All data were analyzed using the Statistical Package for Social Science (IBM-SPSS, version 24.0 for Windows; SPSS Inc., Chicago, IL, USA). All continuous variables were expressed as means and standard deviations (Mean±SD) while categorical variables were reported as frequencies and percentages (N and %). To measure the relationship between dependent and independent variables the *t-test* was used for continuous variables and the chi-square test for categor-ical variables.

The Receiver Operating Characteristic (ROC) curve analyses were used to compare the MetS predictive abilities of different anthropometric indices and to determine the optimal cut-off values. Using the same method, the area under the curve (AUC) with 95% Confidence Intervals (CIs) were also estimated. The AUC was used to measure the accuracy for each anthropometric index to discriminate between individuals who presented with MetS and those who did not. The AUC values between ≥0.5 and <0.6 (50 and 60%), ≥0.6 and <0.7 (60 and 70%), ≥0.7 and <0.8 (70–80%), and ≥0.8 and ≥0.9 (80–90%) were regarded to have poor, acceptable, excellent and outstanding abilities to predict MetS, respectively (50). The best cut-off points were determined as those closest to the upper left angle of the ROC curve (51). In this approach, the lowest cut-off value corresponds to a Sensitivity = 1 and Specificity = 0. Until a cut-off value corresponding to a test Sensitivity = 0 and Specificity = 1 is reached, the test Sensitivity declines, and the test Specificity increases as the cut-off value rises. There is a cutoff value over this interval at which the test's sensitivity and specificity are equal. As a result, the criterion for determining the test cut-off value that corresponds to this specific point where Sensitivity = Specificity is the one that is used. This point is analytically the intersection of the line connecting the left-upper corner and the right-lower corner of the unit square (the line Sensitivity = Specificity) of the ROC curve. Logistic regression analysis was applied to calculate the association between each of the anthropometric indices (BMI, WC, WHtR, %BF, BRI, CUN-BAE, ABSI and CI), MetS and its risk factors. Combinations of several indices were investigated to comprehensively predict the risk of MetS among taxi drivers The associations were presented as odds ratios (ORs) with CI that did not overlap and $p < 0.05$ showing significant differences between the OR outcomes. The OR outcomes were also adjusted by age group, race, employment, province, locality, education, smoking, alcohol intake and physical activity. Three logistic regression models were applied: *model 1*, adjusted for age; *model 2*, adjusted for age, race, marital status, driving experience in years, and education; and *model 3*, further adjusted for age, race, marital status, driving experience in years, education, smoking, alcohol intake and physical activity. $P < 0.05$ and CIs that did not overlap were assumed statistically significant for all other calculations.

Result

Table 1 presents the sociodemographic and anthropometric characteristics of 185 male participants who completed the study.

TABLE 6 The risk for metabolic syndrome among South African males aged 20 years and older by anthropometric indices.

	Unadjusted			Adjusted OR model 1			Adjusted OR model 2			Adjusted OR model 3		
Anthropometric indices	**Crude OR**	**95% CI**	***p*-Value**	**Crude OR**	**95% CI**	***p*-Value**	**Crude OR**	**95% CI**	***p*-Value**	**Crude OR**	**95% CI**	***p*-Value**
BMI (kg/m^2)	1.277	1.182–1.379	<0.001	1.261	1.166–1.363	<0.001	1.271	1.170–1.382	<0.001	1.269	1.165–1.382	<0.001
WHtR (cat)	0.023	0.003–0.174	<0.001	0.026	0.003–0.196	<0.001	0.028	0.004–0.215	0.001	0.030	0.004–0.232	0.001
%BF	1.214	1.145–1.288	<0.001	1.213	1.137–1.294	<0.001	1.221	1.140–1.308	<0.001	1.220	1.136–1.309	<0.001
ABSI (cat)	2.853	0.254–32.041	0.395	1.663	0.145–19.041	0.683	2.228	0.170–29.270	0.540	1.754	0.123–25.036	0.679
BRI	1.922	1.549–2.386	<0.001	1.817	1.466–2.250	<0.001	1.860	1.478–2.342	<0.001	1.819	1.442–2.294	<0.001
CUN-BAE	1.215	1.146–1.288	<0.001	1.202	1.132–1.276	<0.001	1.210	1.136–1.289	<0.001	1.210	1.134–1.292	<0.001
CI cat	2.853	0.254–32.041	0.395	1.663	0.145–19.041	0.683	2.228	0.170–29.270	0.540	1.754	0.123–25.036	0.679
MetS risk factors												
Triglycerides (mmol/L)	5.468	2.879–10.387	<0.001	5.883	2.957–11.703	<0.001	6.205	2.986–12.892	<0.001	7.370	3.337–16.279	<0.001
HDL-c (mmol/L)	0.089	0.026–0.308	<0.001	0.085	0.023–0.320	<0.001	0.079	0.020–0.308	<0.001	0.067	0.016–0.288	<0.001
FBG (mmol/L)	1.869	1.402–2.492	<0.001	1.765	1.317–2.366	<0.001	1.693	1.254–2.286	0.001	1.770	1.295–2.419	0.001
SBP (mmHg)	1.063	1.037–1.089	<0.001	1.064	1.037–1.092	<0.001	1.070	1.041–1.101	<0.001	1.067	1.037–1.098	<0.001
DBP (mmHg)	1.121	1.080–1.163	<0.001	1.117	1.075–1.161	<0.001	1.121	1.077–1.167	<0.001	1.119	1.073–1.168	<0.001
Hypertension (cat)	0.099	0.049–0.201	<0.001	0.108	0.052–0.223	<0.001	0.092	0.042–0.203	<0.001	−0.102	0.046–0.226	<0.001
WC (cm)	1.097	1.065–1.129	<0.001	1.090	1.059–1.122	<0.001	1.092	1.059–1.126	<0.001	1.090	1.056–1.124	<0.001

Three logistic regression models were applied: model 1, adjusted for age; model 2, adjusted for age, race, marital status, driving experience in years, and education; and model 3, further adjusted for age, race, marital status, driving experience in years, education, smoking, alcohol and physical activity. BMI, Body Mass index; WC, Waist circumference; WHtR, waist-to-height Ratio; %BF, percentage body fat; ABSI, a body shape index; BRI, body roundness index; CUN-BAE, Clínica Universidad de Navarra-Body Adiposity Estimator; CI, Conicity index; MetS, metabolic syndrome; HDL-C, high-density lipoprotein cholesterol; FBG, fasting blood glucose; SBP, systolic blood pressure; DBP, diastolic blood pressure; WC, waist circumference. Cat: categorical variable, Hypertension: systolic blood pressure ≥ 130 mmHg and/or diastolic blood pressure ≥ 85 mmHg, WHtR: (> 0.5), CI: (>1.25), ABSI: > 0.086.

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TABLE 7 The unadjusted and adjusted odds ratios (ORs) of the combination BMI and BRI, BMI and WHtR, and BRI and WHtR for prediction of MetS and its risk factors.

Unadjusted

	BMI and BRI			BMI and WHtR			BRI and WHtR		
	OR	95% CI	*P*-value	OR	95% CI	*P*-value	OR	95% CI	*P*-value
MetS	1.211	1.141–1.286	<0.001	1.274	1.180–1.375	<0.001	1.871	1.522–2.302	<0.001
Triglycerides	1.072	1.029–1.117	<0.001	1.095	1.038–1.156	<0.001	1.222	1.069–1.397	0.003
HDL-c	1.088	1.045–1.133	<0.001	1.121	1.062–1.182	<0.001	1.256	1.097–1.439	<0.001
FBG	1.051	1.015–1.087	0.005	1.065	1.019–1.114	0.005	1.173	1.041–1.321	0.009
Hypertension	1.056	1.021–1.093	0.002	1.073	1.026–1.123	0.002	1.184	1.053–1.332	0.005
WC	1.564	1.388–1.761	<0.001	1.601	1.419–1.806	<0.001	9.955	5.234–19.010	<0.001
Adjusted OR model 1									
MetS	1.197	1.128–1.277	<0.001	1.258	1.165–1.358	<0.001	1.773	1.444–2.177	<0.001
Triglycerides	1.072	1.028–1.118	0.001	1.094	1.036–1.156	0.001	1.219	1.063–1.397	0.005
HDL-c	1.092	1.047–1.138	<0.001	1.125	1.064–1.187	<0.001	1.267	1.101–1.458	<0.001
FBG	1.039	1.004–1.076	0.030	1.051	1.005–1.100	0.030	1.124	0.995–1.269	0.060
Hypertension	1.048	1.012–1.086	0.009	1.063	1.016–1.113	0.008	1.150	1.020–1.297	0.023
WC	1.584	1.396–1.797	<0.001	1.629	1.429–1.857	<0.001	9.783	5.091–18.800	<0.001
Adjusted OR model 2									
MetS	1.203	1.130–1.280	<0.001	1.264	1.167–1.370	<0.001	1.777	1.436–2.199	<0.001
Triglycerides	1.072	1.027–1.120	0.002	1.094	1.034–1.158	0.002	1.225	1.065–1.408	0.004
HDL-c	1.094	1.047–1.142	<0.001	1.127	1.065–1.193	<0.001	1.266	1.097–1.460	0.001
FBG	1.039	1.003–1.076	0.035	1.050	1.004–1.100	0.035	1.122	0.993–1.267	0.065
Hypertension	1.049	1.011–1.088	0.010	1.064	1.015–1.115	0.010	1.151	1.018–1.301	0.025
WC	1.581	1.394–1.795	<0.001	1.625	1.425–1.853	<0.001	9.979	5.158–19.307	<0.001
Adjusted OR model 3									
MetS	1.191	1.118–1.269	<0.001	1.250	1.153–1.356	<0.001	1.710	1.384–2.113	<0.001
Triglycerides	1.072	1.026–1.121	0.002	1.094	1.033–1.160	0.002	1.274	1.059–1.415	0.006
HDL-c	1.097	1.047–1.148	<0.001	1.131	1.066–1.201	<0.001	1.260	1.088–1.460	0.002
FBG	1.036	0.999–1.074	0.054	1.047	0.999–1.097	0.055	1.114	0.983–1.262	0.092
Hypertension	1.040	1.002–1.080	0.039	1.053	1.003–1.106	0.036	1.115	0.981–1.266	0.096
WC	1.610	1.404–1.846	<0.001	1.639	1.427–1.883	<0.001	10.798	5.362–21.744	<0.001

Three logistic regression models were applied: model 1, adjusted for age; model 2, adjusted for age, race, marital status, driving experience in years, and education; and model 3, further adjusted for age, race, marital status, driving experience in years, education, smoking, alcohol and physical activity. BMI, Body Mass index; WC, Waist circumference; WHtR, waist-to-height Ratio; BRI, body roundness index; MetS, metabolic syndrome. HDL-C, high-density lipoprotein cholesterol; FBG, fasting blood glucose; WC, waist circumference.

The Mean ± SD age of the participants was 39.84 ± 10.45 years. The mean values for BMI, WC, WHtR, %BF, BRI, CUN-BAE, ABSI and CI were 28.60 ± 6.20 kg/m^2, 99.13 ± 17.59 cm, 0.58 ± 0.10, 27.28 ± 8.28%, 5.09 ± 2.33, 27.78 ± 8.34, 0.08 ± 0.01 and 1.70 ± 0.19, respectively. Overall, 41.6% participants presented with MetS, while those with MetS were significantly older ($p < 0.001$) than those without MetS (mean age of 43.73 ± 10.34 vs. 37.27 ± 10.21 years).

The mean values for BMI, WC, WHtR, %BF, BRI, CUN-BAE, ABSI and CI were significantly ($p < 0.001$) higher in participants with MetS compared to those without MetS. The mean values for all 4 skinfolds were significantly ($p<0.001$) higher among participants with MetS than those without MetS.

Table 2 presents mean NCD risk factors by the presence/absence of metabolic syndrome. Participants who presented with MetS displayed significantly ($p < 0.001$) higher mean values for TG (1.88 ± 1.49 vs. 0.96 ± 0.45), FBG (7.87 ± 4.82 vs. 5.33 ± 1.13), SBP (141.47 ± 18.79 vs. 127.40 ± 13.33) and WC (110.83 ± 16.72 vs. 90.72 ± 14.50) compared to those without MetS. Participants who presented with MetS displayed significantly lower mean values for HDL-c compared to those without MetS (1.00 ± 0.28 vs. 1.20 ± 0.36, $p < 0.001$).

Table 3 shows the distribution of normal/abnormal proportions of different risk factors for MetS. Abnormal values were recorded for TGs (20.8%), HDL-c (51.6%), FBG (51.7%), SBP (59.7%), DBP (43.3%), BP (35.5%) and WC (59.9%) Based on the participants who had abnormal risk factor outcomes

significantly more of them also presented with clustering of these risk factors (presented with MetS) when compared to those who had normal risk factor outcomes [TG (40.3 vs. 6.5%), HDL-c (75.3 vs. 34.3%), FBG (76.6 vs. 30.6%,) SBP (71.4 vs. 49.1%), DBP (70.1 vs. 26.0%), BP (70.1 vs. 14.8%) and WC (92.2 vs. 36.1%)].

Based on Table 4, the most sensitive AUC outcomes for screening MetS were for the %BF (84.8%) and CUN-BAE (84.6%) followed by the BMI (83.8%) and WHtR (83.2%), and lastly the BRI (83.2%). All these indices displayed outstanding discriminatory power for predicting MetS since their AUCs and sensitivity values were all above 80%. The BMI, WHtR, %BF, BRI, and CUN-BAE, cut-off points for detection of MetS in this group were 28.25 kg/m^2, 0.55, 25.29%, 4.55, and 27.10, respectively. While the CI showed the excellent AUC (76.2%) for predicting the MetS with the cut-off point

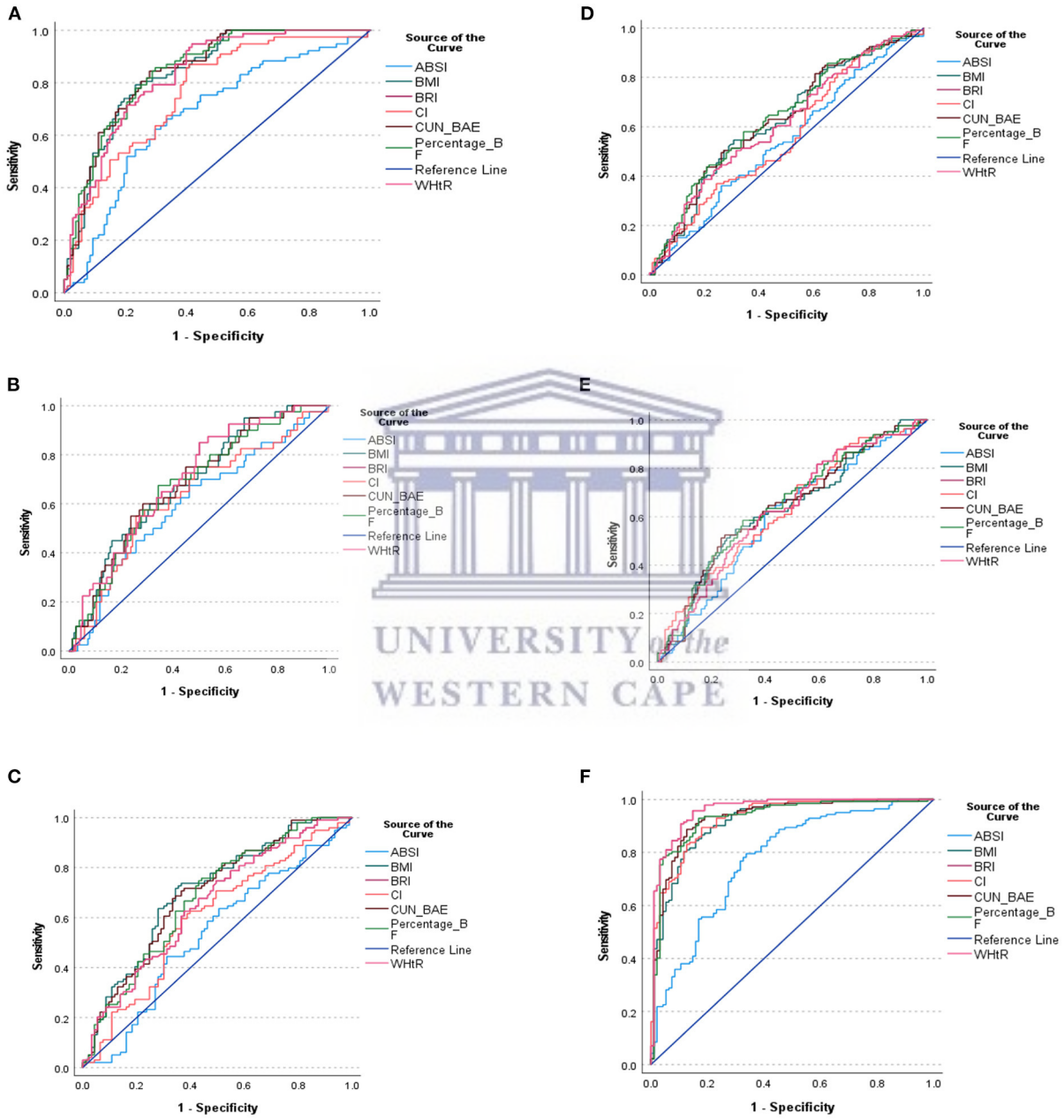

FIGURE 2
(A) ROC curve of the anthropometric indices for the prediction of MetS. **(B)** ROC curve of the anthropometric indices for the prediction of triglyceride. **(C)** ROC curve of the anthropometric indices for the prediction of HDL-C. **(D)** ROC curve of the anthropometric indices for the prediction of FBG. **(E)** ROC curve of the anthropometric indices for the prediction of Hypertension. **(F)** ROC curve of the anthropometric indices for the prediction of WC. **(A–F)** shows the ROC curve of the anthropometric indices cut off points for the prediction of MetS and its components.

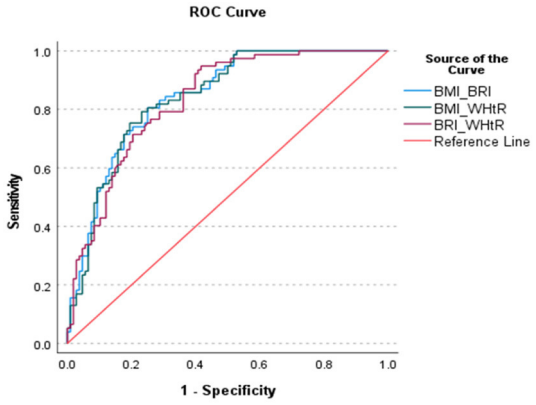

FIGURE 3
ROC curve of the various combination of two anthropometric indices fir identifying the MetS.

of 1.70 and the sensitivity of 74% the ABSI only showed acceptable discriminatory power for predicting MetS, with an AUC of 67.7%, and the cut-off point of 0.8, while its sensitivity was 70.1%. The virtualization of the anthropometric indices cut off points for the prediction of MetS and its components is shown in Figures 2A–F.

Of note is that, based on the CIs that overlapped, there were no significant differences between AUC outcomes for %BF, CUN-BAE, BMI, WHtR, BRI and CI. Moreover, the CIs for the ABSI overlapped with those of the CI, but did not overlap with the rest of the other indices. This showed that, while there was no significant difference between the AUC outcomes for ABSI and CI, there were significant difference between the AUC outcomes for ABSI and those of the other anthropometrical indices. This showed that the ABSI predicted MetS to a significantly lesser degree than the BMI, WHtR, %BF, BRI, and CUN-BAE.

It is further shown that some of these anthropometric indices could not predict the individual risk factors for MetS (predict TG, HDL-c, TG, FBG and BP) since none of these risk factors produced AUCs above 70% in this group of participants, satisfactorily. The only AUCs ≥70% observed was with BMI's and CUN-BAE's ability to predict low HDL-c with the cut-off points at 27.74 kg/m^2 and 26.85, respectively. The rest of the indices only produced AUC outcomes (>60%) with ABSI still performing more poorly than the other indices (AUC < 60%). It is further imperative to note the outstanding predictive powers of BMI, %BF, CUN-BAE and CI to predict WC as an important risk factor for MetS with the respective, cut-off points at 25.52 kg/m^2, 23.84, 25.12 and 1.66. The highest AUC outcomes for screening WC were for the CI and %BF, followed by CUN-BAE then BMI (93.5 and 92.9%, followed by 92.8% then 91.8%), respectively.

According to Table 5, only the DBP and WC could outstandingly predict MetS, with cut-off points of 85.5 mmHg and 99 cm and Sensitivity levels of 70.1 and 81.8%, respectively. The rest of the risk factors managed to predict MetS excellently.

The outcomes of the logistic regression analyses are shown in Table 6. The unadjusted odds ratios (OR) and adjusted odd ratio (AOR) with 95% confidence intervals (95% CIs) are also presented. While the BMI, WHtR, %BF, BRI and CUN-BAE yielded OR and AOR outcomes (for all the 3 models) that showed significant probability for MetS risk, the OR outcomes for ABSI and CI were not significant. The highest positive (increased) likelihood for MetS risk was with the BRI (almost 2 times more likelihood), than the BMI (almost 1.3 times more likelihood), followed by %BF and CUN-BAE (1.214 and 1.215 more likelihood, respectively). All the $p < 0.001$ and the positive likelihoods remained after removing the confounding effects of age, race, marital status, driving experience in years, education, smoking, alcohol intake and physical activity. The WHtR on the other hand yielded a negative (0.977 less likelihood) for MetS risk (where the p-value for OR was <0.001). This less likelihood persisted after removing the confounding effects of age, race, marital status, driving experience in years, education, smoking, alcohol intake and physical activity.

Moreover, the TG, FBG, SBP, DBP and WC yielded positive outcomes (increased likelihood of 5.5, 1.9, 1.1, 1.2 and 1.1 times) for MetS risk, respectively. All the $p < 0.01$ and these remained after adjusting for age, race, marital status, driving experience in years, education, smoking, alcohol intake and physical activity. The HDL-c and hypertension on the other hand yielded negative outcomes (reduced likelihood of 0.911 and 0.901) for MetS risk, respectively. All the $p < 0.001$ and these remained after adjusting for age, race, marital status, driving experience in years, education, smoking, alcohol intake and physical activity.

We further investigated how the combinations of two indices behaved in predicting MetS among study participants in Table 7. It was shown that all combination of two indices had significantly better performances in predicting MetS. e.g., One unit increase in the combination of BRI and WHtR increased two times chances of MetS (OR: 1.871 95% CI 1.522–2.302, $p <$ 0.001) for unadjusted. While in the adjusted model 1, increased 1.7 times chances of MetS incident (OR 1.773 95CI 1.444–2.177, $p < 0.001$).

Since we had the evidence that the anthropometric indices would predict the risk of MetS, we now investigated how much it could be improved with combinations of indices using AUC. Figure 3 and Table 8 show the AUC's of various combinations of two indices for predicting MetS. It was obvious that the predictive capacity for MetS with two indices was much better than that with a single index. For example, the AUC of BMI and BRI, BMI and WHtR and BRI and WHtR for predicting MetS were 0.843, 0.839 and 0.832, respectively.

Discussion

The current study aimed to examine the power of anthropometric indices such as the BMI, WC, WHtR, ABSI, BRI, %BF, CI, and CUN-BAE to predict MetS, and determine

TABLE 8 Area under the curves (AUC) for the various combinations of two anthropometric indices for identifying MetS.

	The area under the curve ROC	*P*-value	95% CI	
BMI and BRI	0.843	<0.001	0.788	0.898
BMI and WHtR	0.839	<0.001	0.783	0.895
BRI and WHtR	0.832	<0.001	0.775	0.889

BMI, Body Mass index; WC, Waist circumference; WHtR, waist-to-height Ratio; BRI, body roundness index; MetS, metabolic syndrome. HDL-C, high-density lipoprotein cholesterol; FBG, fasting blood glucose; WC, waist circumference.

the cut-off points to identify male South African taxi drivers at risk of MetS. The mean age of the participants was 39.84 years. Overall, more than 41% of the participants had MetS. Participants presenting with MetS were significantly older than those without MetS. The highest AUC outcomes for screening MetS were for the %BF and CUN-BAE, followed by the WC, WHtR and BMI, and lastly by the BRI. All these anthropometric indices had outstanding discriminatory powers for predicting MetS since their AUC outcomes were above 80%. While all the indices had outstanding capabilities to predict MetS, ABSI was considered a poor indicator of MetS when compared to the rest of the indices. In terms of the abilities of the indices to predict the risk of elevated TGs, FBG and BP, as well as reduced HDL-c, only the BMI and CUN-BAE produced AUC outcomes that were above 70%. Finally, based on the logistic regression models shown in the current paper, the taxi drivers that presented with abnormal levels of BMI, WHtR, %BF, BRI, CUN-BAE, TG, HDL-c, FBG, SBP, DBP and WC displayed an increased risk of MetS.

The prevalence for MetS in our study appears to be high (41.6%) when compared to other documented South African studies. In fact, Motala et al. (21); Motala et al. (22) and Sekgala et al. (24) found MetS to be 7.9, 10.5 and 8.6% in rural South African men, respectively. Peer et al. (23), on the other hand, reported a 17.9% prevalence of MetS in black men living in urban townships in Cape Town, South Africa. Our results are also higher than the prevalence of 17.1% observed by Mabetwa et al. (52) among taxi drivers operating in the City of Tshwane and the prevalence of other international studies among occupational drivers for example Chen et al. (2) (6.23%), Montazerifar et al. (3) (20.0%) and Saberi et al. (4) (35.9%). However, we need to mention that the prevalence of MetS might be different according to the definition used to determine MetS. Several international studies define MetS using the Adult Treatment Panel III for Asians which considers any three of MetS clusters while for Sub-Saharan Africa (SSA) the IDF European definition is used which considers WC and any two clusters of cardiometabolic disorders.

The increased prevalence might also be attributed to the fact that almost 60% of the taxi drivers participating in the current research presented with central obesity while the majority the taxi drivers with central obesity also presented with MetS. Though comparable to the 50% of international male long distance and long duration drivers observed by Hirata, et al. (29) and Saberi et al. (4), the current abnormal WC prevalence outcome is still the highest when compared to all other outcomes we could review from literature. In the current study it has also been shown that WC correlates well with other anthropometric indices including the BMI, WHtR, %BF, BRI, CUN-BAE (AUC >90%).

Because central obesity explains fat mass that lines internal organs, if in excess, it is likely to disturb the natural functioning of these organs, hence it is detrimental to human health. According to available South African (21–24, 52, 53) and international (4, 54) studies, central obesity is more prevalent in middle age to older men, and it positively correlates with other body composition outcomes including abnormal BMI, WC, waist to hip ratio (WHpR), %BF and all sorts of CVD risk factors and MetS.

Other notable outcomes of the current study indicated that indices which determine body fat distribution, %BF, CUN-BAE, WHtR and BRI, specifically showed outstanding discriminatory power for predicting the risk of MetS. These findings are corroborated by other cross-sectional South African (53) and international (34, 55) studies conducted among different ethnic groups of men operating in the driving industry. Moreover, in line with our current findings, Głuszek et al. (34) showed that the ABSI index showed the lowest discriminatory powers to predict MetS when compared to other anthropometrical indices with an AUC of 60%. Zhang et al. (56), also showed the weakness of CI in predicting MetS in Chinese male adults with the AUC of 66%. These outcomes can be attributed to the fact that the algorithms for ABSI and CI consider BMI and body weight, respectively. Evidence suggests that the BMI and body weight do not consider the distribution of adipose tissue. Earlier presented evidence indicate that MetS is sensitive to central obesity (57, 58). Moreover, Głuszek et al. (34), Mongraw-Chaffin et al. (59), and Heymsfield et al. (60) have eloquently argued that the cut-off points for the BMI and weight do not consider the individual's ethnicity, gender and age-group, hence they appear to be less sensitive in predicting MetS, especially in a group of participants in the current study, who were males of whom the majority were of black decent.

