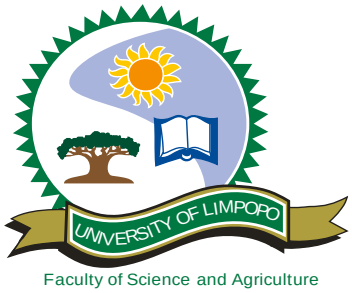

Faculty of Science and Agriculture

INVESTIGATING THE ASSOCIATION BETWEEN SUGAR-SWEETENED BEVERAGES INTAKE AND RISK OF METABOLIC SYNDROME AMONG ELLISRAS RURAL YOUTH: ELLISRAS LONGITUDINAL STUDY

by

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[redacted]

DISSERTATION

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"Do the best you can do till you know better· Then when you know better, do better" ~ Maya Angelou

DEDICATION

This dissertation is dedicated to my son, daughter and family. My special gratitude goes to my mother (Moyahabo Mafokoane) and grandmother (Makoma Seloka) who have continuously been the pillar and source of wisdom, strength, motivation, and support throughout my studies even in times of adversities. My aunty Matsatsi Moseamo, sisters (Pleasure Mafokoane, Ntebaleng Seloka and Ntebatse Mafokoane), brothers (Tebatso Moseamo, Moloka Moseamo, Moshike Mafokoane, Makwarela Mafokoane, Thoriso Moseamo) and nieces (Mahlogonolo Mafokoane, Pretty Mafokoane) for their endless love, care and support and taking and keeping my son and daughter's company. Moreover, this dissertation is also dedicated to my son and daughter (Boikanyo and Botshelo Seloka) for tolerating my divided attention and busyness during the completion of this dissertation.

DECLARATION

I Mohlago Ablonia Seloka declare that INVESTIGATING THE ASSOCIATION BETWEEN SUGAR-SWEETENED BEVERAGES INTAKE AND RISK OF METABOLIC SYNDROME AMONG ELLISRAS RURAL YOUTH: ELLISRAS LONGITUDINAL STUDY is my work and that all sources that I have used or quoted have been indicated using complete references and that this work has not been submitted before for any other degree at any other institution.

…MA…Seloka…. **…29/October/2021…**

Full names **Date**

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ABSTRACT

Background: Metabolic syndrome (MetS) is amongst the underlying causes of mortality and morbidity globally. However, lifestyle habits such as frequent consumption of sugar-sweetened beverages (SSBs) contributes to its onset. The study was aimed at investigating the association between MetS and SSBs intake among Ellisras rural youth. Additionally, to find the best obesity indices to predict MetS.

Methods: The current study included a total of 593 Ellisras rural youth, aged 22 to 30 years (289 males and 304 females). Anthropometric measurements, blood pressure (BP), and biochemical assessment were taken using standards procedures. A validated 24hrs recall questionnaire and food manuals were used to collect SSBs data. Binary logistic regression was applied to determine the association between SSBs intake and MetS components for the adjusted model. Confirmatory factor analysis was used to test the best single-factor models to predict MetS on commonly selected obesity indices.

Results: The SSBs quartile 4 was associated with a high risk of high fasting blood glucose (FBG) for adjusted (OR=2.32; CI=1.15-4.70; p<0.05) and unadjusted (OR=2.34; CI=1.16-4.73; p<0.05) models were a significant linear trend (p for trend=0.049) in males was found. Low risk of reduced high density lipoprotein cholesterol (HDL-C) was associated with the second and fourth SSBs quartiles for unadjusted ((OR=0.40; CI=0.18-0.85; p<0.05; OR=0.37; CI=0.13-0.80; p<0.05) respectively and adjusted model (OR=0.40; CI=0.18-0.85; p<0.05; OR=0.37; CI=0.17-0.80; p<0.05) respectively in females. Moreover, the fourth SSBs quartile was likely to decrease the risk of high triglycerides (TG) for unadjusted (OR=0.12; CI=0.01-0.87; p<0.05) and adjusted (OR=0.10; CI=0.01-0.83; p<0.05) models were the significant linear trend (p= trend 0.006) was observed also in females. There was a significant linear trend association between SSBs quartiles consumption and high TG in males and high waist circumference (WC) in females, but logistic regression analysis didn't depict any significant association (p>0.05). In males, single model fit built based on WC (comparative fit index (CFI)=1.00; turker lewis index (TLI)=1.05; RMSEA=0.00; akaike information criterion (AIC)=-2680) and waist to height ratio