There is growing evidence (53, 61) that highly recommend WC and WHtR as the best anthropometric indices to be used in the diagnosis of MetS and its risk factors. Both these indices have been shown to produce AUC outcomes that are >80% when detecting MetS and its risk factors including diabetes mellitus. Moreover, Rajput et al. (62) previously argued that the WHtR can be used independently as a universal screening tool to identify individuals at high risk of developing metabolic complications, regardless of the individuals' gender or geographical location. Other researchers have also advocated the

importance of using the WC, WHtR, BRI and CUN-BAE in the diagnosis of cardiometabolic disorders and MetS (36, 45, 63, 64). According to Thomas et al. (36), the BRI was created to measure body fat and the percentage of visceral adipose tissue by using WC and height in the algorithm. Pairing WC and height in the same algorithm elevates the discriminatory power of the index to predict the risk of MetS. It should also be noted that, according to Maessen et al. (65), the BRI has a relatively strong correlation ($r = 0.999$) with WHtR among the Dutch population. Several other studies have confirmed the BRI's ability to identify the risk of MetS in both men and women (56, 66, 67).

Prospective studies (68–70) have highlighted the usefulness of anthropometric indices to identify individuals at risk of cardiometabolic disorders such as hypertension, elevated blood glucose and blood lipids. However, none of the anthropometrical indices produced AUCs above 70% in the calculations undertaken to predict FBG, TGs, hypertension, DBP, and SBP, with the exceptions being the BMI's and CUN-BAE's ability to predict low HDL-c (where both AUC outcomes were 70%), with the cut-off points at 27.74 kg/m^2 and 26.85, respectively.

Similar results were reported by Głuszek et al. (34) where CUN-BAE, BMI, and WC in men (AUC = 0.734, 0.728, and 0.728, respectively) had the highest discriminatory power for the identification of at least one MetS component. Contrary to our outcomes, none of the anthropometric indices were shown to predict the incidence of low HDL-c in the study by Latifi et al. (71). It is unclear why such contrasting outcomes were observed. However, it needs to be acknowledged that these studies were undertaken, to a large extent, in different ethnic groups, genders, age groups and geographic location.

The current research outcomes also established new anthropometric indices' cut-off points to predict MetS among South African taxi drivers. For instance, the cut-off point established for BMI (28.25 kg/m^2) in the current study seems lower than 30 kg/m^2 recommended by the IDF (49). Al-Odat et al. (72) found lower cut-off points of 28.4 kg/m^2 in their research conducted in the male Jordan population while Ofer et al. (73) reported cut-off points of 27 kg/m^2 in the retrospective, observational, cohort-based study. Even though several papers, including the current manuscript highlight the limitations of using BMI independently (28, 74, 75) to predict MetS, BMI can still be a very user friendly, non-invasive and affordable tool to measure adiposity and predict other of chronic metabolic diseases.

In terms of WC cut-off points to predict MetS, ours were within the range recommended by the IDF and WHO. In fact, 99 vs. 94 cm and 102 cm, respectively, were observed in the current study. Moreover, the cut-off point of 0.55 for WHtR reported falls within the range of 0.51 to 0.58 as recommended by the IDF and Głuszek et al. (34). Moreover, several studies (56, 76–78) recommend a WHtR cut-off value of >0.5 as a simple and reliable outcome to identifying those individuals (male and female) who are at an increased risk of metabolic complications.

According to the IDF (2005), the European cut-off point for abdominal obesity should be 94 cm for men (49), whereas the WHO cut-off point is 102 cm for men (47). These figures have been found to be highly correlated with a BMI of around 30 kg/m^2.

In the current study, we also observed that the %BF and the CUN-BAE were better predictors of MetS (79), compared to BMI, WHtR, CI and BRI. We could attribute these outcomes to the fact that the total body fat predicts metabolic disorders more precisely than other anthropometric indices derived from WC (80). In fact, according to Lear et al. (81) % BF highly correlates with visceral adipose tissue (VAT) hence the excess body fat is primarily responsible for the health consequences associated with obesity (55, 82, 83).

Similar to Macek et al. (84) findings (25.8%), the optimal cut-off point for %BF in the current study was 25.29%. These outcomes were expected given that in the afore-mentioned two studies, men of a similar age group were studied. Similarly, Joseph et al. (85) indicated that 25.5 %BF was sufficient to predict cardiovascular risk in Asian Indian men. Our cut-off point was also similar to the cut-off point recommended by the WHO (25%). However, 25.29% is lower than the outcomes observed in the improving interMediAte RisK management (MARK) study (cut-off point of 31.22%) by Gomez-Marcos et al. (55). The differences could probably be ascribed to the different age groups studied. Gomez-Marcos et al. (55) studied 35–74-year old participants, while in the current research taxi drivers 20 years and older were included.

Finally, based on the logistic regression models shown in the current paper, abnormal BMI, WHtR, %BF, BRI, CUN-BAE, TG, FBG, SBP, DBP and WC outcomes showed increased likelihood for MetS while abnormal HDL-c outcomes showed less likelihood for MetS. There is South African (52, 53) evidence on men and taxi drivers including long distance and long duration drivers, respectively to corroborate these outcomes. However, the outcome in the current study that suggested that hypertensive taxi drivers had decreased likelihood of MetS was surprising. Nonetheless, blood pressure results further showed that elevated DBP and SBP were significantly positively associated with the likelihood of developing MetS among participants. This outcome seems similar to the study of Mabetwa et al. (52). Even though not significant ($p = 0.117$), taxi drivers with hypertension in Mabetwa et al. (52) study were 45% less likely to present with MetS (CI: 0.261–1.161). The take-home messages from the current study are summarized in Box 1.

Limitations

While several strengths of the current study are outlined above, there are limitations that should be considered when interpreting the current outcomes. Firstly, this study was the cross-sectional design which cannot infer causality. Secondly,

BOX 1
Take-home messages from the current research.

- Based on the current study, Overall, 41.6% of the South African men taxi drivers had MetS.
- The mean values for BMI, WC, WHtR, %BF, BRI, CUN-BAE, ABSI and CI were significantly higher in older participants and those that presented with MetS compared to younger participants without MetS.
- Participants who presented with MetS had higher mean values for triglycerides (1.88 vs 0.96), FBG (7.87 vs. 5.33), SBP (141.47 vs. 127.40) and WC (110.83 vs. 90.72) as compared to those without MetS.
- Overall, 20.8, 51.6, 51.7, 59.7, 43.3, 35.5 and 59.9% of the participants had abnormal Triglyceride, HDL-c, FBG, SBP, DBP, Hypertension and WC, respectively.
- The highest AUC outcomes for screening MetS were for the %BF and CUN-BAE and then followed by the WC, BMI and WHtR, and lastly the BRI (84.8 and 84.6%, and then followed by 83.8 and 83.2%, and lastly the 83.2%, respectively).
  - ➢ This means that all these anthropometrical indices had outstanding discriminatory power for predicting MetS since their AUC and sensitivity levels were above 80%.
- The BMI, WHtR, %BF, BRI, and CUN-BAE, had cut-off points for detection of MetS in South African men at 28.25 kg/m^2, 0.55, 25.29%, 4.55, and 27.10, respectively.
- While the CI only showed the excellent AUC (76.2%) for predicting the MetS with the cut-off point of 1.70 and the sensitivity of 74%.
- Some of these anthropometric indices could not satisfactorily predict the individual risk factors for MetS (i.e., predict TG, HDL-c, TG, FBG and BP).
- ➢ This means that none produced the AUCs that were above 70% in this group of participants.
- ➢ The only acceptable outcome (AUCs ≥70%) observed was with BMI's and CUN-BAE's ability to predict HDL-c with the cut-off points at 27.74 kg/m^2 and 26.85, respectively.
- ➢ There was outstanding predictive powers of BMI, %BF, CUN-BAE and CI to predict WC with the cut-off point at 25.52 kg/m^2, 23.84, 25.12 and 1.66, respectively.
- ➢ This means that all these anthropometrical indices had outstanding discriminatory power for predicting WC since their AUCs and sensitivity values were all above 90%.
- ➢ DBP and WC showed outstanding predictive powers to diagnose MetS with cut-off points of 85.5 mmHg and 99 cm, respectively.
- We observed the highest positive likelihood for BRI and BMI to increase the incidence of MetS in the unadjusted and all the adjusted models.
- Increased in CUN-BAE and %BF were positively associated with likelihood of MetS incidence.
- High triglycerides had a greater risk of increasing MetS in both adjusted and unadjusted models.

the sample size because of the specific nature of the chosen participants (male and taxi drivers), therefore, as only male taxi drivers that were recruited conveniently are included, the outcomes obtained can only be generalizable in populations with similar characteristics as the current participants. Possible reasons for the high prevalence of MetS in our analysis might be influenced by genetic variation and epigenetic factors (86), adipose-related hormonal and immunological reactions can exacerbate metabolic disorders, such as dyslipidemia and high blood pressure (87). The main environmental factors influencing the expression of genes involved in the occurrence of MetS are eating habits and physical activity (88). Diets high in fat, particularly saturated fat, with a high glycemic index and low fiber content can increase the risk of MetS. Therefore, not all MetS cases can be characterized by high anthropometric indices as MetS can be linked not only to excess adipose tissue but also to its location.

Conclusion

The results of our study confirmed the usefulness of BMI, WHtR, %BF, BRI, and CUN-BAE for identifying MetS in male drivers, whereas ABSI was found to be the weakest predictor of the syndrome.

Therefore, the cut-off points proposed in this study provide an earlier diagnosis of MetS than the commonly accepted obesity criterion (BMI ≥30 kg/m^2). In our analysis, we included the MetS definition (three of five components according to the IDF) and anthropometric indices excluding WC. To avoid a late diagnosis of MetS, consideration should be given to setting cut-off points for the indicators in question that would allow people with only one MetS component to be diagnosed. This data might be clinically significant, as anthropometric index reference thresholds can be used to identify those adults who are at high metabolic risk. Additionally, these results highlight the usefulness of BMI, WHtR, %BF, BRI, and CUN-BAE for public health purposes given their higher accuracy and low cost for measurement.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Ms. Patricia Josias Research Ethics

Committee Officer University of the Western Cape. The patients/participants provided their written informed consent to participate in this study.

Author contributions

MDS and ZJ-RM: conceptualization and funding acquisition. MDS: formal data analysis, methodology, and writing-original draft. ZJ-RM and MO: supervision and writing-review and editing. BM: biochemical analysis. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2022.974749/full#supplementary-material

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Chapter 6: Socio-demographic and lifestyle factors and the risk of metabolic syndrome in taxi drivers. A focus on street food

Machoene Derrick Sekgala, Maretha Opperman, Buhle Mpahleni, Zandile June-Rose Mchiza

Abstract

In South Africa, like other populous countries, the taxi industry is a predominant form of transportation that contributes to the country's development. Hence, minibus taxi driving is an occupation characterized by strenuous activities, such as long hours of driving, short sleep duration and challenges related to securing passengers, among several other things. Consequently, in an attempt to reduce stress, some commercial drivers turn to smoking, excessive intake of unhealthy food, mostly sold around the transport interchange areas (i.e. taxi ranks), and engaging in sedentary activities. Most of these activities are the risk factors for metabolic syndrome (MetS). This study, aimed to investigate the sociodemographic and lifestyle factors predisposing South African minibus taxi drivers, operating around the Cape Town Metropole area, to develop MetS. This cross-sectional study included 185 20-year and older male minibus taxi drivers, who were interviewed about their sociodemographic characteristics, and lifestyle factors, using a previously validated questionnaire. They also underwent physical and metabolic assessments, and the International Diabetes Federation (IDF) criteria were used to diagnose those with MetS. Overall, the taxi drivers' mean age and driving experience were 40.0 years (SD: 10.7) and 9.1 years (SD: 7.4), with those presenting with MetS being significantly older and having more driving experience than those without MetS. Older participants and those with a driving experience of 8 years and more were 3 times significantly more likely to present with MetS than those younger and had 7 years or less of driving experience. Most taxi drivers (70%) met the IDF diagnostic criteria for MetS. Smokers, those who spent 100 ZAR (5.90 USD) or more and those who expended less than 1.4 MET-minute/week were 1.96, 2.0 and 13.6 times significantly more likely to present with MetS compared to their counterparts who did not smoke, those who spent less than 100 ZAR and those who expended 1.4 or more MET-minute/week. Alcohol and sugar-sweetened beverages (SSBs) consumption, as well as the consumption of takeaway and fried foods, snacks, and crisps sold by street food vendors, increased the likelihood of MetS, abnormal high density lipo-protein cholesterol (HDL-C), triglycerides (TG), and hypertension, while avoiding takeaway and fried foods decreased this likelihood. Those taxi drivers who also avoided consuming fresh fruits had low HDL-C, while those who consumed canned fish daily and 1–3 times a week had a reduced likelihood of MetS and elevated TG. These outcomes have a public health implication that calls for South African policymakers to endorse system-level approaches where taxi drivers' lifestyle changes are motivated within the taxi industry to improve their health risk profile.

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Sociodemographic and lifestyle factors and the risk of metabolic syndrome in taxi drivers: A focus on street food

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Background: In South Africa, similar to other populous countries, the taxi industry is an important form of transportation that contributes to the country's development. As a result, minibus taxi driving is an occupation characterized by strenuous activities such as long hours of driving, limited rest, and challenges related to securing passengers, among several others. Consequently, to combat stress, some commercial drivers resort to smoking, overeating unhealthy food sold at transportation interchange areas (i.e., taxi ranks), and participating in sedentary behaviors. Most of these activities are risk factors for metabolic syndrome (MetS).

Aim: Therefore, this study aimed to investigate the sociodemographic and lifestyle factors that predispose South African taxi drivers who work in the Cape Town Metropole area to the risk of developing MetS.

Methods: This cross-sectional study used a convenient sampling method that included 185 male minibus taxi drivers aged 20 years or above. The participants were interviewed using a validated questionnaire to gather information regarding their sociodemographic characteristics and lifestyle practices. They also underwent physical and metabolic assessments, and the International Diabetes Federation (IDF) criteria were used to diagnose people with MetS.

Results: Overall, the mean age and driving experience of the taxi drivers were 40.0 years (SD: 10.7) and 9.1 years (SD: 7.4), respectively, with those with MetS being significantly older and having more driving experience than those without. Older participants were 3 and 2.9 times more likely to be diagnosed with MetS than the younger participants. Most taxi drivers (70%) met the IDF diagnostic criteria for MetS. Smokers, those who spent more than 100 ZAR (USD 5.9) and those who spent less than 1.4 MET-minutes per week on physical activity were 1.96, 2.0, and 13.6 times more likely to suffer from MetS that those who were nonsmokers, those who spent less than 100 ZAR and those who spent <1.4 MET-minutes per week on physical activity. Consumption of alcohol and sugar-sweetened beverages (SSBs), as well as takeaway and fried foods, snacks, and sold by the SF vendors, increased the likelihood of developing MetS, abnormal HDL-C, TG, and hypertension, while avoiding takeaway and fried foods decreased this likelihood. Taxi drivers who also avoided consuming fresh fruits had abnormal HDL-C.

Conclusion: These findings have significant public health implications, highlighting the need for South African policymakers to adopt a system-level approach to promote lifestyle changes among taxi drivers within the taxi industry.

This can help reduce the health risks faced by these drivers and improve their overall health profile.

KEYWORDS

street food, metabolic syndrome, male taxi drivers, physical activity, socio-economic status, South Africa, waist circumference

Introduction

Several international epidemiological studies have found the prevalence of metabolic diseases to be high among occupational drivers compared to other professionals, such as industrial and office workers (1–3). For example, the majority of professional drivers are at an increased risk of hypertension, myocardial infarction, and hemorrhagic stroke (4). Furthermore, most drivers are in the habit of eating large main meals and consuming snacks (often oily and fried) and fast-food items from street vendors between trips. In addition, many of them resort to alcohol and smoking to overcome stress. It follows logically that they may have an additional risk of developing metabolic diseases. According to Kurosaka et al. (5), taxi driving is characterized by poor eating habits, ongoing stress from driving, and exposure to various health hazards such as air pollution and a lack of physical activity.

In South Africa, taxi drivers and commuters are major consumers of street food (SF) since it is relatively cheap and easily accessible at taxi ranks and bus stations (6, 7). According to Mchiza et al. (8) and Hill et al. (9), the food sold in the streets of Cape Town and surrounding areas seems to be a public health risk since it is energy-dense and high in saturated fat, trans fats, salt, and sugar. Taxi drivers working in these areas may be at risk of developing metabolic syndrome (MetS) as they have been identified to be among the 38% of individuals who consume SF almost daily (6).

Good health is a basic constitutional right for all South African citizens (10). The Occupational Health and Safety Act (OHSA) Section 12(C) (11) requires medical surveillance for all individuals who have high-risk occupations, such as taxi drivers. Similar to other countries, the taxi industry is an important form of transportation in South Africa, contributing to the country's development (12). However, less focus has been given to this industry to ensure that its workers are in good health. To the best of our knowledge, there has never been any health intervention directed at improving the health condition of taxi drivers in South Africa. Substantiated evidence (13–18) suggests that a healthy lifestyle, including healthy eating and regular physical activity, can help to reduce weight, reduce blood pressure, and improve lipid disorders, including raising high-density lipoprotein cholesterol (HDL-C) and lowering triglycerides (TGs). Moreover, unhealthy eating habits and a sedentary lifestyle are known as modifiable risk factors for MetS among taxi drivers (19).

To our knowledge, to date, there are no data on lifestyle and SF consumption in relation to metabolic syndrome (MetS) among minibus taxi drivers in the Western Cape, South Africa. The current study is the first of its kind in South Africa since it investigated the understudied population of minibus taxi drivers, examining their biochemical parameters, sociodemographic characteristics, and lifestyle practices, with a particular focus on SF consumption and the association of these factors with MetS and its components. The results of this study provide valuable insights for further public health research in this neglected field. Moreover, it will contribute to developing targeted interventions to curb the escalation of MetS in adult male South Africans, especially those working in long-duration driving business.

Materials and methods

Study participants and sampling size

This cross-sectional study was conducted among 185 professional taxi drivers, who were recruited from taxi ranks in Bellville and Cape Town. They were at least 20 years old. This study used a convenient sampling method, and its aim was not to make generalizations about the entire population but rather to focus on taxi drivers who consume SF. These taxi ranks were chosen because they are the two major transport interchange hubs in the Cape Metropolitan Area in South Africa's Western Cape Province. Some of the data used in this study were used in a previous paper (20). The detailed sample size selection, including the power sampling calculation for the current study, is presented elsewhere (20). The participants of this study were full-time minibus taxi drivers, who had been working in this field for at least 1 year and consumed SF at least three times per week. They donated blood samples that were analyzed in a laboratory to diagnose the presence of MetS. We excluded taxi drivers who had a history of non-communicable diseases (NCDs) such as hypertension, kidney failure, hypo- or hyper- thyroidism, liver diseases, known cardiovascular diseases (CVDs), or diabetes mellitus since their eating habits might have been changed based on the advice given by their health practitioners.

Data collection

Data on sociodemographic and lifestyle practices

A previously validated and structured questionnaire developed and validated for use in South Africans aged 15 years and older, which was successfully used in the first South African National Health and Nutrition Examination Survey (SANHANES-1) (21), was administered by a trained researcher to collect data on sociodemographic characteristics (i.e., age, marital status, race, and education level) and lifestyle practices (i.e., physical activity levels, alcohol consumption, and cigarette smoking) from the taxi drivers *via* face-to-face interviews. Moreover, the duration of

sleep, driving experience, and money spent on purchasing SF were assessed using a validated questionnaire used in the study by Hill et al. (6).

The International Physical Activity Questionnaire (IPAQ) (22) was also used to measure the level of physical activity (PA). The results were then based on the calculated physical activity levels (PAL) using the MET-minutes per week criteria. In this case, a sedentary lifestyle was regarded as PAL < 1.4 MET-minutes per week, with low being PAL between 1.4 and 1.69 MET-minutes per week, moderate being PAL between 1.7 and 1.9, and vigorous being PAL ≥ 2 (23).

Frequency of consuming street food

The SANHANES-1 questionnaire (21) was also used to collect information regarding the frequency of consuming street food (FF). The FF list comprised processed meat (i.e., sausages, polony, and cold cuts, such as Viennas, Frankfurters, Russians, and salami); fast food/takeaway foods, including pizzas, fried chicken, fried fish, and burgers, that were packaged to take home; fried meat and fish dishes (i.e., chips, fried chicken, and fried fish) that were consumed on site; deep-fried snacks (i.e., fries/chips, vetkoek, samoosas, and doughnuts), fresh fruits (i.e., all kinds of fruits, excluding fruit juices and dried fruits), sugar-sweetened beverages (SSBs) (i.e., gas/fizzy and reconstituted cold drinks). Consumption frequency for each food item was measured as "none", "every day", "1–3 times per week", and "4–6 times per week".

Anthropometric measurements

A nonelastic tape was used to measure the waist circumference (WC) at the narrowest point between the lower rib and the upper iliac crest. A cut-off point of ≥94 cm was used to determine abnormal WC levels in men (24).

Blood pressure

After the participant had been seated for 5 min or longer, three blood pressure (BP) readings were taken from the right arm in a sitting position using an electronic Micronta monitoring kit (25). Normal systolic BP (SBP) was regarded as a BP that was ≤ 130 mmHg or a diastolic BP (DBP) that was ≤85 mmHg (24).

Biochemical parameters

The fasting blood glucose (FBG) was estimated using the capillary method with a glucometer (OneTouch®). To measure biochemical parameters, a venous fasting blood sample was obtained. The plasma lipid profile was used for MetS analysis. The concentration of triglycerides was assessed using the phosphoglycerides oxidase peroxidase method, while the HDL-C was analyzed using the colorimetric non-precipitation method. The IDF criterion was used to diagnose MetS (26). According to the IDF definition, abdominal obesity (i.e., an abnormal WC reading) and two or more of the other four metabolic risk factors are required to diagnose MetS. The cutoff points for the five MetS risk factors are as follows: WC ≥94 cm for men; TG ≥ 1.7 mmol/l; SBP ≥ 130mmHg or DBP ≥ 85 mmHg; FBG ≥ 5.6 mmol/l; and HDL-C < 1.0 mmol/l.

Statistical analysis

Descriptive statistics were used to describe the basic features such as the categories, distribution, and spread of metabolic status, dietary intake, and lifestyle practices using sociodemographic characteristics. In this case, data were analyzed using the analysis of variance (ANOVA) and the Kruskal–Wallis tests and presented as frequencies, means, medians, and standard deviations, depending on whether they were categorical or continuous. The associations between different variables were analyzed using the Chi-square test. A binary logistic regression analysis was conducted to examine the odds ratios (OR). Multivariate analyses using multiple logistic regression models, which incorporated all risk factors for MetS while adjusting for the effect of possible confounders such as age, employment status, marital status, ethnicity, physical activity, and monthly income, were also applied (AOR). 95% confidence intervals (CIs) that did not overlap and *p*-values that were less than 0.05 indicated significant differences and associations between variable results. All data were analyzed using the statistical package for social sciences (SPSS version 28.0 for Windows; SPSS Inc., Chicago, IL, USA).

Results

Table 1 presents the sociodemographic characteristics of the study participants based on their MetS status. Overall, the mean age of the participants was 40.0 years (SD: 10.7), with those suffering from MetS being significantly older than those without. There were 10.2% more participants within the age group of 20–39 years. There was a significantly higher prevalence of participants with MetS in the older age group than in the younger age group (61 vs. 39%).

While there were no other significant differences in sociodemographic characteristics in relation to MetS in this cohort, the mean driving experience of the participants was 9.1 years (SD: 7.4). In this case, the participants who presented with MetS had significantly higher driving experience compared to those without. There was also a significantly higher prevalence of participants with MetS who had a driving experience of 8 years or more compared to those with a driving experience of one to seven years (59.7 vs. 40.3%).

Table 2 shows that older participants were 3 and 2.9 times more likely to have MetS than younger participants. While the significant association of MetS with age was unavailable when the data were adjusted for lifestyle practices (i.e., cigarette smoking, alcohol consumption, sleeping duration, physical activity level, and money spent on SF each day), it was available for age after we removed the confounding effects of the other sociodemographic variables explored in the current analysis.

When examining the components of MetS (Table 3), the overall mean values for WC, TG, HDL-C, SBP, DBP, and FBG were 99.1 (SD: 18.3), 1.3 (SD: 1.1), 1.1 (SD: 0.3), 133.4 (SD: 17.2), 84.8 (SD: 13.2), and 6.4 (SD: 3.5), respectively. We also observed that there were many participants with abnormal WC (59.5%), HDL-C (51.4%), and SBP (58.4%). However, there were few participants with abnormal TG (20.5%) and DBP (43.2%). The participants with MetS had significantly higher abnormal WC (64.5% vs. 35.5%), TG (81.6 vs. 18.4%), HDL-C (61.1 vs. 38.9%), SBP (50.9 vs. 49.1%),

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TABLE 1 The distribution of sociodemographic characteristics of South African minibus taxi drivers by metabolic syndrome status.

	N = 185	IDF MetS		*P* value
		No (*n* = 108)	Yes (*n* = 77)	
Age_(years)				
M ± SD	40.0 ± 10.7	37.3 ± 10.2	43.7 ± 10.3	<0.001
N(%)				
20-39	102 (55.1)	72 (66.7)	30 (39.0)	
≥40	83 (44.9)	36 (33.3)	47 (61.0)	<0.001
Ethnicity				
N(%)				
Black	146 (78.9)	85 (78.7)	61 (79.2)	
Non-Black	39 (21.1)	23 (21.3)	16 (20.8)	0.932
Level of Education *N* (%)				
No schooling/primary education	58 (31.4)	35 (32.4)	23 (29.9)	
Some high school/high education	127 (68.6)	73 (67.6)	54 (70.1)	0.714
Marital status				
N (%)				
Single/separated/divorced	97 (52.4)	60 (55.6)	37 (48.1)	
Married/living as married	88 (47.6)	48 (44.4)	40 (51.9)	0.314
Driving experience (years)				
M ± SD	9.1 ± 7.4	7.2 ± 6.1	11.7 ± 8.4	<0.001
N(%)				
1–7	103 (55.1)	72 (66.7)	31 (40.3)	
≥8	82 (44.3)	36 (33.3)	45 (59.7)	<0.001

IDF, International Diabetes Federation; MetS, metabolic syndrome.

DBP (67.5 vs. 32.5%), and FBG (64.1 vs. 35.9%) compared to those without.

Seventy-seven (n = 77) study participants met the IDF diagnostic criteria for MetS (i.e., had a clustering of 3 or more metabolic disorders), of which 46 had three (3) risk factors, 25 had four (4) risk factors, and 6 had five (5) risk factors. The distribution is shown in Table 4.

Table 5 presents the lifestyle practices based on the outcomes of MetS. Overall, the participants smoked an average of almost 10 cigarettes (SD: 5.3) a day, slept an average of 6.1 h (SD: 1.1) each day, spent an average of ZARR 92.1 (exchange rate: ZARR 1 = United States Dollar [USD]$ 17.23) (SD: 36.7) on SF each day, and had an average PAL of 1.42 MET-minutes per week (SD: 0.14). While there were no significant differences regarding the average number of cigarettes smoked by the participants or the average amount of money spent on SF between those who had MetS and those without MetS.

In terms of participant lifestyle distribution based on the MetS status, while there were no significant differences between participants with and without MetS for lifestyle practices such as alcohol consumption and sleeping duration, there were significantly higher number of nonsmokers who were positive for MetS (those who gave an affirmative response for smoking) and those who were negative for MetS (those who gave a negative response for smoking). There were also significantly more participants with MetS who spent ZARR 100 or more than those who spent less than 100 ZAR (57.1% vs. 42.9%, p=0.022). Finally, there were significantly more sedentary participants with MetS compared to those with low and moderate PAL (79.2% vs. 14.3% and 6.5%).

According to Table 6, smokers, those who spent ZARR 100 or more and those who spent <1.4 MET-minute/week were 1.96, 2.0, and 13.6 times significantly more likely to suffer from MetS compared to those who did not smoke, those who spent less than ZARR 100, and those who spent 1.4 or more MET-minute/week. While the increased significant likelihood of MetS for sedentary activity remained, even after removing the confounding effects of sociodemographic characteristics and other lifestyle practices explored in the current study, the likelihood of smoking and the amount spent on SF disappeared. It is also important to note that removing the confounding effects of the other lifestyle facts of the participants resulted in an increased significant likelihood for developing MetS by 2.2 and 2.1 times for those who consumed alcohol and those who slept 7 h or more, respectively.

The frequency of SF consumption in relation to the likelihood of developing MetS and its components was also analyzed and is presented in Supplementary Table 1. Approximately 40.0% of the

TABLE 2 A binary logistic regression analysis to show the association between the sociodemographic characteristics and the MetS status of South African minibus taxi drivers.

	IDF Metabolic syndrome											
				Model 1			Model 2			Model 3		
	Crude	95% CI	*P* value	AOR	95% CI	*P* value	AOR	95% CI	*P* value	AOR	95% CI	*P* value
Age (years)												
20–39	1			1			1			1		
≥40	3.133	1.706–5.756	<0.001	0.541	0.217–1.351	0.188	0.589	0.225–1.539	0.280	2.955	1.2955–6.969	0.013
Ethnicity												
Black	1			1			1			1		
Non-Black	0.969	0.473–1.987	0.932	0.908	0.356–2.312	0.839	0.991	0.378–2.597	0.986	0.560	0.245–1.280	0.169
Level of Education												
No schooling/primary education	1			1			1			1		
Some high school/high education	1.126	0.598–2.120	0.714	2.880	1.212–6.847	0.017	2.676	1.103–6.506	0.030	2.004	0.940–4.273	0.072
Marital status												
Single/separated/divorced	1			1			1			1		
Married/living as married	1.351	0.752–2.429	0.314	0.557	0.254–1.219	0.143	0.639	0.282–1.450	0.284	0.893	0.449–1.778	0.748

OR, odds ratio; AOR, adjusted odds ratio. Model 1: adjusted for Cigarette smoking, Physical Activity Level and Money spent on Street Food each day; Model 2: adjusted for Cigarettes smoking, Alcohol drinking, sleeping duration, Physical Activity Level and Money spent on Street Food each day; Model 3: adjusted for age ethnicity, level of education, marital status and driving experience.

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TABLE 3 The distribution of South African minibus taxi drivers by components of MetS.

	Entire cohort ($n = 185$)		IDF MetS				*P* value "between groups"
	Mean ± SD	*n* (%)	No MetS (77)		With MetS (108)		
			Mean ± SD	*n* (%)	Mean ± SD	*n* (%)	
Waist circumference (cm)	99.1 ± 18.3		90.7 (14.5)		110.8(16.7)		<0.001
Normal <94		75 (40.5)		69 (92.0)		6(8.0)	
Abnormal ≥94		110 (59.5)		39 (35.5)		71(64.5)	
Triglycerides (mmol/l)	1.3 ± 1.1		1.0 (0.4)		1.9(1.5)		<0.001
Normal <1.7		147 (79.5)		101 (68.7)		46(31.3)	
Abnormal ≥1.7		38 (20.5)		7 (18.4)		31(81.6)	
HDL-C (mmol/l)	1.1 ± 0.3		1.2 (0.4)		1.0(0.3)		<0.001
Normal ≥1.0		90 (48.6)		71 (78.9)		19(21.1)	
Abnormal <1.0		95 (51.4)		37 (38.9)		58(61.1)	
Systolic blood pressure (mmHg)	133.4 ± 17.2		127 (13.3)		141(18.8)		0.002
Normal <130		77 (41.6)		55 (71.4)		22(28.6)	
Abnormal ≥130		108 (58.4)		53 (49.1)		55(50.9)	
Diastolic blood pressure (mmHg)	84.8 ± 13.2		79 (9.1)		92.7(13.9)		<0.001
Normal <85		105 (56.8)		82 (78.1)		23(21.8)	
Abnormal ≥85		80 (43.2)		26 (32.5)		54(67.5)	
Fasting blood Glucose (mmol/l)	6.4 ± 3.5		5.3 (1.1)		7.9(4.8)		<0.001
Normal <5.5		93 (50.3)		75 (80.6)		18(19.4)	
Abnormal ≥5.5		92 (49.7)		33 (35.9)		59(64.1)	

HDL-C, high density lipoprotein cholesterol; IDF, international diabetes federation; MetS, metabolic syndrome.

TABLE 4 The distribution of South African minibus taxi drivers by the clustering of MetS components.

Number of metabolic disorders	*n* (%)
0	22 (11.9)
1	40 (21.6)
2	46 (24.9)
3	46 (24.9)
4	25 (13.5)
5	6 (3.2)

Metabolic disorders (abnormal WC, TG, SBP, DBP, HDL-C and FBG).

entire population consumed processed meat (sausages, polony, and cold cuts Viennas, Frankfurters, Russians, and salami) at least 1–3 times a week, with a significantly higher proportion (44.4%) of them experiencing abnormal BP compared to those with normal BP (37.5%). Similar results were also observed for the participants who consumed takeaway foods. Moreover, a higher proportion of participants with MetS and hypertension consumed fried food and snacks (i.e., chips, vetkoek, fried chicken, fried fish) compared to those who did not consume these foods. The daily consumption of deep-fried foods was also associated with an abnormal WC.

As illustrated in Table 7, consuming processed meat daily increases the risk of abnormal HDL-C by 3.7 times, while avoiding processed meat reduces hypertension. Further, avoiding takeout reduced the likelihood of developing MetS by 68.2% and abnormal TG by 25%. Daily takeout meal consumption increased hypertension risk by 3.1 times, even after adjusting for age and sociodemographic charactristics. The daily consumption of fried meat and fish increased the likelihood of developing MetS, abnormal WC, and hypertension by 2.1, 2.2, and 2.3 times, respectively. The association remained unchanged, even after removing the confounding effects of age, ethnicity, money spent on buying these foods, sociodemographic characteristic, and unhealthy lifestyle practices.

Moreover, the consumption of these foods 1–3 times a week increased the likelihood of developing abnormal HDL-C by 2.5 times, and this interaction also remained unchanged, even after removing all the confounding effects. The daily consumption of fried snacks also increased the likelihood of developing MetS, abnormal WC, abnormal HDL-C, and hypertension by 3.8, 1.7, 2.3, and 1.9 times, respectively. The consumption of packaged snacks such as crisps and amazimba (Niknaks Maize Snack) every day also increased the likelihood of abnormal HDL-C by eight times. Moreover, consuming these snacks 1–3 times a week increased the likelihood of developing MetS by 4.1 times. These interactions remained unchanged even after removing

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TABLE 5 The distribution of the South African minibus taxi drivers by their lifestyle risk factors (i.e., cigarettes smoking, alcohol consumption, physical activity level, sleep duration and money spent on street food each day) and MetS.

	Entire cohort ($n = 185$)	IDF metabolic syndrome		*P* value
		No ($n = 108$)	Yes ($n = 77$)	
	n (%)	*n* (%)	*n* (%)	*n* (%)
Cigarettes smoking				
Yes	80 (43.2)	54 (50.0)	26 (33.8)	
No	105 (56.8)	54 (50.0)	51 (66.2)	0.028
Average number of cigarettes smoked each day				
M ± SD	9.9 ± 5.3	9.3 ± 4.9	11.0 ± 5.9	0.179
1–5	24 (30.0)	17 (31.5)	7 (26.9)	0.793
6-9	7 (8.8)	4 (7.4)	3 (11.5)	
≥10	49 (61.3)	33 (61.1)	16 (61.5)	
Current alcohol drinking				
Yes	100 (54.1)	55 (50.9)	45 (58.4)	0.312
No	85 (45.9)	53 (49.1)	32 (41.6)	
Frequency of alcoholic beverage consumption				
Monthly or less	52 (36.9)	31 (36.9)	24 (37.0)	0.248
2–4 time a month	51 (34.2)	30 (35.7)	21 (32.3)	
2–3 times a week	28 (18.8)	12 (14.3)	16 (24.6)	
4 or more time a week	15 (10.1)	11 (13.1)	4 (6.2)	
Number of alcoholic beverages consumed on a typical day				
1 or 2	9 (9.0)	4 (7.3)	5 (11.1)	0.906
3 or 4	9 (9.0)	4 (7.3)	5 (11.1)	
5 or 6	59 (59.0)	34 (61.8)	25 (55.6)	
7,8 or 9	18 (18.0)	10 (18.2)	8 (17.8)	
10 or more	5 (5.0)	2 (5.5)	2 (4.4)	
Sleeping duration (hours)				
M ± SD	6.1 ± 1.1	6.1 ± 1.0	6.2 ± 1.2	0.624
n (%)				
<6	112 (60.5)	70 (64.8)	42 (54.5)	
≥7	73 (39.5)	38 (35.2)	35 (45.5)	0.159
Money spend on street food each day (ZAR)				
M ± SD	92.1 ± 36.7	88.6 ± 37.7	96.9 ± 34.9	0.056
N (%)				
<R99.00	96 (52.7)	63 (60.0)	33 (42.9)	
≥R100.00	86 (47.5)	42 (40.0)	44 (57.1)	0.022
Physical activity level (MET-minutes per week)				
N ± SD	1.42 ± 0.14	1.35 ± 0.12	1.51 ± 0.10	<0.001
Sedentary PAL				
<1.4	94 (50.8)	33 (30.6)	61 (79.2)	
Low PAL				
1.4-1.69	86 (46.5)	75 (69.4)	11 (14.3)	
Moderate PAL				<0.001
1.70-1.99	5 (2.7)	-	5 (6.5)	
Vigorous PAL				
≥2	-	-	-	

IDF, International Diabetes Federation; ZAR, South African Rand (exchange rate 17.23 United States Dollar); PAL, physical activity level.

TABLE 6 Binary logistic regression analysis to show the association between the lifestyle factors and MetS status of the South African minibus taxi drivers.

	IDF—metabolic syndrome											
	Crude			Model 1			Model 2			Model 3		
	OR	95% CI	*P* value	AOR	95% CI	*P* value	AOR	95% CI	*P* value	AOR	95% CI	*P* value
Current cigarettes smoking												
No	1	1.072–3.590	0.029	1	0.301–1.063	0.077	1	0.318–1.142	0.120	1	0.270–1.208	0.143
Yes	1.962			0.566			0.602			0.571		
Alcohol consumption												
No	1			1			1			1		
Yes	1.355	0.751–2.444	0.312	1.776	0.935–3.374	0.079	1.706	0.886–3.287	0.110	2.191	1.021–4.699	0.044
Sleeping duration												
<6	1			1			1			1		
≥7	1.535	0.844–2.791	0.160	1.558	0.832–2.915	0.166	1.497	0.786–2.851	0.220	2.107	0.977–4.521	0.057
Money spends on street food each day (ZAR)												
<R99.00	1			1			1			1		
≥R100.00	2.000	1.101–3.633	0.023	1.225	0.619–2.423	0.560	1.400	0.691–2.838	0.350	1.157	0.548–2.441	0.702
PAL (MET−minutes per week)												
Active (low, moderate and vigorous) PAL≥1.4	1	6.388–29.109	<0.001	1	5.449–29.354	<0.001	1	5.769–32.780	<0.001	1	6.769–36.891	<0.001
Sedentary (<1.4)	13.636			12.647			13.751			15.802		

IDF, International Diabetes Federation; ZAR, South African Rand (exchange rate 17.23 United States Dollar); PAL, physical activity level; OR, odds ratio; AOR, adjusted odds ratio = Model 1: adjusted for age and driving experience; Model 2: adjusted for age, ethnicity, level of education, marital status and driving experience; Model 3: adjusted for tobacco smoking, alcohol consumption, sleeping duration, PAL and money spent on street food each day.

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TABLE 7 The logistic regression analysis to show the association between the street foods consumed by the South African minibus taxi drivers and their MetS status.

	MetS		Abnormal WC		Abnormal FBG		Abnormal HDL–C		Hypertension		Abnormal triglyceride	
Frequency of food consumption	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Processed meat (sausages, polony, and cold cuts Viennas, Frankfurters, Russians, salami)												
None	0.963	0.416–2.227	1.024	0.477–2.199	0.842	0.390–1.819	1.056	0.477–2.376	0.413*	0.182–0.937	1.165	0.459–2.957
Every day	1.143	0.318–4.109	0.594$	0.208–1.702	0.605$	0.205–1.783	3.667*#○@$^	4.881–15.264	1.353	0.461–3.975	0.879	0.200–3.859
1–3 times last week	0.830	0.366–1.882	1.007	0.481–2.107	0.756	0.357–1.599	0.850	0.388–1.860	0.831	0.390–1.768	0.563	0.210–1.506
4–6 times last week	1		1		1		1		1		1	
Takeaway food (pizza, burgers, chicken and fish parcels)												
None	0.318*	0.115–0.878	1.618	0.266–9.852	0.865	0.163–4.602	1.250	0.173–9.019	0.767	0.075–7.860	0.750*○@$	1.574–67.602
Every day	1.227	0.263–5.734	1.014	0.448–2.298	1.300	0.583–2.899	0.833	0.338–2.052	3.097*#$	1.123–8.544	3.055	0.680–13.729
1–3 times last week	0.738	0.275–1.981	0.518	0.177–1.514	1.615	0.538–4.853	0.917	0.276–3.040	1.533	0.402–5.841	1.853	0.277–12.389
4–6 times last week	1		1		1		1		1		1	
Fried meat and fish dishes (chips, vetkoek, fried chicken, fried fish)												
None	1.778	0.236–13.405	1.200$	0.471–3.056	1.059	0.406–2.762	1.128	0.393–3.236	1.310	0.465–3.684	2.000	0.533–7.508
Every day	2.051*#○@$^	1.757–5.558	2.223*#○@^	1.007–4.904	1.310	0.595–2.882	1.974	0.851–4.580	2.278*	1.977–5.312	2.082	0.696–6.227
1–3 times last week	1.697	0.447–6.439	1.079	0.850	1.116	0.501–2.486	2.538*#○@$^	1.089–5.918	0.776	0.314–1.916	1.358	0.437–4.228
4–6 times last week	1		1		1		1		1		1	
Fried snacks (vetkoek, samoosas, doughnuts)												
None	1.786	0.550–5.802	0.457	0.191–1.096	1.315	0.551–3.138	1.875	0.678–5.182	0.483	0.180–1.301	0.520	0.139–1.945
Every day	3.772*○@	1.479–9.616	1.760#○	0.693–4.470	1.004	0.431–2.342	2.333*#	2.880–6.188	2.194*	1.927–5.191	1.354	0.459–3.998
1–3 times last week	1.875	0.730–4.816	0.656	0.320–1.342	0.994	0.494–2.001	2.035	1.898–4.611	0.842	0.403–1.703	0.780	0.303–2.006
4–6 times last week	1		1		1		1		1		1	
Packaged snacks (chips/crisps, mazimba)												
None	3.036	0.593–15.547	0.606	0.186–1.977	0.643	0.201–2.052	3.354	0.716–18.637	0.381	0.117–1.241	3.056	0.351–26.593
every day	3.125	0.474–20.583	0.273	0.063–1.178	1.111	0.262–4.719	8.000*#○@$^	1.215–52.693	0.889	0.216–3.662	3.300	0.294–37.103
1–3 times last week	4.113*○@^	1.862–19.626	0.739	0.244–2.237	0.705	0.239–2.086	6.538$	1.373–31.132	0.660	0.226–1.926	3.075	0.379–24.933
4–6 times last week	1		1		1		1		1		1	
Sugar Sweetened beverages (gas/fizzy cold drink and reconstituted)												
None	0.545	0.133–2.236	0.541	0.186–1.577	0.923	0.317–2.685	0.426	0.127–1.427	0.500	0.127–1.965	0.967	0.229–4.087
Every day	1.660*	1.796–3.461	1.164	0.608–2.228	1.620	0.850–3.088	0.833	0.416–1.668	1.691	0.848–3.372	0.767	0.324–1.812
1–3 times last week	1.889	0.772–4.619	0.854	0.383–1.904	0.997	0.444–2.235	1.193	0.502–2.833	1.442	0.610–3.409	1.364	0.507–3.669
4–6 times last week	1		1		1		1		1		1	

FF, food frequencies; OR: *$p < 0.05$; #Model 1= AOR, $p < 0.05$ adjusted for age; ○Model 2 = AOR, $p < 0.05$ adjusted for ethnicity; @Model 3 = AOR, $p < 0.05$ adjusted for money spent on street food each day; $Model 4 = AOR, $p < 0,05$ adjusted for all socio demographic status, ^Model 5 = AOR, $p < 0.05$ adjusted for all lifestyle factors.

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the confounding effects such as age, ethnicity, money spent on these foods, and sociodemographic status, and unhealthy lifestyle practices. The daily consumption of SSB increased the likelihood of developing MetS by 1.6 times. However, this interaction disappeared after removing the confounding effects such as age, ethnicity, money spent on these foods, sociodemographic characteristics, and unhealthy lifestyle practices.

Discussion

The current study aimed to investigate the risk factors for MetS among the male minibus taxi drivers working in Cape Town and the surrounding areas. The majority of the taxi drivers had abnormal levels of WC, HDL-C, SBP, and FBG. Approximately 70% of the taxi drivers had clusters of three or more of these health issues. These results are corroborated by both national and international literature that show that individuals who are in the long-duration driving occupation, including taxi drivers, have a high likelihood of developing metabolic disorders compared to other professionals such as industrial and office workers (1–3, 27–30). In addition, these studies also identified age, driving duration, and driving experience as factors that accelerate the onset of these metabolic diseases (31–34). More importantly, Hildrum et al. (35) long argued that this condition strongly increases with age, regardless of any algorithm used to measure MetS. Indeed, in the current study, the mean age of the minibus taxi drivers was 40 years, with older participants having more driving experience compared to their younger counterparts. Even though the current analysis did not demonstrate a significant relationship between driving experience and MetS, it showed that old age increased the likelihood of developing MetS by up to 2.95 times.

Moreover, like in the current study, the majority of occupational drivers involved in other studies (28, 36) reported sleeping hours that are less than the recommended 6 h of sleep each day (37). This may be due to these drivers' long and irregular shift hours (28, 31). Unlike the aforementioned international researchers who reported sleep duration and its quality as the determinants of MetS, in the current study, the association between sleeping duration and MetS was significant. However, it is important to note that the majority of the minibus taxi drivers participating in the current research also reported long working hours such that their daily shifts started as early as 5 am most days and sometimes ended after 10 pm. They cite reasons such as the need to secure passengers who start work early and those who knock off late in the evenings from work because of their long working hours.

In the current study, despite no significant differences observed in the number of cigarettes smoked by those who had MetS and those without MetS, on average, the minibus taxi drivers smoked almost 10 cigarettes each day, and smoking increased their likelihood of developing MetS by up to two times. However, this interaction disappeared after we removed the confounding effects, such as sociodemography and other lifestyle practices investigated in the current study. Therefore, this suggests that factors such as age, ethnicity, the number of cigarettes smoked, and so on moderate propensity of smoking and the likelihood of developing MetS. Additionally, while some of the literature (32, 33) could not establish a relationship between smoking and the likelihood of developing MetS among occupational drivers, Appiah et al. (38) found that non-users of tobacco are less likely to suffer from MetS and its components. Mohebbi et al. (31) also showed that smokers are more likely to suffer from with MetS than nonsmokers. It is also important to explain the differences in the results regarding smokers between the current study and a recent study by Mabetwa et al. (32), which was also conducted for South African taxi drivers. Mabetwa et al.'s (32) study was conducted in the Gauteng province, while the current study was conducted in the Western Cape province. According to Statistics South Africa (39), Cape Town has the highest concentration of male smokers in South Africa. Additionally, it is commonly reported that smokers often smoke in public places, increasing the likelihood of exposure to secondhand smoke for nonsmokers. Therefore, we observed a high prevalence of MetS among nonsmokers in the current study. Moreover, it is important to highlight that the prevalence of smokers in the current study was higher than that of smokers reported in Mabetwa's study (43 vs. 30%).

In the current study, we also found results suggesting that minibus taxi drivers with a sedentary lifestyle had a 13-fold increased risk of developing MetS. This relationship remained strong even after removing the confounding effects such as sociodemography and other lifestyle factors investigated in the current study. This study indicates that physical activity has an independent and significant impact on metabolic health independently, regardless of other social determinants of health. These results are corroborated by substantiated evidence from international studies(40, 41) suggesting a significant negative correlation between physical activity and the likelihood of developing MetS among bus and taxi drivers. Moreover, Chen et al. (1) showed that sedentary occupations, including taxi driving, increase the risk of developing MetS. Several international studies have shown the dose–response relationship between physical activity and metabolic outcomes (13–18). According to Myers et al. (42), most active individuals generally have a low risk of developing metabolic diseases. Additionally, the aforementioned studies found that even meeting the minimal physical activity requirements outlined in the health guidelines (14) (i.e., at least 150 min per week of moderate-intensity activity or 75 min per week of vigorous activities) has significant benefits for reducing metabolic risk. However, we also have to acknowledge that, in our analysis, even though the participants who suffered from MetS had a higher PAL than those without MetS, their activity levels were still within the low PAL range (i.e., they were within the range of 1.4 and 1.7 Met-minutes per week). Thus, the average 1.51 MET-min per week dosage they obtained could not improve their metabolic health. We also must acknowledge that other studies could not find a significant association between physical activity and MetS (32, 38). The reason for this is currently unknown and needs further investigation.

Other interesting results from the current research were that the type and quality of food and beverages consumed by minibus taxi drivers impacted their metabolic health. For instance, when the confounding effects of other lifestyle factors were removed from the current study, alcohol consumption increased the risk of MetS by

up to two times. Even though we did not measure the exact amount of alcohol consumed by the minibus taxi drivers participating in our research, the majority reported that they consumed alcoholic beverages that ranged from 5 to 9 standard drinks most days. This is a cause for concern given that studies by Hernández-Rubio et al. (43) and Fan et al. (44) found that heavy drinking is independently associated with reduced kidney function and metabolic risk factors such as impaired fasting glucose/diabetes mellitus, abdominal obesity, arterial stiffness and plaque buildup, hypertension, and dyslipidemia. In the current analysis, we also found that the consumption of takeaway foods, fried foods, and snacks such as crisps and SSB sold by the SF vendors increased the likelihood of developing MetS, abnormal HDL-C, TG, and hypertension. We also found that avoiding takeaway and fried foods decreased the likelihood of MetS.

International research by Kim and Je (45) corroborates our finding in that individuals with MetS generally consume large quantities of processed meat (such as sausages, polony, and cold cuts such as Viennas, Frankfurters, Russians, and salami). Furthermore, the aforementioned study also found that participants in the highest category of total meat, red meat, and processed meat consumption had an increased risk of developing MetS by approximately 14, 33, and 35%, respectively, compared to those in the lowest consumption category of these foods. A meta-analysis of studies (46, 47) revealed a strong correlation between the consumption of red meat and the likelihood of developing MetS after excluding studies from Asia. For instance, Pan et al. (48) found that even a slight increase in the daily consumption of red and processed meat had a 14% and 32% increase in the likelihood of type 2 diabetes mellitus, respectively. Abete et al. (49) also found high rates of mortality due to metabolic disorders in populations with high consumption of processed meat.

Some potential mechanisms have been explained to indicate the association between processed meat consumption and the likelihood of developing MetS. Among these are the findings that total and saturated fat contained in processed meat increase the risk of MetS through increased body fat centralization, hyperinsulinemia, and hyperglycemia, which are important components of MetS (50). According to Abete et al. (49), the aforementioned mechanism is mediated by nitrosamines. This chemical is toxic to pancreatic cells formed from the nitrates used as preservatives in processed meat. Additionally, these compounds cause insulin resistance.

Moreover, Marku et al. (51) argue that because iron is a strong pro-oxidant, it causes oxidative stress, which can harm tissues such as pancreatic beta cells. Furthermore, the aforementioned researchers argue that high iron levels may inhibit glucose metabolism and reduce pancreatic insulin synthesis and secretion. Based on the literature, we must also acknowledge that high levels of inflammatory mediators, such as C-reactive protein, in people who consume a high amount of red and processed meat could be another reason for the increased risk of MetS. Because C-reactive proteins also increase blood pressure (52), this could explain the association we found in the current research between the consumption of processed meat and hypertension. Griep et al. (53) reported similar results that suggest high consumption of processed meat is positively associated with the risk of hypertension. Another possible explanation for our findings may be those given by Micha et al. (54), who suggest that the high sodium content of processed meat results in elevated blood pressure.

Our current study further found the association between MetS risk and high consumption of fried food bought from street vendors and consumed on-site (i.e., fries/chips, vetkoek, fried chicken, and fried fish, to be specific). Our results were unsurprising given that the food sold on South African streets, including at the transport interchange areas where we recruited our participants, is not healthy. Additionally, Mchiza et al. (8) and Flores et al. (55) showed that, besides fruits and vegetables, most of the SF sold by vendors are not healthy as they are deep-fried, which is associated with cardiovascular risks. However, we must acknowledge that not all researchers have found associations between fried food and the risk of MetS. For instance, upon investigating a Mediterranean cohort of young Asian adults, Sayon-Orea et al. (56) and Kang and Kim (57) found no association between MetS and the frequency of consuming fried foods. The differences between the results of our study and those of the aforementioned Asian studies could be based on the type of food groups included in the current study and the two Asian studies; among the four groups of fried food included in the Asian studies were fried vegetables, fried fish, and fried seaweed. Therefore, we must always be cognizant of the literature that associates plant foods and fish with preventing metabolic diseases (58, 59). In the current study, on the other hand, the four groups of fried food were deep-fried potato chips (or French fries), vetkoek (a cake of deep-fried dough that is stuffed inside), fried chicken, and fried fish. In this case, fried vegetables and seaweeds impact health differently than fried potatoes and fried starch. Finally, the frying mechanisms in these studies were also different. In Asia, pan frying is mostly preferred, while deep frying is favored in South Africa, and these cooking methods have also been shown to impact health differently (60, 61).

This study's results found a statistically significant association between fast-food consumption and MetS risk. These results are consistent with those of Bahadoran et al. (62), where they showed evidence that regular fast-food consumption has a detrimental effect on general health and can increase the risk of obesity, insulin resistance, and other metabolic abnormalities. Several mechanisms have been proposed to explain the negative effects fast foods have on health outcomes. One such mechanism is that fast foods are energy-dense, thus modulating the weight gain process (63). Indeed, Mchiza et al. (8) showed that most fast foods sold in the streets of South Africa are energy dense and have an energy density that is almost two times the recommended energy for a healthy meal. Moreover, the mean total energy of these meals is estimated to be approximately 158–163 kcal per 100 g of food, with the total fat percent of beef hamburgers, chips, chicken hamburgers, and hot dogs being reported to be about 35.8 ± 10.7, 35.8 ± 8.7, 23.0 ± 5.1, and $34.0 \pm 13.5\%$, respectively, with most of this fat being saturated fat (64).

The current study also showed that consuming packaged snacks (chips/crisps and mazimba) 1–3 times a day was associated with an increased risk of developing MetS. In agreement with this study's results, a significant relationship was also shown between dyslipidemia and the frequency of consumption of hydrogenated

fat, fast foods, cheese puffs, and crisps in both urban and rural areas of Iran (65).

The current analysis also showed that the consumption of SSBs increased the risk of MetS by up to 1.8 times. Consistent with this study's are a few international studies (66, 67) that reported that SSB intake has significant effects on MetS risk. Moreover, a study conducted on 596 young adult South Africans by Seloka et al. (68) also showed that high consumption of SSBs increases the risk of high FBG in men. This is not a surprise since Deshpande et al. (67) have long shown that sweetened beverages disrupt the hormones involved in regulating energy balance and the satiety center within the human limbic system, which may lead to overeating and result in an increase in positive energy balance in the body. Therefore, the results are body weight gain and an increase in WC. It is also important to note that the SSBs that were included in our study consisted of cold drinks and reconstituted gas/fizzy drinks. Overconsumption of fructose and sucrose from these SSBs has been shown to stimulate and initiate lipid production in the liver, resulting in higher serum triglyceride and cholesterol levels, visceral fat accumulation, and plaque buildup (69). Moreover, glucose in SSBs has a higher glycaemic index, which can cause high blood glucose spikes and may lead to glucose intolerance, insulin resistance, and an increase in inflammatory biomarkers (70).