(WHtR) (RMSEA=0.00, CFI=1.00; AIC=-2662, TLI=1.05;) suggested a better fit index as compared to body mass index (BMI) and neck circumference (NC). Among females, a single model fit built on NC obtained a better fit index (RMSEA=0.05, CFI=0.90, and AIC= -429.21, TLI=0.71).

Conclusion: In this study, there was an association between SSBs consumption and some MetS components (high TG, reduced HDL-C, and high FBG). Obesity indices including WHtR, NC, and WC were the best predictors of MetS. Future studies are recommended to further investigate the association of the risk of MetS and the consumption SSBs and the best obesity indices to predict MetS to assist in efforts to help curb MetS and related risk factors in rural areas of South Africa.

Key concepts: metabolic syndrome, obesity indices, rural, area; sugar-sweetened beverages; South Africa; youth.

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AACE: American association of clinical endocrinologists

AHA: American heart association

AIC: Akaike information criterion

AIDS: Acquired immune deficiency syndrome

Anova: Analysis of variance

ATP: Adenosine triphosphate

BI: Bioelectrical impendence

BMI: Body mass index

BP: Blood pressure

CFA: Confirmatory factor analysis

CFI: Comparative fit index

CI: Confidence interval

Cm: centimetre

CRIBSA: Cardiovascular risk study in black South Africans

CT: Computed tomography

CVDs: Cardiovascular diseases

DGA: Dietary guidelines for Americans

DRI: Daily reference intakes

DXA: Dual-energy x-ray absorptiometry

EC: Eastern Cape

EFSA: European food safety authority

EGIR: European group for study of insulin resistance

ELS: Ellisras longitudinal study

FBG: Fasting blood glucose

FFA: Free fatty acids

FFQ: Food frequency questionnaire

FS: Free State

GI: Glycaemic index

GFI: Goodness of fit index

HDL-C: High-density-lipoprotein cholesterol

HFCS: High-fructose corn syrup

HIV: Human immune deficiency virus

IDF: International diabetes federation

IFG: Impaired fasting glucose

IGT: Impaired glucose tolerance

IM: Institute of medicine

JIS: Joint interim statement

Kg/m2: Kilograms per square metre

KZN: Kwa-Zulu Natal

LDL-C: Low-density lipoprotein cholesterol

MAP: Mean arterial pressure

MetS: Metabolic syndrome

Mm/Hg: millimetres of mercury

Mmo/l: millimoles per litre

NAFLD: Non-alcoholic fatty liver disease

NC: Neck circumference

NCDs: Non-communicable diseases

NCEP ATP III: National cholesterol education program adult treatment panel III

NHNES: National health and nutrition examination survey

OR: Odds ratio

P-value: Probability value

Q1: Quartile one

Q2: Quartile two

Q3: Quartile three

Q4: Quartile four

RMSEA: Root mean square approximation

ROC: Receiver operating characteristics

SA: South Africa

SA-FBDG: South African food-based dietary guidelines

SANS: South African national survey

SAS: Statistical analysis system

SD: Standard deviation

SES: Socioeconomic status

SPSS: Statistical package for social sciences

SSBs: Sugar-sweetened beverages

STATA: South Texas art therapy association

SUN: Seguimiento Universidad de Navarra

T2DM: Type 2 diabetes mellitus

TG: Triglycerides

TLI: Turker lewis index

TREC: Turfloop ethics research committee

USA: United State of America

VAT: Visceral adipose tissue

VLDLs: Very-low-density lipoprotein

WC: Waist circumference

WC: Western Cape

WHO: World health organisation

WHtR: Waist to height ratio

CHAPTER 1

PROBLEMS AND AIMS OF THE STUDY

1.1. Problem statement

1.2. Motivation

1.3. Aim and objectives

14. Research questions

1.5. Hypothesis

1.6. Scientific contribution

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1.1. PROBLEM STATEMENT