Finally, in the current study, we found that avoiding the consumption of fresh fruits increased the likelihood of developing abnormal HDL-C. Although we could not specify the type, color, and amount of fruit we referred to in our research, we could attribute these significant interactions to the fiber and antioxidants that fresh fruit and vegetables have, which are compounds that have been shown to mitigate metabolic risks (71). Although several epidemiological studies have evaluated the association between fruit and vegetable consumption and the risk of MetS, the results remain controversial. For instance, some studies have emphasized fruits' and vegetables' roles in mitigating metabolic disease risk or eliminating the disease entirely (72–74), while others have shown the opposite or no association at all with disease downregulation (75). However, a meta-analysis of international studies by Tian et al. (76) cleared up the controversy by showing that, when data from these studies were combined, high fruit and vegetable consumers were 13% and 24% less likely to have MetS, respectively. This meta-analysis of 78 studies further investigated the relationship between the consumption of fruits, vegetables, and MetS risk. When these researchers stratified these interactions by continent, the inverse association of fruit and vegetable consumption was observed to be OR: 0·86 (0·77, 0·96) and OR: 0·86 (0·80, 0·92), respectively, with the risk of MetS remaining significant in Asia. Based on these results, they concluded that people should consume more fruits and vegetables to reduce the risk of metabolic diseases. However, we should be cognizant of the amount, type, and quality of fruit and vegetables that bring about this kind of health benefit. Studies by Nguyen et al. (77) and Sharma et al. (78) suggest that plant foods high in fiber, such as brown and white rice, have greater metabolic health benefits. Numerous substantiated pieces of evidence suggest that the consumption of good fatty acids can prevent MetS risk and its components (79–83). Sekgala et al. (81), in their recent research, eloquently indicated that substituting SFA for PUFA significantly decreases the likelihood of elevated BP by 7%.

To end the aforementioned arguments, it is also important to highlight that, unlike many studies conducted in South African populations with financial constraints, the current study was based on a population that could afford to procure food. Hence, the majority spent more than ZARR 100 on buying SF. A hundred ZAR and more a day is way above the recommended amount (ZARR 40 per day) per person recommended as enough budget to spend on healthy food each day. Abraham et al. (84) have long suggested that, on average, for an adult South African man, a healthier diet costs ZARR 17.3 (which is about USD$ 1) per day. In the current research, the minibus taxi drivers who spent more than ZARR 100 on SF had two times greater risk of MetS than their counterparts who spent ZARR 99 or less. This adverse outcome of MetS could be attributed to the unhealthy food options readily available near transportation hubs. While this relationship was lifestyle and sociodemography dependent, the amount spent on SF was not found to be the mediator/moderator of the type of foods purchased and consumed by the minibus taxi drivers included in the current study.

Limitation

Despite the notable and important results of the current study outlined above, there are a number of limitations to this study that need to be considered. First, the study was cross-sectional. Hence, causal inferences cannot be drawn from this study's results. Second, the results of the current study focused only on South African male taxi drivers. Therefore, they can only be generalized to occupational drivers in the long-duration driving business but not to the general population. Finally, even though most of the major confounders have been taken into account in most of the studies, there is still a chance of unmeasured and residual confounding factors impacting in the current study. The confounders that were taken into account in the current study were also different from those in the other international studies that have been used to corroborate/contrast this study's results. Hence, notable differences were observed.

Conclusion

In the current study, we have shown the significant determinants of MetS and its components among South African minibus taxi drivers who presented with abnormal levels of WC, HDL-C, SBP, and FBG, of whom 70% were diagnosed to have MetS according to the IDF diagnostic criteria. Among these important determinants of MetS, we showed that sociodemographic factors such as age and high experience in taxi driving are significantly associated with MetS risk and its components. Moreover, lifestyle factors such as fewer sleeping hours, smoking many cigarettes each day, alcohol and SSB consumption, spending a lot of money on SF, and being sedentary impacted the minibus taxi drivers' metabolic health. More importantly, the consumption of fried food, processed foods, and commercially packaged snacks like crisps, obtained as takeaways, increased the likelihood of minibus taxi drivers developing MetS and its components. However, avoiding the consumption of takeaway and fried foods reduces the risk of MetS. Finally, avoiding the consumption of fruit increased MetS

risk. These results have significant public health implications, as policymakers need to adopt evidence-based strategies to encourage a healthy lifestyle among South African men, especially minibus taxi drivers.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by Ms. Patricia Josias Research Ethics Committee Officer University of the Western Cape. The patients/participants provided their written informed consent to participate in this study.

Author contributions

MS and ZM: conceptualization and funding acquisition. MS: formal data analysis, methodology, and writing–original draft. ZM and MO: supervision, writing, review, and editing. BM: biochemical analysis. All authors contributed to the article and approved its submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2023.1112975/full#supplementary-material

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Chapter 7: Association between macronutrient and fatty acid consumption and metabolic syndrome: A South African taxi driver survey

Machoene Derrick Sekgala, Maretha Opperman, Buhle Mpahleni, Zandile June-Rose Mchiza.

Abstract:

We aimed to examine the association between macronutrient and fatty acid intake and metabolic syndrome (MetS) and its components in South African male mini-bus taxi drivers. One hundred and eighty-five (n = 185) male taxi drivers, aged 20 years and older, who operate in the Cape Town metropole, South Africa, were included. The International Diabetes Federation (IDF) algorithm was used to define MetS. The association between macronutrient and fatty acid intake (assessed using 24 h recall) and MetS were analyzed using multivariable nutrient density substitution models. Overall, protein consumption significantly increased the likelihood of high blood pressure (HBP) and significantly lowered the likelihood of having low levels of high-density lipoprotein cholesterol (HDL-C). In an isoenergetic state, the intake of protein instead of carbohydrates (CHOs) and total fat, reduced the likelihood of elevated triglycerides by 6.7% and 6.6%, respectively. The intake of CHOs instead of protein and total fat, reduced the likelihood of HBP by 2.2% and 2.8%, respectively. In the same isoenergetic state, the intake of saturated fatty acids (SFAs) instead of mono-unsaturated fatty acids (MUFAs) increased the likelihood of HBP by 9.8%, whereas the intake of polyunsaturated fatty acids (PUFAs) instead of SFAs decreased the likelihood of HBP by 9.4%. The current study showed that when total food energy intake is kept constant, a diet that is high in protein, CHOs and PUFAs reduces triglycerides and BP, whereas the intake of total fat and SFAs had the opposite effect. It should, however, be noted that these outcomes were produced using mathematical models, as such we recommend further prospective studies in real life that will reveal the actual associations between the consumption of macronutrients and fatty acids and MetS and its components.

Keywords: macronutrient intake; fatty acids intake; metabolic syndrome; substitution mode; diet; South African taxi drivers

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Association between Macronutrient and Fatty Acid Consumption and Metabolic Syndrome: A South African Taxi Driver Survey

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Abstract: We aimed to examine the association between macronutrient and fatty acid intake and metabolic syndrome (MetS) and its components in South African male mini-bus taxi drivers. One hundred and eighty-five (n = 185) male taxi drivers, aged 20 years and older, who operate in the Cape Town metropole, South Africa, were included. The International Diabetes Federation (IDF) algorithm was used to define MetS. The association between macronutrient and fatty acid intake (assessed using 24 h recall) and MetS were analyzed using multivariable nutrient density substitution models. Overall, protein consumption significantly increased the likelihood of high blood pressure (HBP) and significantly lowered the likelihood of having low levels of high-density lipoprotein cholesterol (HDL-C). In an isoenergetic state, the intake of protein instead of carbohydrates (CHOs) and total fat, reduced the likelihood of elevated triglycerides by 6.7% and 6.6%, respectively. The intake of CHOs instead of protein and total fat, reduced the likelihood of HBP by 2.2% and 2.8%, respectively. In the same isoenergetic state, the intake of saturated fatty acids (SFAs) instead of mono-unsaturated fatty acids (MUFAs) increased the likelihood of HBP by 9.8%, whereas the intake of polyunsaturated fatty acids (PUFAs) instead of SFAs decreased the likelihood of HBP by 9.4%. The current study showed that when total food energy intake is kept constant, a diet that is high in protein, CHOs and PUFAs reduces triglycerides and BP, whereas the intake of total fat and SFAs had the opposite effect. It should, however, be noted that these outcomes were produced using mathematical models, as such we recommend further prospective studies in real life that will reveal the actual associations between the consumption of macronutrients and fatty acids and MetS and its components.

Keywords: macronutrient intake; fatty acid intake; metabolic syndrome; substitution mode; diet; South African taxi drivers

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1. Introduction

Metabolic syndrome (MetS) is defined as a cluster of metabolic disorders, which include central obesity, abnormal blood glucose levels, dyslipidemia and hypertension [1] [2]. According to Sekgala et al. (2018) [3], the current prevalence of MetS in adult South African men is more than 23% and is even higher among male mini-bus taxi drivers [4]. Metabolic syndrome has also been linked to an increased risk of cardiovascular disease (CVD), diabetes and chronic kidney diseases [5]. Even though the etiology of MetS is not fully understood, the interaction of genetics, lifestyle and environmental factors have been implicated in the development of MetS [6]. Among lifestyle factors, dietary intake is

receiving the most attention and, as a result, comprehensive dietary-related interventions have been proclaimed to improve all aspects of MetS [7,8].

Despite the aforementioned evidence, to date, no specific diet has been shown to treat MetS in totality. Some studies have found that the Mediterranean [9,10] and DASH [11] diets can help to improve MetS and its components. However, the evidence suggests that a diet that is high in CHOs raises serum triglycerides, lowers serum high-density lipoprotein cholesterol (HDL-C) and impairs glucose metabolism, all of which are MetS components [12,13].

Through a Korean population-based survey among 6737 males and 8845 females, Kwon et al. (2018) [14] aimed to examine the role of CHOs and fat intake in MetS. The reported outcomes suggested that most males who consumed high proportions of CHOs in their diet presented with MetS. However, other studies produced conflicting findings between CHO intake and MetS risk [15–17]. For instance, in a cross-sectional study by Motamed et al. (2013) [18], which included 3800 men and women between the ages of 35 and 65 years, no significant relationship was indicated between CHO intake and MetS. Additionally, Eilat-Adar et al. examined the association between macronutrient intake, gender, MetS and insulin resistance (IR) among non-diabetic American Indians. In both men and women, no association was found between macronutrient intake and the prevalence of MetS [19]. A cross-sectional study of 1626 patients with a history of cardiovascular disease was conducted by Skilton et al. (2008) [20]. Conversely, their study showed that high CHO consumption reduced the prevalence of MetS.

Evidence has also shown that foods that are high in saturated fatty acids (SFAs) increase the risk of MetS [21]. Several studies have shown that the consumption of vegetable fat as opposed to animal fat is associated with a lower incidence of cardiometabolic disease and diabetes mellitus [22,23]. More importantly, there is evidence that the different types of fatty acids affect MetS differently. SFA consumption aggravates IR, whereas mono- and polyunsaturated fatty acid (MUFA and PUFA) consumption has the opposite effect [24].

It has been further indicated that high fat, salt and sugar, and low complex CHO eating habits among the South African population demonstrates a transition to a westernized diet over the last two decades [25–27]. This nutrition transition has been escalated by the dominance of big food (large retail markets) [28,29], which makes unhealthy food available in South African retail and informal markets. Moreover, the South African food environment, especially the food that is sold in the streets of South Africa, does not foster good health [30].

Despite the findings between macronutrients and the prevalence of MetS being contentious, we acknowledge that the proportions and types of macronutrients and fat in individuals' diets may either impair health or result in the successful prevention and treatment of MetS and its components in South Africa—hence the current study. We ought to mention that a previous analysis on the same population examined MetS's predictive power of anthropometric indices to determine the cut-off points and to identify male South African taxi drivers with MetS [4]

We, therefore, in the current study, conducted mathematical models to allow for the hypothetical substitution of one macronutrient or fatty acid for another, within an isoenergetic condition, to determine whether there is an association with the metabolic outcomes of male taxi drivers operating in the urban areas of South Africa. The relationship between macronutrient and fatty acid intake—with health markers such as waist circumference (WC), diastolic and systolic blood pressures (DBP and SBP), fasting blood glucose (FBG), dyslipidaemia (low-density lipoprotein (LDL-C)), HDL-C triglycerides and the clustering of MetS components—were included in the models. To the best of our knowledge, there is no study that has considered macronutrient substitution and the risk of MetS in South Africa. Furthermore, no literature could be found on a diet customized to prevent or reduce MetS within a South African context. Hence, we attempted to use the multivariable nutrient density substitution models to examine the association between

macronutrient and fatty acid intake and MetS and its components in male mini-bus taxi drivers operating in the urban areas of South Africa. The outcomes of this research will be used to influence the interventions directed at preventing and reducing the prevalence of metabolic disorders in South Africa, especially among men working in the mini-bus taxi driving industry.

2. Materials and Methods

2.1. Study Population

This research formed part of a cross-sectional study, conducted with 237 male mini-bus taxi drivers, aged 20 years and older (mean age 39.9 ± 10.5 years), who operated in the Cape Town metropole, South Africa. For the current analysis, 185 taxi drivers who consumed street food at least three times a week; those who had at least one year of full-time employment as a mini-bus taxi driver; and those who donated a blood specimen, which was analyzed in the laboratory to estimate the MetS components, were included. Taxi drivers who had a history of underlying diseases including hypertension, kidney failure, hypo/hyperthyroidism liver diseases, known cardiovascular disease and diabetes mellitus were excluded from the analysis. More details of the study sample are presented elsewhere [4]. The protocol of the study was approved by the Biomedical Science Research Ethics Committee of the University of the Western Cape (ethics reference number: BM20/6/8). Informed consent was also obtained from all the participants.

2.2. Assessment of Socio-Economic and Lifestyle Variables

A previously validated questionnaire, which was used for the South African National Health and Examination Survey (SANHANES-1) [31], was used in this study to record information on sociodemographic characteristics—including age, sleeping duration, driving experience, money spent a day on SF, educational level, smoking status, race, marital status and alcohol intake. Age and driving experience were recorded in years. The sleeping duration was recorded in hours. Educational level was categorized as 1 = no schooling or primary, 2 = some high school and higher education. Smoking status was categorized as 1 = current smoker and 2 = non-smoker. Race was categorized as 1 = black and 2 = non-black. Marital status was categorized as 1 = single/separated or divorced and 2 = married or living as married. Two questions on alcohol consumption were also included. The first question was, 'How often do you drink?' The choices were as follows: (i) 'I have never drunk alcohol', (ii) 'I no longer drink alcohol'; (iii) 'I drink alcohol very rarely, less than once a week, 1 or 2 days a week, or 3 or 4 days a week'; (vii) '5 or 6 days a week'; and (viii) 'every day'. A person was considered to be a current drinker for any choice between (iii) and (viii). The second question was, 'On a day when you drink something with alcohol, how many standard drinks do you have/tend to have?' The questionnaire defined a standard drink as 'a small glass of wine, a regular beer can (330 mL), a shot of liquor or a cocktail.' The choices were as follows: '13 or more standard drinks'; (ii) '9 to 12 standard drinks'; (iii) '7 to 8 standard drinks'; (iv) '5 to 6 standard drinks'; (v) '3 or 4 standard drinks'; and (vi) '1 or 2 standard drinks.' The survey did not ask about the average duration of a drinking session.

The International Physical Activity Questionnaire (IPAQ) was used to measure the level of physical activity (PA). IPAQ included questions about the frequency and duration of vigorous-, moderate- and low-intensity physical activities, as well as how often and how long the taxi drivers had walked during the past week. For each category of walking— moderate and vigorous intensity—the physical activities were divided into the following four groups: work-related, transportation-related, household-related and leisure-related. Each type of activity (walking, moderate-intensity and vigorous-intensity) was counted separately by multiplying the number of days in a week by how long an average day is. The IPAQ core group [32] provided the following definitions of low, moderate and high levels of physical activity: low—no activity was reported or there was some activity

but not enough to meet the criteria for the other activity categories; moderate—(a) 3 or more days of vigorous-intensity activity for at least 20 min per day, (b) 5 or more days of moderate-intensity activity or walking for at least 30 min per day, or (c) 5 or more days of any combination of walking, moderate-intensity or vigorous-intensity activities, which added up to at least 600 MET-minutes per week. Vigorous meant either (a) 3 or more days of vigorous-intensity activity, which added up to at least 1500 MET-minutes per week or (b) 7 days of walking, moderate-intensity activities or vigorous-intensity activities, which added up to at least 3000 MET-minutes per week. It has been reported that the IPAQ is reliable and valid [33].

2.3. Dietary Assessment

Dietary intake was assessed using 24-h dietary recalls. Dietary composition was analyzed using the South African Medical Research Council (SAMRC) FoodFinder 111 [34]. Analyzed diet components included macronutrients (total, grams and proportions of CHOs, protein and fat) and fatty acids (total and grams of SFAs, MUFAs and PUFAs). Other dietary intake variables were also assessed but not as dietary components of interest for the current analysis.

2.4. Assessment of MetS Components

Bodyweight and height were measured using a platform scale and a fixed stadiometer, while wearing light clothing, without shoes. The body mass index (BMI) was calculated by dividing weight (kg) by height squared (m^2). A non-elastic tape measure was used to measure the waist circumference (WC) at the narrowest point between the lower edge of the rib and the upper-iliac crest. Following a 10-min rest, systolic and diastolic blood pressure were taken three times on the right arm, using a standard sphygmomanometer. For analysis, the average of the 2 last blood pressure (BP) readings were used.

To measure biochemical parameters, a venous fasting blood sample was sourced from the participants after an 8-h overnight fast and was kept on dry ice and transported to the laboratory for processing. The anthropometrical and biochemical measurements, and their categorization and analysis are explained in detail elsewhere [4].

2.5. Assessment of MetS

International Diabetes Federation (IDF) criteria was used to indicate MetS [35] among the participants. According to the IDF criteria, abdominal obesity (WC ≥94 cm for men), accompanied by two or more of the following cut-points are required to confirm MetS: triglycerides ≥1.7 mmol/L; systolic blood pressure (SBP) ≥130 mmHg, or diastolic blood pressure (DBP) ≥85 mmHg; fasting blood glucose (FBG) ≥5.6 mmol/L; and HDL-C <1.03 mmol/L, in men

2.6. Statistical Analysis

For continuous normally distributed data, descriptive statistics were reported as mean values and standard deviations (SD), and for continuous non-normally distributed data, as median and interquartile ranges (IQR). The independent samples *t*-test was used to compare participants with MetS and those without MetS. Multivariable nutrient density substitution models, as described by Skilton et al. (2008) [20] and Willett (1998) [36], were applied to investigate the relationship between macronutrient and fatty acid intakes and MetS. It should be noted that the substitution models represent an increase in the intake of one macronutrient, accompanied by a decrease in the intake of another macronutrient in isoenergetic conditions, in real life. For example, in the model used in the current research, a decrease in the percentage of calories consumed from total proteins were replaced by CHOs and fats, and vice versa. For fatty acids, the grams of MUFAs and PUFAs were replaced by SFAs, and vice versa. For the regression models, the presence of MetS and its components were entered as the dependent variables in the logistic

regression models, while the linear regression model was used to analyze the continuous variables, including MetS and its components. To allow for the study of the effects of diet composition, all models were adjusted for total energy intake and alcohol intake. In each model, one macronutrient was included as a variable of interest and the respective macronutrient was excluded, while the other macronutrients were included as cofactors to adjust for their confounding effects in the models.

Results were interpreted as follows: if the outcome variable increased or decreased when the relevant macronutrient was removed from the model, then the relevant macronutrient was an isoenergetic substitute for the variable in question. Thus, for example, to examine the substitution of CHOs for protein, protein was included as an independent variable of choice/interest; CHOs were excluded from the model; and the model was adjusted for fat and energy intake. In this case, the odds ratio (OR) for protein represented substituting protein for an isoenergetic quantity of dietary protein. All macronutrients were entered into the models as percentages (%E). Furthermore, all the models were first adjusted for lifestyle factors, e.g., age, race, marital status, level of education, smoking status, driving experience, alcohol intake and physical activity. BMI was used to adjust for models that examined the non-abdominal obesity of the MetS, including elevated triglycerides, low HDL-C, as well as elevated BP and FBG. A two-tailed p value of <0.05 was deemed statistically significant. IBM SPSS Statistics for Windows, version 28.0, was used to analyze all data (IBM Corp).

3. Results

Descriptive Analysis

The sociodemographic and physical characteristics of the study participants are shown in Table 1. The mean age of the 185 men was 39.9 ± 10.7 years. These men had 9 years of driving experience as taxi drivers, slept an average of 6 h per night and displayed mean WC, WhtR, BMI and FBG levels above the normal ranges. Participants with MetS were significantly ($p < 0.001$) older (43.7 ± 10.3 vs. 37.3 ± 10.2 years) and had more driving experience (11.7 ± 8.4 vs. 7.2 ± 6.1 years), compared to those without MetS. Moreover, participants with MetS had significantly ($p < 0.001$) higher mean values for WC (110.8 ± 16.7 vs. 90.7 ± 14.5 cm); FBG (7.9 ± 4.8 vs. 5.3 ± 1.1); SBP (141.5 ± 18.8 vs. 127.4 ± 13.3); DBP (92.7 ± 13.9 vs. 79.1 ± 9.1); triglycerides (1.9 ± 1.5 vs. 1.0 ± 0.4); BMI (32.7 ± 5.9 vs. 25.7 ± 5.2); WHtR (0.6 ± 0.1 vs. 0.5 ± 0,1); and low HDL-C (1.0 ± 0.3 vs. 1.2 ± 0.4), compared to those without MetS.

Table 1. Characteristics of the study participants in relation to their MetS status.

			IDF MetS				
	Entire Cohort (n = 185)		No (n = 108)		Yes (n = 77)		
	Mean	SD	Mean	SD	Mean	SD	p-Values
Age (years)	39.9	10.7	37.3	10.2	43.7	10.3	<0.001
Years in the taxi driving industry (n)	9.1	7.4	7.2	6.1	11.7	8.4	<0.001
Sleep duration (hours)	6.1	1.1	6.1	1.0	6.2	1.2	0.624
WC_(cm)	99.1	18.3	90.7	14.5	110.8	16.7	<0.001
Weight_(kg)	84.6	20.4	75.5	16.4	97.3	18.7	<0.001
Height_(cm)	171.9	8.1	171.4	7.2	172.6	9.3	0.346
FBG_(mmol/L)	6.4	3.5	5.3	1.1	7.9	4.8	<0.001
SBP_(mmHg)	133.3	17.2	127.4	13.3	141.5	18.8	<0.001
DBP_(mmHg)	84.7	13.2	79.1	9.1	92.7	13.9	<0.001
hsCRP_(mg/L)	4.9	8.4	4.3	9.6	5.6	6.5	0.287
LDL-C _(mmol/L)	2.8	0.82	2.7	0.8	2.8	0.8	0.336
Triglycerides_(mmol/L)	1.3	1.1	1.0	0.4	1.9	1.5	<0.001

HDL-C_(mmol/L)	1.1	0.3	1.2	0.4	1.0	0.3	<0.001
BMI_(kg/m²)	28.6	6.5	25.7	5.2	32.7	5.9	<0.001
WHtR	0.6	0.1	0.5	0.1	0.6	0.1	<0.001

SD—standard deviation; IDF—International Diabetes Federation; WC—waist circumference; FBG—fasting blood glucose; SBP—systolic blood pressure; DBP—diastolic blood pressure; hsCRP—high-sensitivity C-reactive protein; LDL-C—low-density lipoprotein cholesterol; HDL-C—high-density lipoprotein; BMI—body mass index; WHtR—waist-to-height ratio.

Table 2 shows the participants' ranges of macronutrients and other nutrient intakes by the MetS status. The overall median energy intake was 11,059.0 kJ/d (IQR 7441.0–17,195.5). The overall median intakes of CHOs, protein and fats—expressed as percentage of energy (%E)—were 57.3 (IQR 49.6–67.7), 14.9 (IQR 12.2–17.8) and 25.0 (IQR 17.0–33.4). No significant associations were observed between nutrient intake and the prevalence of MetS. Despite no significant associations being found, the median values of the variables among participants with MetS were higher than those without MetS. Finally, the median values for plant protein, CHOs (% E), protein (% E) and PUFAs were similar between the participants with and those without MetS.

Table 2. Median and interquartile ranges of macronutrients and other nutrient intakes by the MetS status.

			IDF MetS Classification				
	Entire Cohort (*n* = 185)		**No (*n* = 108)**		**Yes (*n* = 77)**		
	Median	**IQR**	**Median**	**IQR**	**Median**	**IQR**	***p*-Values**
Moisture (g)	1134.3	838.5–1621.1	1096.9	831.7–1375.7	1270.2	822.4–1805.8	0.257
Energy (kJ/d)	11,059.0	7441.0–17,195.5	10,900.0	7852.3–15,319.5	12,340.0	5861.0–18,765.5	0.704
Total protein (g)	96.7	67.0–143.3	95.7	75.4–127.6	115.2	57.2–180.5	0.360
Animal protein (g)	46.0	25.6–78.0	45.9	27.5–65.4	53.3	22.3–90.0	0.220
Plant protein (g)	27.9	17.3–42.4	28.5	18.5–41.2	28.8	16.3–46.0	0.515
Available CHOs (g)	349.8	225.6–522.7	349.8	237.7–459.5	375.7	193.8–579.1	0.958
Total CHOs (g/d)	379.6	252.3–558.1	378.2	259.7–497.2	409.9	206.5–651.2	0.957
CHO (% E)	57.3	49.6–67.7	57.9	50.0–68.3	57.6	48.8–66.0	0.339
Protein (% E)	14.9	12.2–17.8	14.9	11.5–17.9	15.0	13.1–17.7	0.668
MUFA (g)	23.2	13.1–46.6	21.8	14.1–42.8	27.0	9.5–53.9	0.449
PUFA (g)	20.4	9.2–41.2	20.9	9.5–37.9	21.4	7.1–45.4	0.344
Total fat (g)	83.0	40.8–127.8	70.2	43.1–120.3	87.8	29.8–139.5	0.373
Fat (% E)	25.0	17.0–33.4	24.3	17.0–33.5	27.6	17.3–33.6	0.661
SFA	18.8	10.6–30.3	18.4	11.7–27.3	21.3	9.7–32.9	0.817
SFA (% E)	6.4	4.6–8.4	6.3	4.6–8.2	6.6	4.5–8.5	0.988
MUFA (% E)	8.1	5.5–11.6	7.7	5.5–11.3	8.8	5.4–11.6	0.189
PUFA (% E)	6.7	4.3–10.4	6.7	4.3–10.2	6.7	3.7–11.0	0.983
Starch (g)	8.2	0.0–16.7	10.1	3.9–16.1	7.8	0.0–16.9	0.741
Added sugar	0.0	0.0–0.3	0.0	0.0–0.3	0.0	0.0–0.4	0.406
Total sugar	35.7	12.4–68.7	36.4	13.0–66.0	38.5	8.9–71.6	0.698
Total trans FA	0.4	0.1–1.0	0.4	0.1–0.9	0.6	0.1–1.1	0.757
Total fiber	33.0	22.0–50.3	31.5	24.2–45.5	36.2	18.4–54.9	0.595
Insoluble fiber	2.3	1.1–4.2	2.5	1.4–4.2	1.9	0.3–4.2	0.480
Soluble fiber	1.7	0.9–3.1	1.8	1.1–2.9	1.4	0.3–3.2	0.607

IQR—interquartile range (i.e., 25th–75th percentile); MetS—metabolic syndrome; IDF—International Diabetes Federation; %E—percentage energy; PUFA—polyunsaturated fatty acid; MUFA—monounsaturated fatty acid; CHO—carbohydrate; SFA—saturated fatty acid.

No significant associations ($p > 0.05$) were observed between the %E derived from macronutrient intake and the prevalence of MetS, abdominal obesity (WC), raised triglyceride or FBG (Table 3)—with the exception of the energy derived from protein, which was significantly associated with a raised BP adjusted odds ratio (AOR) (AOR 1.108, 95%CI 1.026–1.197, $p = 0.007$) and low HDL-C (AOR 0.914, 95%CI 0.844–0.988, $p = 0.025$). In this case, it was shown that an increase in protein consumption significantly ($p < 0.007$) increased the likelihood of elevated BP by almost 11% and significantly lowered the likelihood of reduced HDL cholesterol by 8.6%. However, the association of SFA consumption and FBG only tended to significance (AOR 1.096, 95%CI 1.099–1.203, $p = 0.053$).

Table 4 presents the outcomes of the substitution models for protein, CHOs and the total fat. The model was adjusted for age, race, physical activity, marital status, level of education, driving experience, smoking status, total energy, alcohol intake and BMI. Substituting CHOs and total fat for protein, decreased the likelihood of reduced HDL-C by 7% and 7.2% (AOR 0.930 95%CI 0.875–0.989, $p = 0.021$ and AOR 0.928 95%CI 0.874 0.985, $p = 0.014$), respectively. Moreover, substituting total fat for CHOs reduced the likelihood of elevated BP by 2.6% (AOR 0.974 95%CI 0.956–0.992, $p = 0.005$) when dietary CHOs were substituted with protein.

Table 5 presents the outcomes of the substitution models for protein, CHOs and total fat. When no other lifestyle factors were considered, with the exception of keeping the total energy constant (i.e., adjusted for total food energy and alcohol intake), the intake of protein instead of CHOs and total fat, reduced the likelihood of raised triglycerides by 6.7% and 6.6% (AOR 0.933 95%CI 0.880–0.990, $p = 0.021$ and AOR 0.934 95%CI 0.892–0.978, $p = 0004$), respectively. Moreover, the intake of CHOs instead of protein and total fat reduced the likelihood of elevated BP by 2.2% and 2.8% (AOR 0.978 95%CI 0.986–0.991, $p = 0.001$ and AOR 0.972 95%CI 0.957–0.988, $p = 0.001$) respectively. The replacement of protein by total fat only tended to significance ($p = 0.050$), while demonstrating an increased likelihood of raised triglycerides (OR 1.974 95%CI 0.94–0.999).

In Table 6, we repeated the multivariable nutrient density substitution models, however, in this case, using the outcomes for fatty acids. The model was adjusted for age, race, physical activity, marital status, level of education, driving experience, smoking status, and total energy and alcohol intake. No significant associations were observed between the fatty acid outcomes with MetS and its components when MUFAs and PUFAs were substituted for SFAs, and when PUFAs were substituted for MUFAs. However, substituting SFAs for PUFAs significantly decreased the likelihood of elevated BP by 7% (AOR 0.930 95%CI 0.858 0.989, $p = 0.047$). The outcomes for abdominal obesity, raised triglyceride, reduced HDL-C, elevated BP and FBG remained unchanged when SFAs were substituted with MUFAs and MUFAs was substituted with PUFAs.

In Table 7, the multivariable nutrient density substitution models are reported. The model was adjusted for total energy and alcohol intake. Substituting MUFAs for SFAs significantly increased the likelihood of elevated BP by 9.8% (AOR 1.098 95%CI 0.831–0.992, $p = 0.033$), while substituting SFAs for PUFAs decreased the likelihood of elevated BP by 9.5% (AOR 0.905 95%CI 0.845 0.969, $p = 0.004$).

Table 3. The association between dietary CHOs, protein and fat and MetS and its components.

	MetS			Abnormal WC			Raised Triglycerides †			Low HDL-C †			Raised BP †			Elevated FBG †		
	AOR	**95%CI**	***p***	**AOR**	**95%CI**	***p***	**AOR**	**95%CI**	***p***	**AOR**	**95%CI**	***p***	**AOR**	**95%CI**	***p***	**AOR**	**95%CI**	***p***
CHO_% E	1.001	0.998–1.004	0.650	1.008	0.984–1.032	0.517	1.001	0.995–1.004	0.612	1.011	0.985–1.038	0.403	0.994	0.970–1.019	0.639	1.000	0.998–1.002	0.738
Protein _% E	1.016	0.945–1.093	0.667	0.991	0.927–1.060	0.991	1.035	0.954–1.124	0.406	0.914	0.844–0.988	0.025	1.108	1.026–1.197	0.007	1.001	0.937–1.069	0.982
FAT_% E	1.005	0.973–1.038	0.763	0.991	0.964–1.020	0.542	1.027	0.989–1.066	0.168	0.996	0.966–1.027	0.792	1.000	0.972–1.030	0.977	1.024	0.995–1.053	0.106
SFA_% E	1.019	0.925–1.123	0.699	0.965	0.883–1.055	0.434	1.113	0.990–1.251	0.073	0.995	0.906–1.093	0.913	1.012	0.925–1.105	0.795	1.096	1.099–1.203	0.053
MUFA_% E	1.026	0.969–1.086	0.374	1.007	0.990–1.024	0.410	1.002	0.994–1.010	0.679	1.002	0.991–1.013	0.737	1.001	0.993–1.009	0.856	1.063	0.994–1.136	0.074
PUFA_% E	0.977	0.910–1.048	0.515	1.014	0.951–1.081	0.670	1.001	0.922–1.086	0.986	1.001	0.935–1.072	0.974	0.965	0.903–1.033	0.304	0.997	0.938–1.060	0.928

SFA—saturated fatty acid; HDL-C—high-density lipoprotein cholesterol; WC—waist circumference; BP—blood pressure; CHO—carbohydrate; MUFAs— monounsaturated fatty acids; PUFAs—polyunsaturated fatty acids. CHO, protein, fat, SFA, MUFA and PUFA were included as independent variables of interest. The MetS were defined using the IDF definition. Macronutrients and fatty acids were entered as a percentage of total energy intake. The results are presented as OR for the presence of the MetS, per change in the proportion of dietary energy. All models were adjusted for age, race, physical activity, marital status, level of education, smoking status, driving experience, total energy and alcohol intake. OR—odds ratios, 95%; CI—95% confidence intervals. † Also adjusted for BMI.

Table 4. The association between macronutrient (CHOs, protein and total fat) dietary intake and the MetS and its components. The model was adjusted for all lifestyle factors and BMI.

	MetS			Abnormal WC			Raised Triglycerides †			Low HDL-C †			Raised BP †			Elevated FBG †		
	AOR	**95%CI**	***p***	**AOR**	**95%CI**	***p***	**AOR**	**95%CI**	***p***	**AOR**	**95%CI**	***p***	**AOR**	**95%CI**	***p***	**AOR**	**95%CI**	***p***
↑CHO_%E ↓Protein_%E	1.001	0.997–1.005	0.681	1.004	0.963–1.047	0.842	1.002	0.957–1.050	0.926	1.021	0.981–1.062	0.311	0.988	0.951–1.027	0.552	1.001	0.997–1.004	0.777
↑CHO_%E ↓FAT_%E	1.001	0.997–1.005	0.666	1.008	0.983–1.035	0.532	1.001	0.997–1.005	0.639	1.001	0.995–1.006	0.833	0.974	0.956–0.992	0.005	1.000	0.998–1.002	0.737
↑FAT_%E ↓Protein_%E	1.005	0.973–1.038	0.767	1.001	0.954–1.050	0.974	1.027	0.972–1.085	0.338	1.008	0.968–1.064	0.746	1.002	0.959–1.048	0.696	1.020	0.995–1.053	0.151
↑Protein_%E ↓CHO_%E	0.995	0.921–1.075	0.901	0.973	0.914–1.035	0.381	0.940	0.874–1.011	0.059	0.930	0.875–0.989	0.021	1.012	0.951–1.077	0.700	0.975	0.919–1.035	0.405
↑FAT_%E ↓CHO_%E	1.003	0.969–1.038	0.875	0.987	0.955–1.021	0.450	1.002	0.964–1.041	0.926	0.997	0.965–1.029	0.834	0.976	0.943–1.011	0.179	1.022	0.989–1.055	0.190
↑Protein_%E ↓FAT_%E	1.002	0.930–1.080	0.958	0.965	0.912–1.021	0.212	0.947	0.885–1.014	0.118	0.928	0.874–0.985	0.014	1.026	0.965–1.090	0.412	0.994	0.942–1.048	0.823

%E—percentage energy; CHO—carbohydrate; MetS—metabolic syndrome; WC—waist circumference; BP—blood pressure; FBG—fasting blood glucose; HDL-C—high-density lipoprotein cholesterol. Substitution model, where CHOs, protein and fat were included as the variable of interest (↑), or were excluded from the model, when the macronutrient was substituted for (↓), or was adjusted for as a covariate. The MetS was defined using the IDF definition. Macronutrients were entered as a percentage of total energy intake. The results were presented as OR for the presence of MetS per change in the proportion of dietary energy. The OR for the 'opposite' substitution was the inverse of that presented, and the *p* value was the same. For example, the OR for the MetS when substituting fat for CHOs = (OR 1.005 95% CI 0.963–1.054, $p = 0.681$). All models were adjusted for age, race, physical activity, marital status, level of education, driving experience, smoking status, and total energy and alcohol intake. ORs—odds ratios, 95%; CIs—95% confidence intervals. † Also adjusted for BMI.

Table 5. The association between macronutrient (CHOs, protein and total fat) intake and the MetS and its components. The model was adjusted for total energy and alcohol intake.

	MetS			Abnormal WC			Raised Triglycerides			Low HDL-C			Raised BP			Elevated FBG		
	AOR	**95%CI**	***p***	**AOR**	**95%CI**	***p***	**AOR**	**95%CI**	***p***	**AOR**	**95%CI**	***p***	**AOR**	**95%CI**	***p***	**AOR**	**95%CI**	***p***
↑CHO_%E ↓Protein_%E	1.001	0.999–1.002	0.441	1.001	0.997–1.004	0.662	1.001	0.999–1.002	0.284	1.007	0.996–1.018	0.191	0.978	0.966–0.991	0.001	1.001	0.999–1.002	0.519
↑CHO_%E ↓FAT_%E	1.001	0.999–1.002	1.002	1.001	0.998–1.003	0.616	1.001	0.999–1.002	0.387	1.012	0.998–1.027	0.088	0.972	0.957–0.988	0.001	1.000	0.999–1.002	0.507
↑FAT_%E ↓Protein_%E	0.983	0.961–1.005	0.131	0.990	0.968–1.012	0.379	1.974	0.948–0.999	0.050	1.002	0.979–1.025	0.870	0.977	0.952–1.002	0.066	1.004	0.982–1.026	0.738
↑Protein_%E ↓CHO_%E	0.975	0.930–1.023	0.302	1.012	0.965–1.062	0.611	0.933	0.880–0.990	0.021	0.992	0.947–1.040	0.742	0.984	0.937–1.035	0.537	0.989	0.944–1.036	0.630
↑FAT_%E ↓CHO_%E	0.994	0.966–1.023	0.677	0.986	0.958–1.015	0.352	1.002	0.969–1.036	0.924	1.011	0.982–1.040	0.464	0.968	0.938–0.999	0.043	1.009	0.981–1.038	0.527
↑Protein_%E ↓FAT_%E	0.968	0.933–1.004	0.083	0.997	0.961–1.034	0.856	0.934	0.892–0.978	0.004	0.976	0.928–1.025	0.325	1.013	0.963–1.066	0.608	0.998	0.963–1.034	0.899

%E—percentage energy; CHO—carbohydrate; MetS–metabolic syndrome; WC–waist circumference; BP—blood pressure; FBG—fasting blood glucose; HDL-C—high-density lipoprotein cholesterol. Substitution model where CHOs, protein and fat were included as the variable of interest (↑) or were excluded from the model, when the macronutrient substituted for (↓) or were adjusted for as a covariate. The MetS was defined using the IDF definition. Macronutrients were entered as a percentage of total energy intake. The results are presented as AOR for the presence of the MetS per change in the proportion of dietary energy. The AOR for the 'opposite' substitution was the inverse of that presented, and the *p* value was the same. For example, the AOR for the MetS when substituting fat for CHOs = (AOR 1.005 95% CI 0.963–1.054, *p* = 0.681). All models were adjusted for total food energy and alcohol intake. AOR—adjusted odds ratios, 95%; CIs—95% confidence intervals.

Table 6. The association between dietary fatty acids and the MetS and its components. The model was adjusted for all lifestyle factors and BMI.

	MetS			Abnormal WC			Raised Triglycerides †			Low HDL-C †			Raised BP †			Elevated FBG †		
	AOR	**95%CI**	***p***	**AOR**	**95%CI**	***p***	**AOR**	**95%CI**	***p***	**AOR**	**95%CI**	***p***	**AOR**	**95%CI**	***p***	**AOR**	**95%CI**	***p***
↑SFA_%E ↓MUFA_%E	0.830	0.655–1.053	0.124	0.999	0.817–1.223	0.996	1.060	0.825–1.363	0.649	1.127	0.891–1.427	0.319	0.828	0.662–1.034	0.096	1.028	0.837–1.127	0.791
↑SFA_%E ↓PUFA_%E	0.985	0.837–1.158	0.852	0.945	0.818–1.092	0.443	1.108	0.926–1.326	0.262	1.093	0.942–1.292	0.299	0.943	0.805–1.104	0.463	1.0102	0.943–1.286	0.221
↑MUFA_%E ↓PUFA_%E	1.022	0.961–1.088	0.481	1.010	0.982–1.038	0.498	1.001	0.993–1.009	0.821	1.003	0.992–1.013	0.632	1.000	0.992–1.008	0.993	1.061	0.917–1.227	0.429
↑MUFA_%E ↓SFA_%E	1.009	0.982–1.037	0.519	1.004	0.991–1.018	0.546	0.997	0.988–1.005	0.436	1.002	0.993–1.011	0.649	0.997	0.988–1.006	0.503	1.036	0.961–1.117	0.356
↑PUFA_%E ↓SFA_%E	0.950	0.882–1.023	0.174	1.007	0.937–1.083	0.841	0.945	0.865–1.031	0.202	0.981	0.917–1.050	0.587	0.930	0.858–0.989	0.047	0.978	0.907–1.055	0.565
↑PUFA_%E ↓MUFA_%E	0.960	0.892–1.034	0.286	1.022	0.948–1.102	0.569	0.944	0.864–1.032	0.205	0.987	0.921–1.058	0.715	0.938	0.864–1.019	0.132	0.987	0.920–1.058	0.712

%E—percentage energy; MetS—metabolic syndrome; WC—waist circumference; HDL-C—high-density lipoprotein cholesterol; FBG—fasting blood glucose; BP, blood pressure; SFA—saturated fatty acid; MUFA—monounsaturated fatty acid; PUFA—polyunsaturated fatty acid. MUFA, PUFA and SFA intakes were included as either the variable of interest (↑); were excluded from the model, when the fatty acid was substituted for (↓); or were adjusted for as a covariate. The MetS was defined using the IDF definition. Fatty acids were entered as percentage of total energy intake. The results are presented as OR for the presence of the MetS per change in the proportion of dietary energy. All models were adjusted for age, race, physical activity, marital status, level of education, driving experience, smoking status, total energy, alcohol intake, CHO intake, protein intake and *trans* fatty acid intake. † Also adjusted for BMI.

Table 7. The association between dietary fatty acids and MetS and its components. The model was adjusted for total food energy and alcohol intake.

	MetS			Abnormal WC			Raised Triglycerides			Low HDL-C			Raised BP			Elevated FBG		
	OR	**95%CI**	**p**	**OR**	**95%CI**	**p**	**OR**	**95%CI**	**p**	**OR**	**95%CI**	**p**	**OR**	**95%CI**	**p**	**OR**	**95%CI**	**p**
↑SFA_%E ↓MUFA_%E	0.956	0.886–1.032	0.252	0.936	0.867–1.011	0.094	0.971	0.891–1.057	0.492	1.015	0.944–1.091	0.694	1.098	0.831–0.992	0.033	1.018	0.946–1.094	0.639
↑SFA_%E ↓PUFA_%E	0.922	0.844–1.006	0.069	0.936	0.867–1.011	0.092	0.944	0.868–1.028	0.188	1.020	0.952–1.092	0.576	0.874	0.801–0.953	0.202	0.984	0.893–1.085	0.751
↑MUFA_%E ↓PUFA_%E	1.018	0.973–1.065	0.442	1.011	0.982–1.040	0.457	0.999	0.991–1.007	0.834	1.002	0.994–1.010	0.649	1.000	0.992–1.008	0.996	1.024	0.952–1.100	0.528
↑MUFA_%E ↓SFA_%E	1.010	0.988–1.031	0.383	1.005	0.992–1.018	0.438	0.999	0.991–1.007	0.751	1.002	0.994–1.010	0.613	0.998	0.990–1.007	0.656	1.023	0.968–1.081	0.423
↑PUFA_%E ↓SFA_%E	0.957	0.901–1.016	0.149	1.008	0.952–1.069	0.776	0.930	0.862–1.003	0.060	1.022	0.966–1.082	0.448	0.905	0.845–0.969	0.004	0.981	0.921–1.046	0.561
↑PUFA_%E ↓MUFA_%E	0.978	0.917–1.042	0.485	1.035	0.971–1.103	0.293	0.939	0.866–1.018	0.127	1.019	0.958–1.084	0.548	0.934	0.868–1.006	0.072	0.989	0.930–1.051	0.717

%E—percentage energy; MetS—metabolic syndrome; WC—waist circumference; HDL-C—high-density lipoprotein cholesterol; FBG—fasting blood glucose; BP, blood pressure; SFA—saturated fatty acid; MUFA—monounsaturated fatty acid; PUFA—polyunsaturated fatty acid. MUFA, PUFA and SFA intake were included as either the variable of interest (↑); were excluded from the model, when the fatty acid was substituted for (↓); or were adjusted for as a covariate. The MetS was defined using the IDF definition. Fatty acids were entered as percentage of total energy intake. The results are presented as OR for the presence of the MetS per change in the proportion of dietary energy. All models were adjusted for total energy and alcohol intake.

Finally, Table 8 presents the outcomes of linear regression models to show the association between macronutrient and fatty acid consumption substitution and MetS and its components. In this case, substituting protein for total fat was significantly associated with elevated FBG (β 0.491 95%CI 0.009, 0.972, $p = 0.046$). Moreover, when MUFAs were substituted with SFAs, a higher FBG level was observed (β 1.105 95%CI −2.185, −0.025, $p = 0.045$). This meant that a diet that was high in total fat and saturated fat tended to increase FBG levels.

Table 8. Association between dietary macronutrient intake and fatty acids (substitution model) and the components of the MetS (as continuous variables).

	WC		Triglycerides †		HDL-C †		BP †		FBG †	
	β	95%CI	β	95%CI	β	95%CI	β	95%CI	β	95%CI
↑CHO_%E ↓PROTEIN_%E	0.005	−0.001, 0.011	0.000	0.000, 0.001	−0.201	−0.516, 0.114	0.001	−0.005, 0.008	−0.001	−0.005, 0.004
↑CHO_%E ↓FAT_%E	0.006	0.000, 0.012	0.000	0.000, 0.001	−0.149	−0.474, 0.175	0.002	−0.004, 0.008	−0.000	−0.005, 0.004
↑FAT_%E ↓PROTEIN_%E	−0.188	−0.837, 0.460	0.035	−0.016, 0.086	0.008	−0.007, 0.024	0.489	−0.187, 1.165	0.491 *	0.009, 0.972
↑SFA_%E ↓MUFA_%E	0.205	−1.264, 1.673	−0.080	−0.195, 0.034	−0.016	−0.051, 0.019	−0.881	−2.397, 0.636	1.105 *	−2.185, −0.025
↑SFA_%E ↓PUFA_%E	−0.015	−1.060, 1.030	−0.035	−0.113, 0.042	−0.007	−0.030, 0.017	−0.030	−1.127, 1.068	−0.735	−1.509, 0.040
↑MUFA_%E ↓PUFA_%E	0.012	−0.049, 0.072	0.001	−0.003, 0.005	−0.001	−0.002, 0.000	0.006	−0.057, 0.068	−0.030	−0.074, 0.014

SFA—saturated fatty acid; WC—waist circumference; HDL-C—high-density lipoprotein cholesterol; SBP—systolic blood pressure; DBP—diastolic blood pressure; CHO—carbohydrate; MUFA—monounsaturated fatty acid; PUFA—polyunsaturated fatty acid. * $p < 0.05$ All models were adjusted for age, race, physical activity, marital status, level of education, driving experience and smoking status. In each model, a given dietary intake variable of interest was included as an independent variable (↑) and one dietary intake variable (↓) was excluded from the model. The remaining dietary intake variables and total energy were included as covariates. The β represents the increase or decrease in the continuous outcome variable when increasing the independent dietary intake, while simultaneously reducing an isoenergic amount of the excluded dietary intake variable. All dietary variables were entered as percentages of the total energy intake. † Also adjusted for BMI.

4. Discussion

In the present study, we conducted real life simulations of macronutrient and fatty acid substitution, using the multivariable nutrient density substitution models. Taxi drivers who presented with MetS were older, had more driving experience, and presented with larger body sizes and body fat centralization. They also had higher levels of FBG, SBP and triglycerides, but lower levels of HDL-C compared to their counterparts without MetS. These outcomes are corroborated by substantiated international evidence [37], where it has been highlighted that the likelihood of MetS and other metabolic disorders is higher in individuals who are employed in the taxi driving industry [37], those who are older [38], and those who present with larger body sizes and body fat centralization [39,40].

While no significant associations were observed between nutrient intake and the prevalence of MetS, the overall median energy intake of the participants was above the recommended dietary reference intakes for average men (i.e., men with the average BMI of 22.5 m²/kg, which is equal to 10,626 kJ), based on the Food and Nutrition Board (2004) [41]. Kolahdooz et al. (2013) [42] and Wentzel-Viljoen and Kruger (2010) [43] found similar

outcomes for total energy intakes that were above the normal range (i.e., 11,159 kJ and 15,485 kJ among urban South African men, respectively). The elevated total energy intake among the taxi drivers is a cause for concern, as evidence indicates that a higher energy intake than energy output increases the risk of excessive weight gain, especially abdominal fat accumulation [44]. Taxi drivers were sedentary, based on the outcomes of their physical activity/inactivity, where 75.7% engaged in low physical activity, 60.5% slept less than 6 h per night and, on average, sat for 3 h daily in their taxis, without driving. Corroborating other South African evidence [42,45], our outcomes suggested that most of the total energy consumed by urban black South African men come from CHOs (65%), while the energy derived from fat (20%) and protein (10%) were at the lower extreme ends of the recommended macronutrient energy intake for men, based on the recommendations of the Food and Nutrition Board (2004) [41].

The results of dietary macronutrient composition—especially the amount and quality of CHOs, protein, fats, and their impacts on health—have received more attention in recent years. Over the past two decades there has been growing evidence that suggests that weight loss diets that restrict CHOs are more effective, prevent metabolic disorders [46]. In fact, Volek et al. (2008) [12] and Jung and Choi (2017) [13] argued that diets that are high in CHOs raise serum triglycerides, lower serum HDL-C and impair glucose metabolism. Furthermore, Kwon et al. (2018) [14] suggested that males who consume high proportions of CHOs in their diet present with MetS. As in similar studies by Eilat-Adar et al. (2008) [19] and Motamed et al. (2013) [18], our current research did not show such significant associations. We also have to highlight the fact that the increased weight reduction benefits of restricting dietary CHOs, as opposed to restricting dietary fat, as highlighted by the popular and growing body of evidence [47–50], has been challenged by the review article of Naude et al., (2014) [46]. Here, the authors argued that there is little or no difference in metabolic disorder prevalence among overweight and obese adults who follow low CHO diets. Moreover, in their response to the questions raised about their review, Naude et al. (2014) [46] further clarified that a result of 780 g more weight loss after a 3-to-6-month intervention of a low CHO diet compared to other weight loss diets cannot be practically and clinically concluded as more effective in weight loss than the comparative diet. However, it is also important to mention that, in the current analysis, we observed that substituting protein and fat for CHOs, reduced the likelihood of elevated BP. These findings are congruent to those of Teunissen-Beekman et al. (2013) [51], where it was shown that BP decreases more after a high-CHO meal than after a high-protein meal, especially among overweight adults with elevated BP. Indeed, the majority of taxi drivers were overweight and obese, and their mean BMI and BP were above the normal ranges. Moreover, Savoia et al. (2021) [44] argued that *high potassium, antioxidants and fiber-rich sources of CHOs (i.e., fruits, vegetables, potato starch and grains) may be the compounds that contribute to the reduction of blood pressure.*

In the current analysis we also showed that the energy intake derived from protein raised BP. *However, similar studies presented contrasting evidence. They suggested that an increase in dietary protein leads to a decrease in mean SBP and DBP by 4.9 and 2.7 mmHg, respectively [51]. A study by Rebholz et al. (2012) [52] also showed a significant reduction in BP (i.e., 1.8 mmHg for SBP and 1.2 mmHg for DBP decrease) when dietary protein was consumed, compared to CHO or fat consumption. He* et al. *(2011) [53] also demonstrated a significant reduction in SBP (2.0 mm Hg) for both soy protein and milk protein, in comparison with CHOs. According to Melson* et al. *(2019) [54] and Astrup* et al. *(2015) [47], fat, as well as protein, increases satiety, which leads to a reduced energy intake with concomitant weight reduction and, subsequently, to lower BP. In addition, protein is thought to increase postprandial energy expenditure due to the higher metabolic processes needed to metabolize fat and CHOs.*

The consumption of protein by the taxi drivers participating in our research was shown to be beneficial, as it significantly lowered the likelihood of reduced HDL-C. These outcomes were corroborated by the findings of Pasiakos et al. (2015) [55]; Dong et al. (2013) [56]; Layman et al. (2009) [57]; and the 2010 Dietary Guidelines for Americans [58], where

it is reported that the cardiometabolic benefits of high protein diets are often greater than those observed when consuming low-fat and high-carbohydrate diets. However, it should be noted that most of the studies in the literature that have reported the benefits of a high protein intake were conducted on overweight and obese adults, who were undergoing well-controlled weight loss interventions [59]. The evidence suggests that an increased protein intake at the expense of CHOs is generally considered to reduce cardiometabolic disorders, through glycemic [56] and blood lipid [57] regulation. This was observed especially among adults with a high cardiovascular disease risk following a controlled high-protein, low-carbohydrate weight loss diet. Additionally, habitually consuming a high-protein diet was associated with higher HDL-C (and lower adiposity) levels, regardless of total dietary energy, CHO and fat intake. Pasiakos et al. (2014) [55] also argued that the intrinsic properties of protein, unrelated to its energy content, appear to be partially responsible for these effects. Moreover, Hooseini-Esfahan et al. (2019) [60] emphasized that a higher proportion of dietary protein, especially plant-derived protein, in place of CHOs and fat is beneficial to weight loss and reduces body fat centralization. As we have shown in our models—in which we adjusted for socio-economic status, lifestyle and other physiological confounders—there is a robust association between dietary protein and HDL-C, which is particularly intriguing. However, the mechanism by which dietary protein is associated with the upregulation of HDL-C production still requires further investigation.

In the current study, we used the multivariable nutrient density substitution model and we showed that the substitution of dietary protein for energy derived from fat resulted in a significant upregulation of triglycerides. We also showed that a diet that was high in total fat increased the FBG in the taxi drivers. In contrast to our findings, Skilton et al. (2008) [20] reported lower odds of elevated WC when they replaced CHOs with fats. They further reported that an isoenergetic increase in fat intake at the expense of protein reduced the odds for MetS. Considering this contrasting evidence to our outcomes, similar trials to confirm recent findings need to be conducted.

Our findings on BP and PUFAs are similar to those of Jovanovski et al., (2014) [61] and Guo et al., (2014) [62], who argued that PUFA intake lowers BP and MetS risk. Furthermore, SFAs and unsaturated fatty acids are well known for their role in the risk and prevention of MetS, respectively [63]. According to Imamura et al. (2016) [64], PUFAs, as well as MUFAs, reduce IR and also lower LDL-C and apolipoproteins. Guerendiain et al. (2018) [65] further argued that trans FAs and SFAs appear to increase IR and glucose intolerance, which are the major contributors to MetS. Similar significant relationships between MUFA intake and DBP were reported [66], where the authors reported that MUFA intake—especially oleic acid from vegetable sources—may contribute to the prevention and control of adverse BP levels in general populations. More evidence [67–69] indicated, that PUFA and MUFA intakes reduce MetS components such as triglycerides, HDL-C, glucose and BP levels.

Considering the foregoing, it is important to note that the contradictions we found between the outcomes of the current study and the outcomes of the majority of the literature presented, could be ascribed to the fact that the literature outlined above was based on real-life interventions, whereas ours used multivariable nutrient density substitution models. Moreover, none of the evidence we provided attempted multivariable nutrient density substitution models using taxi driver outcomes, or outcomes for the people involved in the taxi driving industry. However, it is important to note that these populations are at risk of cardiovascular diseases since they are exposed to unhealthy food [30,70]. Moreover, their lifestyles—including physical inactivity, excessive alcohol intake and cigarette smoking [71]—put them at an increased risk of MetS. Hence, further research of this kind is needed to identify whether macronutrients and fatty acids should be consumed to reduce MetS and its components, especially in real life.

Limitations

While the aforementioned study has managed to highlight several strengths, there were a number of limitations to be considered when interpreting our results. Firstly, because we used a cross-sectional study design, we could not make definite conclusions about the associations we found between macronutrient and fatty acid intake and MetS risk. As such, we recommend further prospective studies in real life, which will reveal the actual associations between macronutrient and fatty acid consumption and MetS and its components. Secondly, it would be inappropriate to generalize the study outcomes to the entire urban South African population, given that the data were only based on mini-bus taxi drivers, who consumed street food at least three days a week. Thirdly, while the use of a substitution model is justified when studying the health effects of different macronutrients in isoenergetic conditions, it must be acknowledged that this approach is only a mathematical model for dietary intake and not a real-life situation.