Globally the prevalence of metabolic syndrome (MetS) is increasing, and this is also noticed in African countries (Oldewage-Theron and Egal, 2018). Both in low- and middle-income countries MetS was reported to be responsible for 1.9 million deaths among adults (WHO, 2015). This is of significant concern since persons with MetS were reported to have an increased risk of developing cardiovascular diseases (CVDs) and type 2 diabetes mellitus (T2DM) (Gundy, 2008; Statistics SA, 2015). A significant body of evidence shows poor lifestyle choices and modifiable risk factors such as physical inactivity, high sodium intake, high alcohol intake, tobacco smoking and high intake of sugar-sweetened beverages (SSBs) (Imamura et al., 2015; WHO, 2017; WHO, 2018) as the leading contributory factors for the onset of MetS.

Sugar-sweetened beverages are beverages that contribute to excess energy in the body and provide little nutritional value (Tugendhaft et al., 2016). South Africa (SA) was ranked seventh globally in sugar consumption with SSBs sales doubled from 3.0 to 6.0 billion litres annually between 2002 and 2016 (Manyema et al., 2016; Koo and Taylor, 2012; Euromonitor, 2015). Of great concern is that an increased in SSBs consumption is paralleled by an increase in risk factors of non- communicable diseases (NCDs) including MetS (Deshpande et al., 2017, Malik and Hu 2019).

Sugar-sweetened beverages are readily absorbable, addictive and increase postprandial glucose levels, hence suppressing satiety (Avena et al., 2008; Malik and Hu 2019). Consequently, this may encourage over intake thereby promoting the accumulation and deposition of abdominal fat which might increase the risk of obesity (Akram and Hamid, 2013; Malik and Hu, 2019). Additionally, sugars in SSBs have a high glycaemic index (GI) which may result in β-cell dysfunction that may promote insulin resistance and inflammatory biomarkers which increases the risk of T2DM (Malik et al, 2013, Liu et al., 2002). In the Ellisras area, the risk of MetS as a result of lifestyle was studied thus far (Sekgala et al., 2018). No study has reported on the association between the consumption of SSBs and MetS in this area nor rural South African youth to clarify this risk.

1.2. MOTIVATION

The MetS is a group of interrelated metabolic disorders that doubles the burden and progression of CVDs and T2DM (Alberti et al., 2009). Consequently, these metabolic abnormalities increase the chances of morbidities and eventually mortality (Misra, 2018). The WHO. (2015) reported that each year, both low- and middle-income countries MetS is responsible for 1.9 million deaths in adults. Several studies indicate that MetS is linked with modifiable risk factors (Freely and Norris, 2009; Deshpande et al, 2017; Pérez-Martínez et al., 2017).

There is a growing body of evidence that demonstrates poor lifestyle choices and modifiable risk factors such as high salt and excessive alcohol intake, physical inactivity, as well as high consumption of SSBs as leading contributory factors of MetS development (Freely and Norris, 2009; WHO, 2017). Sugar-sweetened beverage consumption is increasing at an alarming rate as an important source of added sugar globally (Voster et al., 2014; Malik and Hu 2019; Audain et al., 2019). This is no exception to SA where many households are still experiencing hunger and food insecurity resulting from a high unemployment rate (Erzse et al., 2019, Okop et al., 2019).

Moreover, SA is predominantly constituted by large numbers of young people (Erzse et al., 2019). As a result, the growing SSBs market targets these individuals (children, adolescents, and youth) through various means of advertisement (Rudd, 2010; Kumar et al., 2015; Brownbill et al., 2018). Therefore, this explains why there is a high intake of SSBs among these individuals (Malik et al., 2013; Voster et al., 2014). The high unemployment rate was stated as the driving force for purchasing cheaper unhealthy food rich in energy (Voster et al., 2014, Nnyepi et al., 2015). Of significant concern, is that poor dietary habits or unhealthy lifestyle choices might result in serious adverse metabolic health effects (Winpeny et al., 2017).