5. Conclusions

The present study indicated that South African, male mini-bus taxi drivers, who operate in the urban areas, consume total dietary energy that is above the recommended dietary allowances and are at risk of MetS. In an isoenergetic state, the taxi drivers' diets—which were high in protein, CHOs and PUFAs—reduced triglycerides and BP, respectively. Whereas, when their diets were high in total fat and SFAs the opposite effects were observed, with an added disadvantage of elevated FBG. It is, however, important to note that these outcomes were produced using mathematical models. As such, we recommend further prospective studies in real life, which will reveal the actual associations between macronutrient and fatty acid consumption and MetS and its components.

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Informed Consent Statement: informed consent was obtained from all subjects involved in the study.

Data Availability Statement: the data presented in this study are available on request from the corresponding author.

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Chapter 8: The discussion and synthesis of the outcomes of the current research

In the current thesis, the primary aim was to document and describe the prevalence, extent, and determinants of MetS among commercial taxi drivers who rely on SF for their daily calorie and nutrient intake. The secondary aim was to use the outcomes of this study to develop recommendations for targeted interventions to improve the health status and lifestyle of South Africans in driving business.

This aim was established by engaging in research undertaken in *3 phases*. *Phase 1 (Chapter 4)* included the secondary SANHANES-1 data analysis to conduct a test to compare the ability of anthropometric indices to predict the risk of DM in South African males. Consequently, of all the essential MetS components, diabetes was chosen, given its significant role in the aetiology of metabolic disorders (Zimmet et al., 1997; Gallagher et al., 2008; Motala et al., 2011), especially in South Africa. Moreover, in South Africa, metabolic diseases are expected to increase dramatically in men because of the rising rates of central obesity and prediabetes in this gender (Shisana et al., 2010; NDoH, 2019).

There is substantiated evidence that associates diabetes and body adiposity (Motala et al., 2011; Gómez-Ambrosi et al., 2011). Also, there is substantial evidence suggesting that metabolic complications relating to obesity are more closely associated with visceral adiposity than overall body adiposity (Tchernof & Després, 2013). However, in South African men, adiposity seems to be undetectable, given the current evidence that suggests the overall mean BMI for men is still within the normal range of weight (i.e., between 18.5 and 25 kg/m^2) (Shisana et al., 2010; NDoH, 2019). Besides, Mchiza et al. (2019) have shown that the distribution of BMI in South African males, compared to the females, shows less variation and a lower median value (22.0 kg/m^2 vs 27.4 kg/m^2, respectively). Thus, finding a suitable body fat adiposity measure sensitive to predicting health risks is pivotal in understanding the aetiology of metabolic disorders among South African males. This body fat adiposity measure would also be instrumental in selecting the suitable algorithm to measure MetS in South African male minibus taxi drivers, who are the focus of the current research.

Phase 2 (Chapter 5) included performing similar analyses to specify the suitable algorithm to identify those South African males taxi drivers who presented with MetS operating in the Cape

Town Metropole. This analysis included reviewing internationally available algorithms to measure MetS to identify the one acclaimed as being suitable for use in South African populations.

IDF criteria were applied based on the fact that these are the most preferred in the Sub-Saharan African studies (Fezeu et al., 2007) and successfully used among urban South African dwellers (Ntandou et al., 2009; Sekokotla et al., 2017). Moreover, it is favoured to use the WC (i.e., one of the central body adiposity measures identified as sensitive in predicting the risk of DM in Phase 1).

Phase 3 (Chapters 6 and 7) included determining the prevalence and extent of MetS among this group of minibus taxi drivers using the selected IDF MetS criteria and detecting critical social determinants of MetS for identifying interventions for action in curbing the syndrome in this group. This phase was undertaken in two different investigations. In the *first investigation (Chapter 6)*, it was sought to determine the socio-demographic and lifestyle factors associated with MetS among minibus taxi drivers who operate in the Cape Town metropole areas.

Having identified these essential MetS predictors in these taxi drivers, a *second investigation (Chapter 7)* was performed that included conducting mathematical models to see what their metabolic status outcome would be if we substituted one macronutrient or fatty acid for another. This substitution was an effort to identify noteworthy interventions for advocating to prevent and reduce the prevalence of MetS among men working in the minibus taxi driving industry.

The outcomes observed from this research are presented in detail in Chapters 4 to 7. In summary, the key learnings are provided in Table 8.1.

Table 8.1: Key findings from thesis.

	Data extractions				
Key findings	**Literature review**	**1st Investigation Predicting the risk of DM**	**2nd Investigation Development of algorithm to identify individuals with MetS**	**3rd Investigation Socio-economic status and sedentary lifestyle as risk factors of MetS**	**4th Investigation Association of macronutrients and fat intake with MetS**
Prevalence of MetS is high in SA	X		X	X	X
Lifestyle factors and dietary intake are modifiable risk of MetS	X			X	X
No specific diet has been shown to treat MetS in totality	X				
SF are high in saturated fatty acids	X				X
Diet that is high in CHO raises serum triglycerides, lowers serum HDL-C	X				X
Consumption of vegetable fat as opposed to animal fat is associated with a lower incidence of cardio-metabolic disease	X				X
SF does not foster good health	X				X
Taxi drivers consume total dietary energy that is above the recommended dietary allowances				X	X
Diet high in protein, CHO and PUFA reduced triglycerides and BP	X				X
Taxi drivers have poor eating habits, and lack of exercise.	X			X	X
Anthropometrical measures show adipose tissue distribution, differentiate central or abdominal obesity for classifying MetS	X		X		
There is limited data on the central obesity status of South African men	X				
There is no best measure to be applied in an algorithm to identify individuals with MetS	X				
Participants with MetS had higher mean values for triglycerides, FBG, SBP and WC as compared to those without MetS.			X		
The highest AUC outcomes for screening MetS were for the %BF and CUN-BAE and followed by the WC, BMI and WHtR			X		

The BMI, WHtR, %BF, BRI, and CUN-BAE, had cut-off points for detection of MetS in South African men at 28.25 kg/m^2, 0.55, 25.29%, 4.55, and 27.10, respectively			X	
Cut-off points proposed in this study provide an earlier diagnosis of MetS			X	
WC, WHR and WHtR are preferred indicators to predict the DM	X	X		
No South African study has previously investigated the specificity and sensitivity of BMI to predict DM	X			
WC, WHR and WHtR excellently predicted the risk of DM		X		
Body mass index (BMI) shows acceptable ability to predict the risk of DM		X		
Good health is a basic constitutional right for all South African citizens. The Occupational Health and Safety Act (OHSA) section 12(C) requires the performance of medical surveillance for high-risk occupations	X			
Regular exercise can help to reduce weight, blood pressure, triglycerides and increase HDL-c	X			X
sociodemographic factors such as age, high experience in taxi driving have significant association with MetS and its components				X
Lifestyle factors such as fewer sleeping hours, smoking cigarettes each day, alcohol and SSB consumption, spending a lot of money on SF and being sedentary impacted the taxi drivers' metabolic health				X
Food that are fried, processed, obtained as take-aways and commercially packaged food such as crisps increased the likelihood of taxi drivers presenting with MetS				X
Avoiding the consumption of take-away and fried foods reduced the risk of MetS				X
Consumption of canned fish more than 3 times each week reduced the likelihood of MetS and its components				X

In the following section, evidence from the literature will be used to discuss the implication of these learnings for South Africans and other countries that shares mutual lifestyles with the study participants.

Key Learning 1 (Chapter 4, Objective 1: To explore anthropometrical indices that are suitable for predicting metabolic disorders among South African males using already existing South African national data sets and their implication for public health

After adjusting for age, South African men with abnormal BMI, WC, WHR and WHtR were 4-, 6-, 5-, and 8-fold more likely to present with higher abnormal levels of HbA1c when compared to their counterparts with normal anthropometrical measurement outcomes. Furthermore, when adjusting for all socio-demographic factors, TG, LDL-C and total cholesterol, the risk of abnormal levels of HbAlc decreased for all indices (i.e., lowered to 2 for BMI, 5 for WC, 3 for WHR, and 5 for WHtR). This finding indicated that socio-demographic factors moderate the risk of abnormal levels of HbA1c in South African men. Moreover, in this research, it was also observed that based on the AUC outcomes, WC, WHR and WHtR better predicted the risk of DM (with corresponding AUCs for these indices being 80.4%, 80.2% and 80.6%, respectively, vs the AUC of 75.6% for BMI).

Consequently, this meant all the anthropometrical indices that measured body fat centralization could be used independently to predict the risk of DM. BMI, on the other hand, could still be used independently to predict the risk of DM. However, it is recommend pairing BMI with another strong index (especially a high-performing index such as WHtR) that considers central adiposity to leverage its ability to predict the risk of DM. In the current research, it was also observed that age is a confounder when using anthropometric indices to predict the risk of DM, as shown by the cut-off points to predict DM among younger men compared with older men.

Key learning 2 (Chapter 5, Objective 2: To examine the MetS and explore anthropometrical indices that are suitable in predicting MetS among 20-year and older minibus taxi drivers operating in the Cape Town metropole areas and their implication for public health

Following the outcomes obtained in Chapter 4 and after conducting an extensive review of the literature, this objective focussed on identifying suitable criteria to measure MetS in the group of taxi drivers. In this research, the IDF MetS criteria (Alberti et al., 2009) defined as the presence of body fat centralization signified as abnormal WC (> 94 cm) and other two or more of the following

four NCD risk factors, i.e., FBG ≥ 5.5 mmol/L; TG ≥ 1.7 mmol/L; HDL-C < 1.0 mmol/L in males and SBP ≥ 130 mmHg or DBP ≥ 85 mmHg, was applied.

In this case, it was observed that most taxi drivers (70%) met the IDF diagnostic criteria for MetS. On investigating different anthropometric indices to predict MetS among this group of taxi drivers, it was observed that all anthropometrical indices, including the BMI, had excellent discriminatory power for predicting MetS since their AUC and sensitivity levels were above 80%.

It is worthwhile highlighting that in this group of taxi drivers, their mean BMI was 28.60 kg/m^2 (SD 6.20), unlike the mean BMI of South African men in general (that is within the normal range of weight) (Mchiza et al., 2019). This finding could be the reason why BMI among this group also performed excellently in predicting MetS. Moreover, in the current study it was observed that the BMI, WHtR, %BF, BRI, and CUN-BAE had cut-off points for MetS detection in South African men at 28.25 kg/m^2, 0.55, 25.29%, 4.55, and 27.10, respectively. These cut-off points are higher than those acclaimed to predict the risk of metabolic diseases by WHO, IDF, UNU, AHA, and others.

In the current research, none of these anthropometrical indices could produce the AUCs above 70% (i.e., they could not predict individual abnormal TG, HDL-C, TG, FBG and BP, excellently) in this group of taxi drivers, except for BMI and CUN-BAE that produced AUCs that were above 70%. The corresponding cut-off points for the BMI and CUN-BAE were 27.74 kg/m^2 and 26.85, respectively.

Finally, it was observed that an increase in CUN-BAE and %BF increased the MetS incidence in this group of taxi drivers. Therefore, this suggested that because South African male minibus taxi drivers have larger body sizes than the general South African male population, indices that measure overall body adiposity, such as the BMI, %BF and CUN-BAE predicted metabolic disorders better.

Key Learning 3 (Chapter 6, Objective 3: To investigate the social determinants of MetS in 20-year and older minibus taxi drivers operating in the Cape Town metropole areas and their implications for public health

Based on key learning 2, it became possible to disclose that IDF MetS criteria grouped the taxi drivers into those who presented with MetS and those who did not. This grouping made it possible to formulate some health comparisons between these groups and identify risk factors for MetS

among South African taxi drivers. Moreover, it was indicated that increasing age and years of driving experience were some of the driving forces of metabolic diseases among male taxi drivers.

Smokers, those taxi drivers who spent more money on SF, and those who expended less than recommended energy levels (< 1.4 MET-minute/week) were 1.96, 2.0, and 13.6 times, respectively, significantly more likely to present with MetS than their counterparts who did not.

Alcohol, SSB consumption and consuming take-away and fried foods, snacks and crisps sold by the SF vendors increased the likelihood of MetS, abnormal HDL-C, TG and hypertension while avoiding take-away and fried foods decreased this likelihood. Those taxi drivers who also avoided consuming fresh fruits had presented with abnormal HDL-C, while those who consumed canned fish daily and 1 to 3 times a week had a reduced likelihood of MetS and elevated TG.

The observed outcomes are corroborated by national and international literature, where it is outlined that individuals who are in the long-duration driving occupation, including taxi drivers in general, have a high prevalence of metabolic disorders when compared to other professionals such as industrial and office workers (Bull et al., 2017; Myers, 2014; Franklin, 2008; Berra et al., 2015; Omura et al., 2018). These studies also implicate age and the duration and experience of driving as amplifiers of metabolic diseases (Mohebbi et al., 2012; Mabetwa et al., 2022). More importantly, the argument by Hildrum et al. (2007) suggesting that regardless of any algorithm used to measure MetS, this condition strongly increases with age has been proven in the current study.

Other researchers, such as Appiah et al. (2020), also corroborate the findings in the current research that non-users of tobacco are less likely to present with MetS and its components. The present and other substantiated international evidence (Myers et al., 2014; Jääskeläinen et al., 2013) suggest that independent of socio-demographic and other lifestyle factors, physical activity attenuates metabolic health, with most active individuals tending to have the greatest reduction in metabolic disease risk, magnifying the importance of physical activity. This evidence also shows that achieving minimal physical activity outlined in the health guidelines (Bull et al., 2017) (i.e. at least 150 minutes per week of moderate-intensity activity or 75 minutes per week of vigorous-intensity activity) has significant benefits on metabolic risk.

Finally, in the current study, as in some other studies conducted internationally (Ebrahimi et al., 2016), it was indicated that consuming unhealthy food (i.e., food fried, processed, or obtained as take-away food, and food that is commercially packaged, e.g. crisps) and beverages (i.e. excessive alcohol and SSB) increase the likelihood of male minibus taxi drivers to present with impaired metabolic health. Avoiding the consumption of some of these foods (take-away and fried foods, to be specific) on the other hand, reduced this health risk. Finally, there are important foods that need to be promoted, especially among people in the long driving business like taxi drivers. These include the consumption of fruit and vegetables, as well as foods containing omega-3 fatting acids such as canned fish as these foods improve metabolic health.

Key Learning 4 (Chapter 7, Objective 4: To examine the association between macronutrient and fatty acid consumption, and the risk of MetS in 20-year and older minibus taxi drivers operating in the Cape Town metropole areas and its implication to public health

The last but not least important learning from the current study was that given all the outcomes from objectives 1 to 3, there are interventions that can be endorsed/promoted by public health practitioners to improve the metabolic health of taxi drivers in South Africa. These include adjusting macronutrients and fatty acids in taxi drivers' diets. We learnt that when the total food energy of the taxi drivers was kept constant, the increase in protein consumption instead of CHO and total fat reduced the likelihood of elevated triglycerides by 6.7% and 6.6%, respectively.

Again, in the same iso-energetic state, the consumption of CHO instead of protein and total fat reduced the likelihood of HBP by 2.2% and 2.8%, respectively. This finding was also observed when manipulating fatty acid consumption. For instance, consumption of SFA instead of MUFA increased the likelihood of HBP by 9.8%, whereas that of PUFA instead of SFAs decreased the likelihood of HBP by 9.4%.

To summarise these outcomes, when the total food energy intake is kept constant, a diet high in protein, CHO, and PUFA reduces TG and BP, whereas the intake of total fat and SFA has the opposite effect. However, it should be noted that these outcomes were produced using mathematical models. As such, further prospective studies in real-life situations that will reveal the actual associations between the consumption of macronutrients and fatty acids and MetS and its components, are recommend.

The mentioned outcomes are also pertinent in understanding metabolic disease epidemiology and how to intervene/curb the escalation of MetS, especially among males in the long-duration business, such as taxi drivers who also spend substantial amounts of money purchasing unhealthy SF. The total food energy consumed by the current male taxi drivers seems to be fuelling their risk of developing diseases. This outcome is a concern, given those of a systematic review and meta-analysis by Fabiani et al. (2019) that suggests energy balance and nutrition to be crucial modifiable factors that affect the MetS risk. Therefore, this evidence has been among the growing evidence (Anderssen et al., 2007; Steckhan et al., 2016) that have resulted in dietary intake receiving the most attention, especially in MetS epidemiology. This evidence also advocates that in other lifestyle factors, comprehensive dietary-related interventions can improve all aspects of MetS.

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Chapter 9: Conclusion, limitations, and recommendations

9.1. Conclusion

The AUCs for WC, WHR and WHtR showed an exceptionally significant ability as opposed to the acceptable ability of BMI to predict DM in adult South African men. While the %BF, CUN-BAE, BMI, WC, WHtR, BRI, CI and CUN-BAE could predict MetS among South African male taxi drivers, these indices were less effective in predicting the individual MetS risk factors such as TG, BP, and FBG. When total food energy intake was kept constant, a diet high in protein, CHO and PUFA reduced TG and BP, whereas the intake of total fat and SFA had the opposite effect. However, it should be noted that these outcomes were produced using mathematical models; as such, we recommend further prospective studies in real-life situations that will reveal the actual associations between macronutrients and fatty acids consumption with MetS and its components.

Furthermore, the intake of fried food and food deep-fried in oil/fat daily, eating snacks, and drinking SSB was associated with an increased risk of MetS. Eating canned fish at least 1-3 days a week is associated with reduced risk of MetS. These outcomes have public health implications that call for South African policymakers to endorse system-level approaches where taxi drivers' lifestyle changes are motivated within the taxi industry to improve their health risk profile.

9.2. Limitations

While this thesis has many strengths, some limitations need to be considered when interpreting the outcomes.

- The causal relationship between anthropometric indices and DM because of the cross-sectional nature of the study design could not be demonstrated.
- This thesis focused on male participants only, as most taxi drivers are men, thus limiting gender difference comparisons. The focus was on men because there is substantiated evidence from South Africa to suggest that the prevalence of uncontrolled DM is higher in females and is mediated by their large body size as measured by BMI. Based on this background, we became concerned that uncontrolled DM might be underestimated in South African men. Possibly, it is partly attributable to existing evidence that South African women, unlike the men, are obese; South African men have a mean BMI within the normal

range of weight (between 22.5 and 24.5 kg/m^2), with few being overweight or obese (Mchiza et al., 2019).

Normal-weight individuals are often assumed to be free of diseases if they do not present with symptoms for these diseases; hence, they are often overlooked when implementing targeted interventions to mitigate metabolic diseases such as DM. Moreover, unlike women, South African men are reluctant to attend health services or participate in health screening/surveillance activities (Zyriax et al., 2011). Since most men only present at health service centres when their DM has progressed, their prognosis for this condition is poor.

- There was no differentiation between the two types of DM, i.e., types 1 and 2, as this was beyond the scope of the current research.
- As only male taxi drivers were recruited by convenience sampling the outcomes obtained can only be generalizable in populations with similar characteristics as the current participants.
- Because of the cross-sectional study design, any conclusions about the temporal association between macronutrient intake and MetS risk were excluded. The findings do not necessarily indicate that eating carbohydrates would be more weight-reducing than eating fat. The causal effect could also be reversed as a low-carbohydrate-high-fat diet has successfully been used as a weight-reduction method.
- There was difficulty generalizing the study results because the data were based only on taxi drivers who consume SF at least three days a week.
- While using a substitution model is justified when studying the health effects of different macronutrients in iso-energetic conditions, it must be acknowledged that this approach is only a mathematical model for dietary intake and not a real-life situation.

9.3 Targeted recommendations based on the key learnings

1. Recommendations for science

- Based on the outcomes for Objective 1, it is recommended that all the anthropometrical indices that measure body fat centralization should be used independently to predict the risk of DM among South African men. Conversely, while BMI could independently predict the risk of DM, it is recommend pairing BMI with another strong index such as WHtR, to leverage its ability to predict the risk of DM.

When using anthropometric indices to predict the risk of DM, and since age is a confounder, we recommend improving the predictability of DM in adult South African men of all ages by using lower cut-off points than those pre-specified by the WHO and IDF. These cut- off points could be WC ≥ 87.45 cm, WHR > 0.88, and WHtR > 0.48.

- Based on the outcomes for Objective 2, in South African men who do not show visible signs of obesity, it is recommended that anthropometrical indices measuring central obesity should be the first choice when screening for the risk of metabolic disorders as they are more sensitive. For men with visible signs of obesity, anthropometrical indices that measure overall body adiposities, such as the BMI, %BF and CUN-BAE, should be the first preference when screening for the risk of metabolic disorders as these are more sensitive.

2. *Recommendation for workplace policy*

- Outcomes for Objective 3 suggest that working conditions for long-duration driving occupations, including taxi driving, put them at risk of metabolic disorders compared to other professions, such as industrial and office work. Thus, it is recommend that existing South African policies on conditions of employment be extended and re-enforced to long-duration driving occupations, including the taxi-driving industry.

3. *Recommendation for workplace health intervention policies*

- Based on the outcomes for Objective 3, which suggest taxi drivers' unhealthy lifestyles, it is recommend that South African policymakers should endorse system-level approaches where taxi drivers' lifestyle changes are motivated within the taxi industry to improve their health risk profile.

  Policies include:

  i. Policies to endorse health promotion (adopting a healthy lifestyle that includes ceasing smoking, engaging in physical activity, and reducing the amounts of alcoholic beverages consumed) should be extended even to the taxi industry.

  ii. Most importantly, policies to discourage the consumption of unhealthy food and beverages while endorsing healthy eating, with a suggestion of specific foods and beverages that are known to improve health, should be leveraged.

iii. Moreover, tobacco smoking in public policy in South Africa should be enforced, especially at workplaces and in areas where people gather to reduce the chance of secondary smoking.

4. Recommendation for nutrition policy to regulate informal food businesses

- Objective 3, suggests that the food environment (SF vendors) close to taxi drivers is rife with unhealthy food and beverages. Based on this evidence it is recommended that existing South African policies regulating the food environment (i.e. policies to stop the sale and promotion of unhealthy foods and beverages and those that endorse selling specific types and quality foods and beverages) should be extended and enforced, especially in the informal business, such as SF vending.

5. Recommendation for policies to scale-up individual healthy literacy

- South African taxi drivers, like any other citizens, should be empowered with food and nutrition literacy, including food and nutrition knowledge. Empowerment should include educating them i). about the combination and access to nutritious food, ii). to make correct and safe decisions about food, and iii) to choose and consume sound amounts of healthy food and beverages. These skills have also been proven by international researchers (Murimi, 2013; Aktaş & Özdoğan, 2016; Colatruglio & Slater, 2014; Worsley, 2002; Cleland, 2013) as essential factors that enable people to identify the foods and beverages that are healthy to procure and consume.

6. Recommendation for the implication of further research

- Finally, further prospective real-life studies, revealing the actual associations between macronutrient and fatty acid consumption and MetS and its components are recommended.

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Appendices

Appendix 1: Research Ethics Committee letter of Ethical approval

UNIVERSITY *of the* WESTERN CAPE

60 YEARS *of hope, action & knowledge*

05 August 2020

Mr MD Sekgala
School of Public Health
Faculty of Community and Health Science

Ethics Reference Number: BM20/6/8

Project Title: Metabolic syndrome and the risk of consuming street food among commercial taxi drivers in South Africa: a cross-sectional study

Approval Period: 05 August 2020 – 05 August 2023

I hereby certify that the Biomedical Science Research Ethics Committee of the University of the Western Cape approved the scientific methodology and ethics of the above mentioned research project.

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

Please remember to submit a progress report annually by 30 November for the duration of the project.

Permission to conduct the study must be submitted to BMREC for record-keeping.

The Committee must be informed of any serious adverse event and/or termination of the study.

Ms Patricia Josias
Research Ethics Committee Officer
University of the Western Cape

Director: Research Development
University of the Western Cape
Private Bag X 17
Bellville 7535
Republic of South Africa
Tel: +27 21 959 4111
Email: research-ethics@uwc.ac.za

NHREC Registration Number: BMREC-130416-050

FROM HOPE TO ACTION THROUGH KNOWLEDGE.

Appendix 2: City of Cape Town permission letter

UNIVERSITY of the WESTERN CAPE

MACHOENE DERRICK SEKGALA <3991963@myuwc.ac.za>

research submission

Jameyah Armien <Jameyah.Armien@capetown.gov.za> Tue, Sep 10, 2019 at 7:36 AM
To: Natacha Berkowitz <Natacha.Berkowitz@capetown.gov.za>, "3991963@myuwc.ac.za" <3991963@myuwc.ac.za>

Good morning Natacha,

Yes, you are absolutely correct in that Derek needs the Health department's approval. However, CCT permission to access the taxi rank and interview taxi drivers are not required and he is thus permitted to engage with all/any taxi drivers.

Hope this clarifies.

Regards

Jameyah

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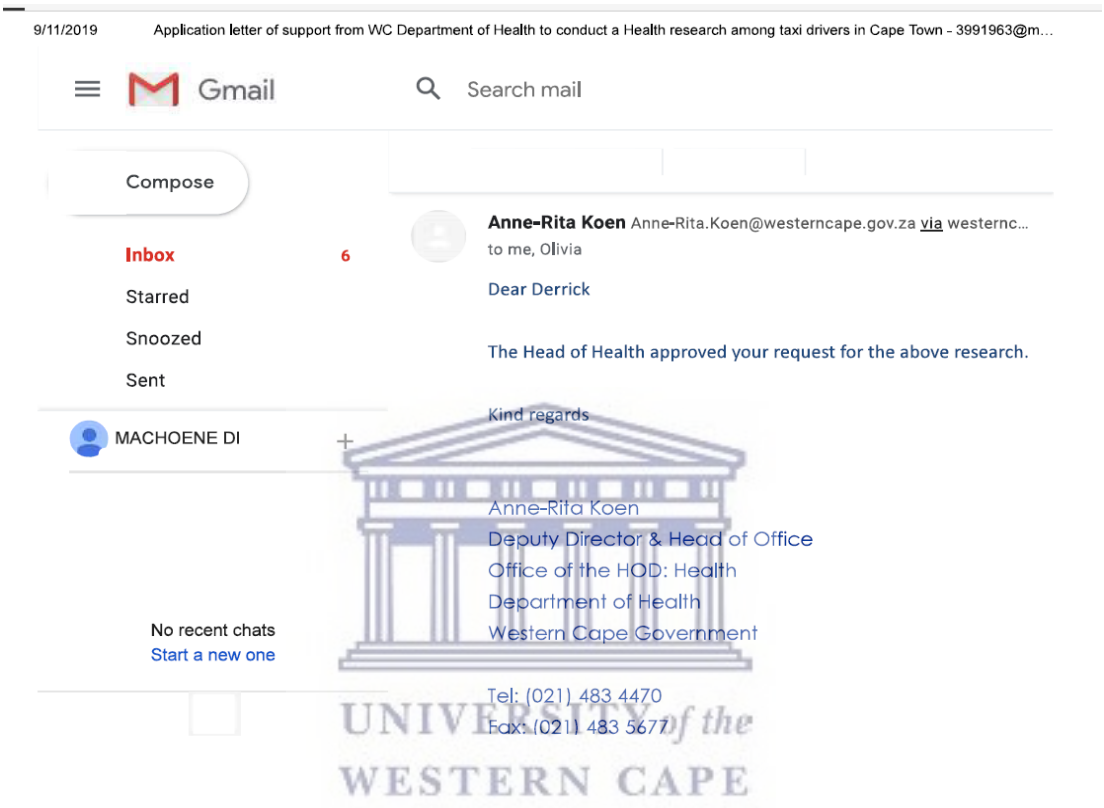
CCT Research Requests Requirements 2019.pdf
561K

Appendix 3: Western Cape Department of Health letter of permission



9/11/2019 Application letter of support from WC Department of Health to conduct a Health research among taxi drivers in Cape Town - 3991963@m...

Gmail Search mail

Compose

Inbox 6

Starred

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Sent

MACHOENE DI

No recent chats
Start a new one

Anne-Rita Koen Anne-Rita.Koen@westerncape.gov.za via westernc...
to me, Olivia

Dear Derrick

The Head of Health approved your request for the above research.

Kind regards

Anne-Rita Koen
Deputy Director & Head of Office
Office of the HOD: Health
Department of Health
Western Cape Government

Tel: (021) 483 4470
Fax: (021) 483 5677

Appendix 4: Information sheet in English

UNIVERSITY OF THE WESTERN CAPE
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Tel: +27 21-959 2760, Fax: 27 21-959 3686
E-mail: research-ethics@uwc.ac.za

INFORMATION SHEET

Project Title: The metabolic profile, blood pressure, body size and behaviours of taxi drivers who operate at selected locations around Cape Town: a focus on street food consumption

Introduction

What is this study about?

This research project is being conducted by Mr Derrick Sekgala at the University of the Western Cape. We are inviting you to participate in this research project because you are aged 18 years and older and in the Taxi Driving Industry that operates in the Cape Metropole Area. The purpose of this research project is to use the responses and blood samples given by someone like you to generate information pertaining blood pressure, blood glucose and cholesterol, as well as fatty acids, vitamin E and carotenoids statuses, which are factors that are important in the development of heart diseases. This will also help us learn more about the South African taxi drivers' health and nutritional status, so as to be able to develop effective interventions and strategies to prevent and treat heart diseases in people of South Africa, especially those who are in the driving business.

What will I be asked to do if I agree to participate?

You will be asked to share your thoughts and blood sample with us. A questionnaire will be used to gather your socio-demographic information, dietary and physical activity practices and other behaviours such as smoking and alcohol use. No personally identifiable information will be gathered. If you choose not to take part in answering the questions and to give a blood sample, you will not be affected in any way. If you agree to participate you may stop me and tell me that you don't want to go on with the blood sampling and answering few questions at any time without any consequences to you. Please understand that your participation is voluntary. You are not being forced to take part in this study. The choice whether to participate or not is yours alone.

Would my participation in this study be kept confidential?

The researchers undertake to protect your identity and the nature of your contribution. To ensure your anonymity, the information you provide will remain confidential and there will be no "come-backs" from the answers and a blood sample you give me. The information you provide will not in any way be shared with any one except the researchers involved in this study project. We will not be recording your name anywhere on the questionnaire and no one will be able to link you to the answers you give me. We will only use an anonymous identification number to record your data. Only the

researchers involved in this research will have access to the linked information. Any reports or publications that may be written on the findings of the study will be done anonymously. To ensure your confidentiality, the paper – based data generated from the information you give us will be locked in a secure filing cabinet in the primary investigator's office that will be locked at all times. She will be the only person that will have the key to the cabinet. Moreover, the information that will be generated from the analysis of the blood that you will give us will be kept as electronic data in the computer that will be password-protected. Only the primary investigator will have this password. This data cannot be linked to your name but can only be identified by the anonymous number given to it. Also, if we write a report or an article about this research project, your identity will be protected. In accordance with legal requirements and/or professional standards, if your blood test results show an increased risk of heart diseases or heart attack, we will immediately refer you to the nearest clinic for further investigation. We will give you a letter for referral that you will give to the nurse and /doctor on call who will verify the health outcomes and give you the necessary treatment.

What are the risks of this research?

If you agree to take part, we will like your permission to complete a series of clinical examinations such as anthropometry (measuring weight and height) and blood pressure, and general health. After the interview you will be asked by a qualified and registered nurse to allow him/her to draw a blood sample from you, about 2-3 tablespoons, to do some investigations that will give us information on your health status (e.g. blood sugar and cholesterol levels, triglycerides, as well as Omega 3 fatty acids, carotenoids and vitamin E). Collecting the samples will take about 10 minutes. You will experience some discomfort but the drawing of the blood sample is not likely to endanger you. The blood sample will be collected using a small needle and a syringe. Only disposable sterile instruments will be used that are clean and completely safe. The drawing of a blood sample is an accepted and safe procedure and is not usually associated with any short or long term adverse effects. The blood sample will be drawn by a qualified nursing sister in the mobile clinic that we brought with us. The blood sample will then be sent to a laboratory to test for blood sugar, cholesterol, triglycerides, vitamin e, and Omega 3 fatty acids status. This information will tell us about your risk to develop heart diseases in order to be able to develop relevant interventions to help you and the community that surrounds you to prevent or manage heart diseases in the future.

If you are interested in knowing the result of your blood test, we will provide you with a Specimen Result Request Voucher referring you to the same health facility we will use to take your blood sample. This voucher will have a unique participant questionnaire number that will assist clinic staff to correctly link the laboratory results to the voucher. Additional information captured on the voucher will include the gender and age of the participant, date of result collection, and the name and address of selected clinic. The clinic staff is aware of the study, and will gladly assist you. All that needs to be done is to present the voucher at the clinic. When providing blood samples, please remember that you will also need to give permission to use the blood sample for the current and any on-going research in the future.

Please also note that all human interactions and talking about self or others carry some amount of risks. We will nevertheless minimise such risks and we will therefore act promptly to assist you if you experience any physical or psychological discomfort, or otherwise during the process of your participation in this study. Where necessary, an appropriate referral will be made to a suitable professional for further assistance or intervention.

What are the benefits of this research?

The benefits to you include the results of the clinical examinations and laboratory investigations that will be made available to you if you need it. If you would like to receive feedback on our study, we will record your phone number on a separate sheet of paper and can send you the results of the study when it is completed at the end of 2019. This research is not designed to benefit you personally and immediately, but the results may help the investigators learn more about South

African taxi drivers' health and their nutritional status, so as to be able to develop effective interventions and strategies to prevent and treat heart diseases in people of South Africa, especially those who are in the driving business, especially the taxi drivers.

Do I have to be in this research and may I stop participating at any time?

Your participation in this research is completely voluntary. You may choose not to take part at all. If you decide to participate in this research, you may stop participating at any time. If you decide not to participate in this study or if you stop participating at any time, you will not be penalized or lose any benefits to which you otherwise qualify.

What if I have questions?

This research is being conducted by ***Mr Derrick Sekgala*** at the University of the Western Cape. If you have any questions about the research study itself, please contact Prof. Zandile Mchiza at: 021 959 2632 or 3991963@myuwc.ac.za or Prof Zandile Mchiza at: 021 953 8677 or zmchiza@uwc.ac.za

Should you have any questions regarding this study and your rights as a research participant or if you wish to report any problems you have experienced related to the study, please contact:

Prof Uta Lehmann
Director: School of Public Health
University of the Western Cape
Private Bag X17
Bellville 7535
Tel: +27 21-959 2809 Fax: 27 21-959 2872
E-mail: soph-comm@uwc.ac.za

OR

Prof Anthea Rhoda
Dean of the Faculty of Community and Health Sciences
University of the Western Cape
Private Bag X17
Bellville 7535
chs-deansoffice@uwc.ac.za

This research has been approved by the University of the Western Cape's Biomedical Research Ethics Committee. Ref No. BM18/9/25

BIOMEDICAL RESEARCH ETHICS ADMINISTRATION
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BMREC Research Development Tel: 021 959 4111 Email: research-ethics@uwc.ac.za

Appendix 5: Information sheet in isiXhosa

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IINKCUKACHA ZENGCACISO

Isihloko sophando: Ukulinganisa i-metabolic syndrome kunye nomngcipheko wokutya ukutya esitratweni phakathi kwabaqhubi beeteksi zorhwebo eMzantsi Afrika: isifundo esiphambeneyo

Intshayelelo- yintoni esi sifundo?

Olu phando luqhutywa ngu Mnu Derrick Sekgala kunye no Prof Zandile Mchiza kwi Dyunivesithi yase Ntshona. Siyakumema ukuba uthathe inxaxheba kolu phando kuba uneminyaka eli-18 nangaphezulu kwaye ukwishishini leTaxi Driving elisebenza kwindawo yeNqila yeKapa. Injongo yale projekthi yophando kukusebenzisa iimpendulo kunye neesampuli zegazi ezinikezwe ngumntu onjengawe ukuvelisa ulwazi oluphathelene noxinzelelo lwegazi, iglucose kunye ne-cholesterol Status, zinto ezo ezibalulekileyo ekuphuhliswini kwezifo zentliziyo. Oku kuyakusinceda ukuba sifunde ngakumbi malunga nemeko yabaqhubi beeteksi yoMzantsi Afrika ngempilo kunye nesondlo, ukuze sikwazi ukuqhubela phambili nokungenelela okusebenzayo kunye neendlela zokuthintela nokunyanga izifo zentliziyo kubantu boMzantsi Afrika, ngakumbi abo bakwishishini lokuqhuba.

Yintoni endiza kucelwa ukuba ndiyenze ukuba ndiyavuma ukuthatha inxaxheba?

Uya kucelwa ukuba wabelane ngeengcinga zakho kunye nesampula yegazi. Kwiphepha lemibuzo liza kusetyenziselwa ukuqokelela ulwazi lwakho ngokwasentlalweni, ukutya kunye nokuziqhelanisa nokuziphatha kunye nokuziphatha okunje ngokutshaya kunye nokusetyenziswa kotywala. Akukho lwazi lubonakalayo luya kuqokelelwa. Ukuba ukhetha ukungathathi nxaxheba ekuphenduleni imibuzo kwaye unike isampula yegazi, awuyi kuchaphazeleka nangayiphi na indlela. Ukuba uyavuma ukuthatha inxaxheba ungandimisa kwaye undixelele ukuba awufuni kuqhubeka nesampula yegazi kwaye uphendule imibuzo embalwa nangaliphi na ixesha ngaphandle kwesiphumo sakho. Nceda uqonde ukuba inxaxheba yakho ngokuzithandela. Akunyanzelekanga ukuba uthathe inxaxheba kolu phando. Ukukhetha ukuba uza kuthatha inxaxheba okanye hayi kukokwakho kuphela..

Ngaba ukuthatha inxaxheba kolu phando kuya kugcinwa kuyimfihlo?

Abaphandi bathembela ukukhusela ubuwena kunye nohlobo lwegalelo lakho. Ukuqinisekisa ukungaziwa kwakho, ulwazi olunikezelayo luya kuhlala luyimfihlo kwaye akuyi kubakho "mva kwakhona" kwiimpendulo kunye nesampulu yegazi ondinika lona. Olu lwazi ulunikezelayo alusayi

kwabiwa nangayiphi na indlela ngaphandle kwabaphandi ababandakanyekayo kolu phando. Asizukurekhoda igama lakho naphi na kwiphepha lemibuzo kwaye akukho mntu uya kuba nakho ukunxibelelanisa neempendulo ondinika zona. Siya kusetyenziswa kuphela inombolo yesazisi engaziwayo ukurekhoda idatha yakho. Ngabaphandi ababandakanyekayo kolu phando kuphela abanokufikelela kulwazi oludibeneyo. Naziphi na iingxelo okanye iimpapasho ezinokubhalwa kwiziphumo zophando ziya kwenziwa ngokungaziwa.

Ukuqinisekisa ubumfihlo bakho, idatha esekwe ephepheni evela kulwazi osinika lona iya kutshixwa kwikhompyuter yokufayilisha ekhuselekileyo kwi-ofisi yomphandi oyintloko eya kuvalwa ngalo lonke ixesha. Uyakuba kuphela komntu oza kuba nesitshixo kwikhabhathi. Ngaphezulu, ulwazi oluza kwenziwa luhlalutyo lwegazi oya kusinika luya kugcinwa njengedatha ye-elektroniki kwikhompyuter ekhuselekileyo. Kuphela ngumphandi oya kuba nale password. Le datha ayinakunxulunyaniswa negama lakho kodwa inokuchongwa kuphela inombolo engaziwayo oyinikiweyo. Kwakhona, ukuba sibhala ingxelo okanye inqaku malunga nolu phando, isazisi sakho siyakukhuselwa.

Ngokuhambelana neemfuno zomthetho kunye / okanye imigangatho yobungcali, ukuba iziphumo zovavanyo lwegazi zibonakalisa umngcipheko wokunyuka kwezifo zentliziyo okanye ukubetha kwentliziyo, ngoko nangoko siya kukuthumela kwikliniki ekufutshane ukuba ufuna uphando. Siya kukunika ileta yokudlulisela oya kumnika yona umongikazi kunye / ugqirha xa ekufowunela oza kuqinisekisa iziphumo zezempilo akunike unyango oluyimfuneko.

Ziziphi iingozi zale phando?

Ukuba uyavuma ukuthatha inxaxheba, singathanda imvume yakho yokugcwalisa uthotho lweemviwo zekliniki ezinjenge-anthropometry (ukulinganisa ubunzima nokuphakama) kunye noxinzelelo lwegazi, kunye nempilo ngokubanzi.

Emva kodliwanondlebe uya kubuzwa ngumongikazi ofanelekileyo kwaye ubhalisile ukumvumela ukuba akhuphe isampula yegazi kuwe, malunga neetafile ezi-2-3, ukwenza uphando oluzakusinika ulwazi ngemeko yakho yezempilo (umz. Iswekile yegazi kunye amanqanaba e-cholesterol, triglycerides). Ukuqokelela iisampulu kuya kuthatha malunga nemizuzu eli-10. Uya kuba nengxaki ethile kodwa ukuzoba isampulu yegazi akunakulibeka emngciphekweni. Isampulu yegazi iya kuqokelelwa kusetyenziswa inaliti encinci kunye nesirinji. Kuphela zixhobo ezinokulahlwa ezinokulahlwa eziya kusetyenziswa. Umzobo wesampula yegazi yinkqubo eyamkelweyo nekhuselekileyo kwaye ayidibani nezinye iingxaki ezifutshane okanye ezinde. Isampulu yegazi iya kutsalwa ngugqirha ofanelekileyo ongumongikazi kwigumbi labucala elinikezelweyo kwiteksi.

Isampulu yegazi iya kuthi emva koko ithunyelwe kwilabhoratri ukuya kuvavanya iswekile yegazi, cholesterol, imeko ye-triglycerides. Olu lwazi luya kusixelela malunga nomngcipheko wakho wokuhlakulela izifo zentliziyo ukuze ukwazi ukuphuhlisa ungenelelo olufanelekileyo lokukunceda kunye noluntu olukujikelezileyo ukunqanda okanye ukulawula izifo zentliziyo kwixesha elizayo.

Ukuba unomdla wokwazi iziphumo zovavanyo lwegazi lakho, siya kukubonelela ngeVawutsha yokuCela iSiphumo seNgcaciso ekudlulisela kwindawo efanayo yezempilo esiya kuyisebenzisa ukuthatha isampula yakho yegazi. Le vawutsha iya kuba nenombolo yodliwanondlebe ethatha inxaxheba eya kunceda abasebenzi baseklinikhi ukuba banxibelelanise ngokuchanekileyo iziphumo zelebhu kwivawutsha. Ulwazi olongezelelekileyo ezifakwe kwivawutsha luya kubandakanya isini nobudala bomthathi-nxaxheba, umhla wokuqokelelwa kweziphumo, kunye negama nedilesi yekliniki ekhethiweyo. Abasebenzi basekliniki bayasazi isifundo, kwaye baya kukunceda ngovuyo. Konke

okufuneka kwenziwe kukuhambisa ivawutsha ekliniki. Xa ubonelela ngeesampulu zegazi, nceda ukhumbule ukuba kuya kufuneka unike imvume yokusebenzisa isampula yegazi kuphando lwangoku kunye naluphi na uphando oluzayo kwixesha elizayo.

Nceda uqaphele ukuba konke ukuhlangana kwabantu kunye nokuthetha ngesiqu sakho okanye abanye abantu kuthwala umngcipheko othile. Nangona kunjalo asizukunciphisa umngcipheko kwaye ke siyakuthatha amanyathelo ngokukhawuleza ukukunceda ukuba uveze ukuba kukhona okungahambi kakuhle emzimbeni nasengqondweni, okanye ngenye indlela ngexesha lokuthatha kwakho inxaxheba kolu phando. Apho kukho imfuneko, ukuthunyelwa okufanelekileyo kuyakwenziwa kwiingcali ezifanelekileyo ngoncedo olungaphezulu okanye ungenelelo.

Ziziphi iingenelo zale phando?

Izibonelelo kuwe zibandakanya iziphumo zeemviwo zeklinikhi kunye nophando olwenziwe elebhu oluzakwenziwa ukuba ulufumane. Ukuba ungathanda ukufumana ingxelo ngophando lwethu, siya kurekhoda inombolo yakho yomnxeba kwiphepha elahlukileyo kwaye singakuthumelela iziphumo zophando xa kugqitywa ukuphela kuka-2020. Olu phando alwenzelwanga ukuba luzuze buqu kwaye kwangoko, kodwa iziphumo zinokunceda abaphandi ukuba bafunda ngakumbi malunga nempilo yabaqhubi beteksi yoMzantsi Afrika kunye nemeko yabo yesondlo, ukuze babe nako ukuphuhlisa ungenelelo olusebenzayo kunye nezicwangciso zokuthintela nokunyanga izifo zentliziyo kubantu boMzantsi Afrika, ngakumbi ezo bakwishishini lokuqhuba, ngakumbi abaqhubi beteksi.

Ngaba kufuneka ndibe kuloluphando kwaye ndivumelekile ukuyeka ukuthatha inxaxheba nanini na?

Uthatho-nxaxheba lwakho kolu phando lukuzithandela ngokupheleleyo. Unokukhetha ukungathathi nxaxheba. Ukuba uthatha isigqibo sokuthatha inxaxheba kolu phando, unokuyeka ukuthatha inxaxheba ngalo naliphi na ixesha. Ukuba uthatha isigqibo sokungathathi nxaxheba kolu phononongo okanye ukuba uyekile ukuthabatha inxaxheba nangaliphi na ixesha, awusohlwaywa okanye uphulukane naziphi na izibonelelo ozifaneleyo.

Kuthekani ukuba ndinemibuzo?

Olu phando luqhutywa ngu Mnu Sekgala Derrick kunye no Prof Zandile Mchiza kwi Dyunivesithi yase Ntshona. Ukuba unayo nayiphi na imibuzo malunga nesifundo sophando uqobo, nceda uqhakamshelane noDerrick Sekgala kule nombolo: 021 466 8058 okanye derrick.sekgala@gmail.com okanye uProf Zandile Mchiza kule nombolo: 021 959 6232 okanye jmchiza@uwc.ac.za

Ukuba unemibuzo malunga nolu phononongo kunye namalungelo akho njengomthathi-nxaxheba ophando okanye ukuba unomdla wokuxela naziphi na iingxaki onazo ezinxulumene nesifundo, nceda uqhagamshelane:

UProf Uta Lehmann
UMlawuli: ISikolo seMpilo yoLuntu
IYunivesithi yeNtshona Koloni
Ingxowa yabucala X17
IBellville 7535
iTel: +27 21-959 2809 Fax: 27 21-959 2872

Appendix 6: Information sheet in Afrikaans

SCHOOL OF PUBLIC HEALTH
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INLIGTINGSBLAD

Navorsing Titel: Meting van metaboliese sindroom en die risiko om straatkos by kommersiële taxibestuurders in Suid-Afrika te eet: 'n deursnitstudie

Inleiding

Waaroor gaan hierdie studie?

Hierdie navorsing word gedoen deur mnr Derrick Sekgala en prof Zandile Mchiza aan die Universiteit van Wes-Kaapland. Ons nooi u uit om deel te neem aan hierdie navorsing omdat u 18 jaar en ouer is en in die taxibedryfbedryf in die Kaapse Metropool-gebied werk. Die doel van hierdie navorsingsprojek is om die antwoorde en bloedmonsters wat deur u soos iemand gegee is te gebruik om inligting te genereer rakende bloeddruk, bloedglukose en cholesterolstatus, wat faktore is wat van belang is vir die ontwikkeling van hartsiektes. Dit sal ons ook help om meer te wete te kom oor die gesondheid en voedingsstatus van die Suid-Afrikaanse taxibestuurders, sodat ons effektiewe ingrypings en strategieë kan ontwikkel om hartsiektes by mense van Suid-Afrika te voorkom en te behandel, veral diegene wat in die bestuursbedryf is. .

Wat sal ek gevra word om te doen as ek instem om deel te neem?

U sal gevra word om u gedagtes en bloedmonster met ons te deel. 'N Vraelys sal gebruik word om u sosio-demografiese inligting, dieetkundige praktyke en ander gedrag soos rook en alkoholgebruik in te samel. Geen persoonlik identifiseerbare inligting sal versamel word nie. As u kies om nie deel te neem aan die beantwoording van die vrae en om 'n bloedmonster te gee nie, sal u op geen manier beïnvloed word nie. As u instem om deel te neem, kan u my stop en sê dat u nie wil voortgaan met die bloedsteekproefneming en enkele vrae beantwoord sonder enige gevolge vir u nie. U moet asseblief verstaan dat u deelname vrywillig is. U word

steriele instrumente sal gebruik word wat skoon en heeltemal veilig is. Die neem van 'n bloedmonster is 'n aanvaarde en veilige prosedure en hou gewoonlik nie verband met enige kort- of langtermyn nadelige gevolge nie. Die bloedmonster word geneem deur 'n gekwalifiseerde verpleegsuster in die privaat kamer wat op die taxistaanplek voorsien word.

Die bloedmonster sal dan na 'n laboratorium gestuur word om te toets of dit bloedsuiker, cholesterol, trigliseriede is. Hierdie inligting sal ons vertel van u risiko om hartsiektes te ontwikkel ten einde relevante intervensies te kan ontwikkel om u en die gemeenskap wat u omring, te help om in die toekoms hartsiektes te voorkom of te bestuur.

As u belangstel om die uitslag van u bloedtoets te weet, sal ons u 'n voorbeeldbewys van die uitslagversoek van u voorbeeld gee wat u na dieselfde gesondheidsfasiliteit sal verwys wat u sal gebruik om u bloedmonster te neem. Hierdie voucher het 'n unieke vraelysnommer vir deelnemers wat kliniekpersoneel kan help om die laboratoriumresultate korrek aan die koopbewys te koppel. Bykomende inligting wat op die koopbewys verkry is, sal die geslag en ouderdom van die deelnemer, die datum van die uitslagversameling en die naam en adres van die geselekteerde kliniek insluit. Die kliniekpersoneel is bewus van die studie en help u graag. Al wat gedoen moet word, is om die koopbewys by die kliniek aan te bied. Wanneer u bloedmonsters lewer, moet u onthou dat u ook toestemming moet gee om die bloedmonster te gebruik vir die huidige en lopende navorsing in die toekoms.

Let ook daarop dat alle menslike interaksies en die praat van self of ander 'n mate van risiko's inhou. Ons sal sulke risiko's egter tot die minimum beperk, en ons sal daarom dadelik optree om u te help as u fisiese of sielkundige ongemak ervaar, of andersins tydens u deelname aan hierdie studie. Waar nodig, sal 'n toepaslike professionele persoon verwys word vir verdere hulp of ingryping.

Wat is die voordele van hierdie navorsing?

Die voordele vir u sluit die uitslae van die kliniese ondersoeke en laboratoriumondersoeke in wat u beskikbaar sal stel indien u dit nodig het. As u terugvoering oor ons studie wil ontvang, teken ons u telefoonnommer op 'n aparte vel papier en kan u die resultate van die studie aan u stuur aan die einde van 2020. Hierdie navorsing is nie bedoel om u te bevoordeel nie persoonlik en onmiddellik, maar die resultate kan die ondersoekers help om meer oor Suid-Afrikaanse taxibestuurders se gesondheid en hul voedingsstatus te leer om effektiewe ingrypings en strategieë te ontwikkel om hartsiektes by mense van Suid-Afrika te voorkom en te behandel, veral dié wat in die bestuursbedryf is, veral die taxibestuurders.

Moet ek aan hierdie navorsing deelneem en mag ek op enige tydstip ophou deelneem?

U deelname aan hierdie navorsing is heeltemal vrywillig. U kan kies om glad nie deel te neem nie. As u besluit om aan hierdie navorsing deel te neem, kan u op enige tydstip ophou deelneem. As u besluit om nie aan hierdie studie deel te neem nie, of as u op enige tydstip

ophou om deel te neem, sal u nie gepenaliseer word of enige voordele verloor waarvoor u anders kwalifiseer nie.

Wat as ek vrae het?

Hierdie navorsing word gedoen deur mnr Sekgala Derrick en prof Zandile Mchiza aan die Universiteit van Wes-Kaapland. As u enige vrae het oor die navorsingstudie self, kontak Derrick Sekgala by: 021 466 8058 of derrick.sekgala@gmail.com of prof Zandile Mchiza by: 021 959 6232 of jmchiza@uwc.ac.za

As u enige vrae het rakende hierdie studie en u regte as navorsingsdeelnemer, of as u probleme wat u ondervind het rakende die studie wil rapporteer, kontak:

Prof Uta Lehmann

Direkteur: Skool vir Openbare Gesondheid
Universiteit van die Wes-Kaap Privaatsak X17
Bellville 7535
Tel: +27 21-959 2809 Faks: 27 21-959 2872
E-pos: soph-comm@uwc.ac.za
OR
Prof Anthea Rhoda

Dekaan van die Fakulteit Gemeenskaps- en Gesondheidswetenskappe Universiteit van Wes-Kaapland

Privaatsak X17 Bellville 7535

chs-deansoffice@uwc.ac.za

Hierdie navorsing is deur die Universiteit van Wes-Kaapland se Biomediese Navorsingsetiekkomitee goedgekeur. REF NO: BM18 / 9/25

BIOMEDICAL RESEARCH ETHICS ADMINISTRATION
Research Office
New Arts Building,
C-Block, Top Floor, Room 28
University of the Western Cape
Private Bag X17
Bellville 7535
BMREC Research Development Tel: 021 959 4111 Email: research-ethics@uwc.ac.za

Appendix 7: Consent form in English

SCHOOL OF PUBLIC HEALTH
FACULTY OF COMMUNITY AND
HEALTH SCIENCES
Private Bag X 17, Bellville 7535, South Africa
Tel: +27 21-959 2809/2132, Fax: 27 21-959 2872
Website:www.uwc.ac.za/faculties/chs/soph

CONSENT FORM

Title of Research Project:

Measuring metabolic syndrome and the risk of consuming street food among commercial taxi drivers in South Africa: a cross-sectional study

CONSENT

I hereby agree to participate in the University of the Western Cape study. The study has been described to me in language that I understand. My questions about the study have been answered. I understand that I am participating voluntarily and without being forced in any way to do so. I also understand that I can stop this interview at any point during the interview should I not want to continue and that this decision will not in any way affect me or my household negatively.

I understand that this is a research project - the purpose of which is not necessarily to benefit me personally.

I have received the telephone number of a person to contact should I need to report any issues which may arise in this interview. I understand that this consent form will not be linked to the questionnaire and that my answers will remain anonymous and confidential.

....
Signature of participant Date

CONSENT TO PROVIDE A BLOOD SPECIMEN

I hereby agree to provide a blood sample as part of the University of the Western Cape study. I understand that I am providing the blood specimen voluntarily and without being forced in any way to do so. I also understand that I do not have to provide a blood specimen if I do not want to and that I can stop this interview at any point should I not want to continue, and that this decision will not in any way affect me or my household negatively.

.....
Signature of participant

.....
Date

Appendix 8: Consent form isiXhosa

SCHOOL OF PUBLIC HEALTH
FACULTY OF COMMUNITY AND
HEALTH SCIENCES
Private Bag X17, Bellville 7535, South Africa
Tel: +27 21-959 2809/2132
Fax: +27 21-959 2872
Website:www.uwc.ac.za/faculties/chs/soph

IFOMU YOVUMELWANO

IINKCUKACHA ZENGCACISO

Isihloko seProjekthi: Ukulinganisa i-metabolic syndrome kunye nomngcipheko wokutya ukutya esitratweni phakathi kwabaqhubi beeteksi zorhwebo eMzantsi Afrika: isifundo esiphambeneyo

Isivumelwano

Ndiyavuma ukuthatha inxaxheba kwiYunivesithi yaseNtshona Koloni. Isifundo sichaziwe kum ngolwimi endisiqondayo. Imibuzo yam malunga nesifundo iphendulwe. Ndiyaqonda ukuba ndithatha inxaxheba ngokuzithandela nangaphandle kokunyanzelwa nangayiphi na indlela ukwenza oko. Ndiyaqonda ukuba ndingayeka udliwanondlebe nangaliphi na ixesha ngexesha lodliwanondlebe ukuba andifuni kuqhubeka nokuba esi sigqibo asizukundichaphazela nangayiphi na indlela okanye indlu yam ibambe kakubi.

Ndiyaqonda ukuba le yiprojekthi yophando-injongo yazo ayisiyonto indinceda mna.

Ndifumene inombolo yefowuni yomntu ekunxibelelana naye xa kufuneka ndixele nayiphi na imicimbi enokuvela kolu dliwanondlebe. Ndiyaqonda ukuba le fomu yokuvuma ayiyi kudityaniswa kwiphepha lemibuzo, kwaye iimpendulo zam ziya kuhlala zingaziwa kwaye ziyimfihlo.

....

Isityikityo **Umhla**

Ndiyavuma ukubonelela ngesampula yegazi njengenxalenye yeYunivesithi yaseNtshona Koloni. Ndiyaqonda ukuba ndinikezela isampuli yegazi ngokuzithandela kwaye ngaphandle kokunyanzelwa nangayiphi na indlela ukwenza njalo. Ndiyaqonda ukuba andizukubonelela ngesampulu yegazi ukuba andifuni kwaye ndingayeka udliwanondlebe nangaliphi na ixesha ukuba andifuni ukuqhubeka, kwaye esi sigqibo asizukundichaphazela nangayiphi na indlela. ngokungathandekiyo.

....

Isityikityo **Umhla**

Appendix 9: Consent form Afrikaans

SCHOOL OF PUBLIC HEALTH
FACULTY OF COMMUNITY AND
HEALTH SCIENCES
Private Bag X17, Bellville 7535, South Africa
Tel: +27 21-959 2809/2132
Fax: +27 21-959 2872
Website:www.uwc.ac.za/faculties/chs/soph

VRYWARINGS VORM

Titel van Navorsingsprojek: Meting van metaboliese sindroom en die risiko om straatkos by kommersiële taxibestuurders in Suid-Afrika te eet: 'n deursnitstudie

TOESTEMMING

Hiermee stem ek in om deel te neem aan die Universiteit van Wes-Kaapland. Die studie is aan my beskryf in 'n taal wat ek verstaan. My vrae oor die studie is beantwoord. Ek verstaan dat ek vrywillig deelneem en sonder dat ek op enige manier gedwing word om dit te doen. Ek verstaan ook dat ek hierdie onderhoud op enige punt tydens die onderhoud kan stop as ek nie wil voortgaan nie en dat hierdie besluit my of my huis nie negatief sal beïnvloed nie.

Ek verstaan dat dit 'n navorsingsprojek is waarvan die doel nie noodwendig persoonlik moet baat nie.

Ek het die telefoonnommer ontvang van 'n persoon om te kontak indien ek enige probleme wat tydens hierdie onderhoud mag ontstaan, moet aanmeld. Ek verstaan dat hierdie toestemmingsvorm nie aan die vraelys gekoppel sal word nie, en dat my antwoorde anoniem en vertroulik sal bly.

....

Handtekening van die deelnemer **Datum**

VERGUNNING OM 'N BLOEDBEPALING TE GEE

Hiermee stem ek in om bloedmonster as deel van die Universiteit van Wes-Kaapland se studie te voorsien. Ek verstaan dat ek die bloedmonster vrywillig verskaf en sonder dat ek op enige manier gedwing word om dit te doen. Ek verstaan ook dat ek nie 'n bloedmonster hoef te lewer as ek nie wil nie en dat ek hierdie onderhoud op enige punt kan stop as ek nie wil voortgaan nie, en dat hierdie besluit my of my huishouding op geen manier sal beïnvloed nie negatief

....

Handtekening van die deelnemer **Datum**

Appendix 10: Participants Socio-demographic Questionnaire

STREET FOOD QUESTIONNAIRE FOR CONSUMERS

SECTION A: Socio-demographic information

ID/study number Location:
Date:
Time:
Interviewer:

1. Age in years	[redacted]	1
	[redacted]	2
	c. 25 - 34	3
	d. 35 - 44	4
	e. 45 – 54	5
	f. 55 - 64	6
	g. 65 +	7
2. Marital status	a. Single	1
	b. Married	2
	c. Living as married	3
	d. Separated	4
	e. Divorced	5
	f. Widowed	6
3. What is your country of origin?	a. South African	1
	b. Other (specify)	2
4. if respondent is South African, indicate race (do not ask but tick)	a. Black African	1
	b. Coloured	2
	c. Indian/Asian	3
	d. White	4
	e. other (specify)	5
5. Level of monthly income	a. < R3 000,	1
	b. R3 000-R4 000,	2
	c. R4 000-R6 000,	3
	d. > R6 000	4
	e. Student	5
	f. Unemployed	6
7. Highest level education	a. Primary school	1

	b. Some high school	2
	c. Matric	3
	d. Diploma	4
	e. Degree	5
	f. No Schooling	6

8. Number of children	a. 1,	1
	b. 2	2
	c. 3	3
	d. Other	4

9.How many hours of sleep do you spend every night?	a.<3	1
	b. 4	2
	c. 5	3
	d.6	4
	e.7	5
	f.8	6
	g.>9	7

10.What is your driving experience in years and months?	.....years: .....months

SECTION B. Purchasing habits

1. How often do you buy food/snack items/drinks from vendors/street sellers?	a. Almost every day;	1
	b. 2 to 3x a week;	2
	c. About once a week;	3
	d. About once or twice a month;	4
	e. Never	5

2. What time of day do you usually buy food/snack items/drinks from vendors/street sellers?	a. Before 10am	1
	b. Between 10am and 12pm	2
	c. Between 12pm and 3pm	3
	d. Between 3pm and 6pm	4
	e. After 6pm	5

3. Where do you usually buy your breakfast/snack/lunch from vendors/street sellers?	a. Near home	1
	b. Near work	2
	c. Near school	3
	d. Near college	4
	e. Other (specify).....	5

4. About how much money do you spend a day on street food in rands? | | | |

SECTION C. Consumption Preferences

1. Which types of foods do you buy most often from vendors / street sellers? (Can give more than 1 answer)	a. Fruit,	1
	b. cold drinks,	2
	c. crisps;	3
	d. biscuits;	4
	e. sweets;	5
	f. chocolates;	6
	g. cooked food;	7
	h. peanuts;	8
	i. fruit juice;	9
	j. Other (specify).....	10

2. If you buy cooked food, what is your favourite cooked street food (**If no, skip to question 5**)
(specify).....
.

3. What does it cost?	a. < R10	1
	b. R10 – R20	2
	c. R20 – R30	3
	d. R30 – R40	4
	e. > R40	5

4. Would you like vendors to sell healthier foods?	a. Yes	1
	b. No	2

5. Which of the following would you be willing to buy from a vendor / street seller? (Can give more than 1 answer)	a. Milk, or milk drinks;	1
	b. yoghurt,	2
	c. yoghurt and muesli;	3
	d. yoghurt and fruit;	4
	e. nuts,	5
	f. fresh fruit juice;	6
	g. fresh vegetable juice ie. carrot juice;	7
	h. salad;	8
	i. fruit;	9
	j. fruit salad;	10
	k. dried fruits;	11
	l. peanuts and raisins;	12
	m. cooked vegetables eg mealie,	13

	n. vegetable skewers;	14
	o. fruit skewers;	15
	p. baked potato;	16
	q. whole wheat sandwich;	17
	r. meat or chicken cooked with vegetables (not fried);	18
	s. veggie burgers;	19
	t. high fibre muffins;	20
	u. pita bread with salad fillings;	21
	v. wraps with healthy fillings	22

6. Do you ever purchase fruit from street food vendors?	a. Yes	1
	b. No	2

7. How often?	a. Every day	1
	b. 2-3 times /week	2
	c. 2-3 times /month	3
	d. Hardly ever/never	4
8. Do you ever purchase vegetables from street food vendors?	a. Yes	
	b. No	
9. How often?	a. Every day	1
	b. 2-3 times /week	2
	c. 2-3 times /month	3
	d. Hardly ever/never	4

Thank You for Completing This Questionnaire

Appendix 11: Participants food frequency Questionnaire

BARCODE

Individual Questionnaire Number: .....00439.....

Adult Questionnaire: 15 years and older

SECTION B-5	PHYSICAL ACTIVITY (GPAQ)		
NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
	The next questions are about the time you spend doing different types of physical activities. You need to think about the time that you spend doing both vigorous and moderate activities in a usual week • 'vigorous-intensity activities' are activities that require strenuous physical effort and cause large increases in breathing and heart rate • 'moderate-intensity activities' are activities that require moderate effort and cause small increases in breathing and heart rate. You need to think about all the activities you do at home, at work, travelling from place to place and during your spare time.		
1	**Work-related Physical** Activity (paid or unpaid work outside your own home). **If you are unemployed,** think about the things that keep you physically active during the day. When answering the following questions, think back over the past 12 months and consider (think of) a usual week.		
1a	Does your work involve vigorous activities that cause large increases in breathing or heart rate, (like heavy lifting, digging, or heavy construction) for at least 10 minutes at a time?	Yes ..... 1 No 2	→2a
1b	In a usual week, how many days do you do vigorous activities as part of your work?	Days	
1c	On a **usual day** on which you do vigorous activities, how much time do you spend doing such work?	Hours ..... Minutes	
2a	Does your work involve moderate-intensity activities that cause small increases in breathing and heart rate (like brisk walking or carrying light loads) for at least 10 minutes at a time?	Yes ..... 1 No 2	→3
2b	In a usual week, how many days do you do moderate-intensity activities as part of your work?	Days	
2c	On a **usual day** on which you do moderate-intensity activities, how much time do you spend doing such work?	Hours ..... Minutes	
3	How long is your usual workday?	Hours ..... Minutes	
4	**Travel-Related Physical Activity:** Other than activities that you've already mentioned, I would like to ask you about the way you travel to and from places (to work, to shopping, to market, to church, etc.).		

1

SECTION B-5	PHYSICAL ACTIVITY (GPAQ)		
4a	Do you walk or use a bicycle (pedal cycle) for **at least 10 minutes** at a time to get to and from places?	Yes ..... 1 No 2	➢5
4b	In a **usual week**, how many days do you walk or cycle for at least 10 minutes to get to and from places?	Days ..... ☐	
4c	On a **usual day,** how much time do you spend walking or cycling for travel?	Hours ..... ☐☐ Minutes ..... ☐☐	
5	**Non-Work Related and Leisure Time Physical Activity:** The next questions exclude the work and transport activities you have already mentioned. Now I am going to ask you about activities you do for sport, fitness or recreation in your leisure or spare time.		
5a	Do you do any **vigorous intensity** sport, fitness or recreational activities in your leisure or spare time, that cause large increases in breathing or heart rate (like running or strenuous sports, weightlifting) for at **least 10 minutes** at a time?	Yes ..... 1 No 2	➢6a
5b	In **a usual week**, how many days do you do **vigorous** activities as part of your leisure or spare time?	Days ..... ☐	
5c	How much time do you spend doing this on a **usual day?**	Hours ..... ☐☐ Minutes ..... ☐☐	
6a	Do you do any **moderate-intensity** sport, fitness or recreational activities in your leisure or spare time that cause small increases in breathing and heart rate (like brisk walking, cycling or swimming) for at **least 10 minutes** at a time?	Yes ..... 1 No 2	➢7
6b	In a **usual week**, how many days do you do **moderate-intensity** activities as part of your leisure or spare time?	Days ..... ☐	
6c	How much time do you spend doing this on a **usual day?**	Hours ..... ☐☐ Minutes ..... ☐☐	
7	**Sitting / Resting Activity:** Now I would like to ask you about the time spent sitting or resting, not including sleeping, **in the past 7 days**. This may include time sitting at a desk, riding in a car or taxi, visiting friends, reading, or sitting down to watch television **during working hours and leisure or spare time**.		
7a	Over the **past 7 days, how** much time did you spend sitting or reclining (lying) on **a usual WEEKDAY** (excluding sleeping)?	Hours ..... ☐☐ Minutes ..... ☐☐	
7b	Over the **past 7 days,** how much time did you spend sitting or reclining (lying) on **a usual WEEKEND day** (excluding sleeping)?	Hours ..... ☐☐ Minutes ..... ☐☐	

SECTION B-6	DIET: FOOD FREQUENCY		
NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
	By using your answers to what you have eaten during the past week, we can determine the usual intake of food by South Africans During the past seven days did you eat the following food? **If YES, ask how often; IF No, circle 1** **Do not read coding categories to the respondent**		
1	Processed meat, e.g. sausages, polony, cold cuts, Viennas, Frankfurters, Russians, salami?	None 1 Every day 2 1-3 times last week 3 4-6 times last week 4	
2	Food covered with pastry or crumbs, e.g. pies, chicken, beef schnitzel, etc?	None 1 Every day 2 1-3 times last week 3 4-6 times last week 4	
3	Food from fast food outlets (take-aways, e.g. pizza, chicken, fish, etc.)?	None 1 Every day 2 1-3 times last week 3 4-6 times last week 4	
4	Fried food bought from street vendors, eg. chips, vetkoek, fried chicken, fried fish, etc?	None 1 Every day 2 1-3 times last week 3 4-6 times last week 4	
5	Low fat fresh/frozen fish, e.g. hake, without batter or crumbs?	None 1 Every day 2 1-3 times last week 3 4-6 times last week 4	
6	Medium fat fresh/frozen, fish, e.g. salmon/mackerel/snoek?	None 1 Every day 2 1-3 times last week 3 4-6 times last week 4	
7	Tinned fish, e.g. sardines/pilchards/salmon (excluding tuna)?	None 1 Every day 2 1-3 times last week 3 4-6 times last week 4	
8	Food deep fried in oil/fat, e.g. fish, fries/chips, vetkoek, samoosas, doughnuts?	None 1 Every day 2 1-3 times last week 3 4-6 times last week 4	
9	Butter, ghee, fat, margarine or oil added to vegetables or other food (like meat) during preparation?	None 1 Every day 2 1-3 times last week 3 4-6 times last week 4	
10	Mayonnaise or salad dressing added to food?	None 1 Every day 2 1-3 times last week 3 4-6 times last week 4	
11	Cookies, rusks, cakes, pastries?	None 1 Every day 2 1-3 times last week 3 4-6 times last week 4	
12	Sweets such as chocolates, fudge or toffees?	None 1 Every day 2 1-3 times last week 3 4-6 times last week 4	

SECTION B-6	DIET: FOOD FREQUENCY		
NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
13	Nuts including peanuts?	None ..... 1 Every day ..... 2 1-3 times last week ..... 3 4-6 times last week 4	
14	Fresh fruit juice, without added sugar?	None ..... 1 Every day ..... 2 1-3 times last week ..... 3 4-6 times last week 4	
15	Fresh fruit (all the fruit, excluding fruit juices and dried fruit)?	None ..... 1 Every day ..... 2 1-3 times last week ..... 3 4-6 times last week 4	
16	Dark green leafy or dark yellow vegetables?	None ..... 1 Every day ..... 2 1-3 times last week ..... 3 4-6 times last week 4	
17	Other vegetables/salad, e.g. cabbage, tomatoes, excluding potatoes?	None ..... 1 Every day ..... 2 1-3 times last week ..... 3 4-6 times last week 4	
18	Snacks such as chips/crisps, *mazimba*, etc.?	None ..... 1 Every day ..... 2 1-3 times last week ..... 3 4-6 times last week 4	
19	Salty foods, e.g. salted nuts, biltong, dried sausage, dried salted fish?	None ..... 1 Every day ..... 2 1-3 times last week ..... 3 4-6 times last week 4	
20	Sweetened cold drink (gas/fizzy cold drink and reconstituted)?	None ..... 1 Every day ..... 2 1-3 times last week ..... 3 4-6 times last week 4	
21	Sweetened fruit juice?	None ..... 1 Every day ..... 2 1-3 times last week ..... 3 4-6 times last week 4	
22	Which type of bread spread, i.e. butter/margarine do you usually spread/use on your bread?	None ..... 1 Margarine Hard type, medium fat (wrapped) ..... 2 Margarine Hard type, low fat (wrapped) ..... 3 Margarine Soft type, regular (tub) ..... 4 Margarine Soft type, medium fat (tub) ..... 5 Margarine Soft type, light (tub) ..... 6 Margarine Soft type, extra light (tub) ..... 7 Cooking fat (eg Holsum) ..... 8 Animal fat (eg beef, chicken, sausage fat) ..... 9 Olive oil margarine ..... 10 Butter (salted) ..... 11 Butter (unsalted) ..... 12 Peanut butter ..... 13 Don't know 14	
23	Which type of oil do you use in food preparation/as salad dressing most of the time?	None ..... 1 Canola oil ..... 2 Olive oil ..... 3 Soya oil ..... 4 Sunflower oil ..... 5 Vegetable oil (mixture) ..... 6 Other (Specify) ..... 7 Don't know 8	

SECTION B-6	DIET: FOOD FREQUENCY		
NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
24	Do you usually eat red meat (beef, mutton and pork) with the fat on, or do you remove the fat from the meat?	Do not eat red meat ..... 1 Meat with fat on ..... 2 Fat removed from the meat 3	
25	Do you usually eat the chicken with the skin, or without the skin?	Do not eat chicken ..... 1 With the skin ..... 2 Without the skin 3	
26	Do you prefer to eat your food usually very salty, lightly salted or not salted?	Very salty ..... 1 Lightly salted ..... 2 Not salted ..... 3 Don't know 4	
27	How much butter, fat or margarine do you usually spread on your bread, crackers, or scones?	None ..... 1 Very thin / scraped on ..... 2 Thin (just covered) ..... 3 Medium (nicely covered) ..... 4 Thick (see teeth marks) ..... 5 Don't know 6	
28	How much milk in total do you usually take in per day?	More than 2 cups ..... 1 1-2 cups ..... 2 ½ - 1 cup ..... 3 Less than ½ cup ..... 4 None ..... 5 Don't know 6	
29	How many fruits do you usually eat per day?	4 or more per day ..... 1 1-3 per day ..... 2 Not every day, but 4 or more per week ..... 3 Not every day, but less than 4 per week ..... 4 None ..... 5 Don't know 6	
30	How much fresh/unsweetened fruit juice do you usually drink per day?	More than 2 cups ..... 1 1-2 cups ..... 2 ½ - 1 cup ..... 3 Less than ½ cup ..... 4 None ..... 5 Don't know 6	
31	How many portions of vegetables, excluding potatoes, do you usually eat per day?	4 or more per day ..... 1 1-3 per day ..... 2 Not every day, but 4 or more per week ..... 3 Not every day, but less than 4 per week ..... 4 None ..... 5 Don't know 6	
32	If there are children under five years old in this household, did they eat from the same pot as the rest of the family at the main meal yesterday?	Yes ..... 1 No ..... 2 No children aged under 5 in household 3	

[3] INSTRUCTION TO INTERVIEWER	Interviewer: Use the example below to help you understand what a standard unit or a standard drink is. One standard drink:


A single tot of spirits (whisky, gin, vodka) (e.g. 25ml at 43%)


A small glass of liqueur or aperitif (e.g. 25ml at 30%)


1 can of ordinary beer (e.g. 340ml at 5%)


1 glass of wine (e.g. 120ml at 12%)


Carton of ordinary commercial sorghum beer (e.g. 500ml at 3%)

SECTION B-7 ALCOHOL

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
1	How often did you have a drink containing alcohol in the past 12 months?	Never ..... 0 Monthly or less ..... 1 2-4 times a month ..... 2 2-3 times a week ..... 3 4 or more times a week 4	→ Filter
2	How many drinks containing alcohol do you have on a typical day when you are drinking?	1 or 2 ..... 0 3 or 4 ..... 1 5 or 6 ..... 2 7 , 8 or 9 ..... 3 10 or more 4	
3	How often do you have (for men) five or more and (for women) four or more drinks on one occasion?	Never ..... 0 Less than monthly ..... 1 Monthly ..... 2 Weekly ..... 3 Daily or almost daily 4	

SECTION D	NUTRITION

SECTION D-1	24 HOUR RECALL

Please describe the foods (meals and snacks and drinks) you ate yesterday during the day and night

Breakfast	Mid-morning	Lunch	Mid afternoon	Supper	After supper

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
1	Did you or anyone in your household eat anything (meal or snack) OUTSIDE the home yesterday?	Yes ..... 1 No 2	
2	Was yesterday a celebration or feast day where your household ate special foods or where your household ate more, or less than usual?	Yes ..... 1 No 2	

[5] INSTRUCTION TO INTERVIEWER	When the interview with the participant is completed, the fieldworker must select the individual food items listed in Section D-1 and link them to the appropriate food groups listed in Section D-2. At the end of the day, the team leader will then double check that the linking has been done correctly

SECTION D-2	LIST OF FOOD GROUPS		
	Group	Foods	Code
3	Cereals	Corn/maize/samp, rice, wheat, sorghum, porridge, phutu, bread, pasta, breakfast cereals, oats, Mabella, Morvite, fortified cereals	Yes.....1 No.....2
4	White roots and tubers	Potato, white sweet potato	Yes.....1 No.....2
5	Yellow/orange vegetables	Carrot, butternut, pumpkin, orange-fleshed sweet potato	Yes.....1 No.....2
6	Dark-green leaves	Spinach, imifino, morogo	Yes.....1 No.....2
7	Vegetables other than dark-green leafy and yellow/orange	Beetroot, brinjals, broccoli, brussels sprouts, cabbage, cauliflower, gem squash, green beans, onion, peas, tomato, turnip, thepe	Yes.....1 No.....2
8	Yellow / orange fruits	Apricot, mango, pawpaw, sweet melon, yellow flesh peach, yellow flesh plums, 100% fruit juice made from these	Yes.....1 No.....2
9	Fruit other than yellow / orange fleshed	Apple, avocado, banana, berries, fig, granadilla, grape, grapefruit, guava, lemon, litchi, marcela, melon, orange, naartjie, peach, pear, pineapple, plum, strawberry, watermelon, 100% fruit juice made from these	Yes.....1 No.....2
10	Organ meat (offal)	Liver, kidney, heart, spleen, lungs, chicken giblets, malomogudo (offal), intestines	Yes.....1 No.....2
11	Meat and poultry (flesh meats)	Beef, goat, lamb, mutton, pork, venison, game, chicken, birds, ostrich, insects, mopani worms, chicken head/feet, sheep head	Yes.....1 No.....2
12	Eggs	Any type of egg	Yes.....1 No.....2
13	Fish and seafood	Fresh, frozen fish or canned fish (sardines, pilchards, tuna), dried fish, shellfish	Yes.....1 No.....2
14	Legumes, nuts and seeds	Dried beans, dried peas, lentils, nuts, peanuts, seeds (or foods made from these e.g. peanut butter)	Yes.....1 No.....2
15	Milk and milk products	Milk, sour milk, cheese, yogurt, custard, or any other milk products, or any drinks made with milk eg. cocoa	Yes.....1 No.....2
16	Fats and oils	Oils, fats, margarine or butter added to foods or used for cooking	Yes.....1 No.....2
17	Sugars and sweets	Sugar, sweets, chocolates, cake and sweetened biscuits, honey, jam, sugar sweetened drinks e.g. cold drinks, sugary foods, sweetened condensed milk	Yes.....1 No.....2
18	Spices and condiments	Spices (salt, pepper, etc), condiments (e.g. chutney, tomato sauce)	Yes.....1 No.....2
19	Drinks	Coffee, tea	Yes.....1 No.....2
20	Drinks	Alcoholic drinks	Yes.....1 No.....2
21	Drinks	Cold drinks (except diet cold drinks) and sweetened beverages	Yes.....1 No.....2

SECTION D-4 DIETARY BEHAVIOUR

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
1	How many meals and snacks do you usually have a day?	More than three meals with eating snacks between meals ..... 1 Three meals with eating snacks between meals ..... 2 Three meals with no eating snacks between meals ..... 3 Two meals with eating snacks between meals ..... 4 Two meals with no eating snacks between meals ..... 5 One meal with eating snacks during the day ..... 6 One meal ..... 7 Nibble the whole day, no specific meals ..... 8 Other (Specify) 9	
2	Do you ever eat in places other than at home?	Yes ..... 1 No 2	->D-4
3	How often do you eat at those places?	More than once a week ..... 1 Weekly ..... 2 Monthly ..... 3 More than once a month ..... 4 Other (Specify) 5	

SECTION D-5 DIETARY PRACTICES

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
1	Please choose one or more factors from the list that influence your choices when you do grocery shopping? **(Multiple responses possible)** **Do not read the options**	The price of the food item ..... 1 Safety (in terms of hygiene) of the food item ..... 2 Taste of the food item ..... 3 Convenience ..... 4 The nutrient content of the food item ..... 5 How well / how long the food item keeps ..... 6 How easy the food item is to prepare ..... 7 Health considerations ..... 8 Other (Specify) ..... 9 Don't do grocery shopping 10	->5
2	Do you read food labels when grocery shopping?	Yes ..... 1 No 2	->5
3	How often do you read food labels?	All the time ..... 1 Sometimes ..... 2 Other (Specify) ..... 3 Never 4	
4	Do you understand the information on the food label?	Yes ..... 1 No 2	
5	How often do you wash your hands before handling food?	All the time ..... 1 Sometimes ..... 2 Other (Specify) ..... 3 Never 4	
6	How often do you wash your hands before eating?	All the time ..... 1 Sometimes ..... 2 Other (Specify) ..... 3 Never 4	

SECTION B-3 TOBACCO USE

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
	The next set of questions are about tobacco use		
1	Have you ever smoked tobacco	Yes, daily ..... 1 Yes, less than daily ..... 2 Yes, but not now ..... 3 No, not at all ..... 4 Don't know 5	 ➢13 ➢13
2	At what age did you start smoking or using tobacco regularly?	Age (in years)	
3	Do you currently smoke tobacco?	Yes, daily ..... 1 Yes, less than daily ..... 2 No, not at all ..... 3 Don't know 4	 ➢5 ➢5
4	For how long have you been smoking tobacco regularly? **If less than one month – enter "00" for years and "00" for months**	Number of years ..... Number of months	➢7
5	For how long did you smoke tobacco? **If less than one month – enter "00" for years and "00" for months**	Number of years ..... Number of months	
6	How long is it since you stopped smoking?	Years ..... Months ..... Weeks ..... Days	➢12
7	<u>Current tobacco use</u>		
7a	On average how many <u>manufactured cigarettes</u> do you smoke each day / week? **VERIFY THIS IS THE NUMBER OF CIGARETTES NOT PACKS** Also let me know if you smoke the product but not every day/week **If respondent reports smoking the product but not every (day/week), enter 88.**	Per day ..... Per week	
8	During any visit to a doctor or other health care provider in the past 12 months, were you advised to quit using tobacco?	Yes ..... 1 No ..... 2 Don't know 3	

SECTION B-3	TOBACCO USE		
NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
9	During the past 12 months have you tried to stop smoking or using tobacco?	Yes, tried to stop smoking ..... 1 Yes, tried to stop using snuff/ chewing tobacco ..... 2 Yes, tried to stop smoking and using snuff/ chewing tobacco ..... 3 No ..... 4 Don't know 5	
10	In the last 30 days, did you notice any health warnings on tobacco packages?	Yes ..... 1 No ..... 2 Did not see any tobacco packages 3	
11	In the last 30 days, have warning labels on tobacco packages led you to think about quitting?	Yes ..... 1 No ..... 2 Don't know 3	
12	**Past tobacco use**		
12a	On average how many manufactured cigarettes did you smoke each day / week? **VERIFY THIS IS THE NUMBER OF CIGARETTES NOT PACKS** Also let me know if you smoke the product but not every day/week **If respondent reports smoking** the product **but not every (day/week), enter** 88.	Per day ..... [ ][ ] Per week ..... [ ][ ]	
13	How often does anyone smoke inside your home?	Daily ..... 1 Weekly ..... 2 Monthly ..... 3 Less than monthly ..... 4 Never ..... 5 Don't know 6	

INSTRUCTIONS	Section G to be completed by the fieldworker

Clinic Fieldworker Start time H H : M M

SECTION G	Anthropometry

	Measurement type	Unit	Recorded measurements
1	Weight (all participants)	kg	1 , 2 , 3 , 4 , 5 , Unable to obtain a measurement
2	Height (all participants)	cm	1 , 2 , 3 , 4 , 5 , Unable to obtain a measurement

Bisceps

Skinfold measurements
All participants

Unable to obtain measurement

Triceps

Skinfold measurements
All participants

Unable to obtain measurement

Subscapula

Skinfold measurements
All participants

Unable to obtain measurement

Suprailiac

Skinfold measurements
All participants

Unable to obtain measurement