The prospective study of a duration of 6 years and follow up has reported that an increase in SSBs consumption was associated with the risk of MetS and its four components (Barrio-Lopez et al., 2013). Those four MetS components include hypertriacylglycerolaemia, impaired fasting glucose, high blood pressure, and central obesity (Barrio-Lopez et al., 2013). Notably, high consumption of SSBs does not only increases the risk of MetS but as well as other risk factors associated with the

disruption in glucose and lipid metabolism (Knopp et al., 2005; Malik and Hu 2019). Those risk factors include gout, cancers, diabetes, non-alcoholic fatty liver (NAFL) diseases, CVDs, obesity, and high uric acid levels to name a few (Knopp et al., 2005; Malik and Hu, 2019). In contrast, a Korean cross-sectional study, a higher SSBs consumption (≥1 serving/day) was not associated with MetS including its components (Shin et al., 2018). Therefore, screening of health risk factors using obesity indices could help identify adverse metabolic health outcomes and help resolve the inconsistencies reported.

A little has been reported on this association in rural youth's dwellers in Limpopo province of South Africa and in the Ellisras area, only the risk of MetS as a result of lifestyle (Sekgala et al., 2018) has been studied thus far.

1.3. AIM AND OBJECTIVES

1.3.1. AIM:

The study aimed to investigate the association between MetS with SSBs intake. Furthermore, to identify the best obesity/anthropometric indices to predict MetS among Ellisras rural youth aged 22 to 30 years.

1.3.2. OBJECTIVES:

The objectives of the study are to:

I. Determine the prevalence of SSBs using a 24-hr recall questionnaire amongst Ellisras rural youth aged 22 to 30 years.

II. Determine the prevalence of MetS components (triglyceride (TG), high density-lipoprotein cholesterol (HDL-C), fasting blood glucose (FBG), waist circumference (WC), systolic blood pressure (SBP), diastolic blood pressure (DBP)) amongst Ellisras rural youth aged 22 to 30 years.

III. Determine which MetS components were associated with the SSBs consumption amongst Ellisras rural youth aged 22 to 30 years.

IV. Determine if there was a risk of developing MetS following SSBs intake amongst Ellisras rural youth aged 22 to 30 years.

V. Determine the best obesity indices for identifying Mets amongst Ellisras rural youth aged 22 to 30 years.

VI. Determine if there was a correlation between obesity indices (body mass index (BMI), waist to height ratio (WHtR), waist circumference (WC), neck circumference (NC)) with MetS components (TG, HDL-C, FBG, WC, mid arterial pressure (MAP) (SBP, DBP)) amongst Ellisras rural youth aged 22 to 30 years.

VII. Determine if there was a correlation between the consumption of SSBs and MetS components amongst Ellisras rural youth aged 22 to 30 years.

1.4. RESEARCH QUESTIONS

I. What is the prevalence of SSBs consumption amongst Ellisras rural youth aged 22 to 30 years?

II. What is the prevalence of MetS components (TG, HDL-C, FBG, WC, SBP, DBP) amongst Ellisras rural youth aged 22 to 30?

III. Which MetS components (TG, HDL-C, FBG, WC, SBP, DBP) were associated with the SSBs consumption amongst ELS rural youth aged 22 to 30 years?

IV. Will the ELS rural youth aged 22 to 30 years be at risk of developing MetS following their SSBs intake?

V. Which obesity (BMI, WHtR, WC and NC) can identify MetS amongst ELS rural youth aged 22 to 30 years?

VI. Is there a correlation between obesity indices (BMI, WHtR, WC, NC) with MetS components (HDL-C, FBG, WC, MAP (SBP, DBP)) amongst ELS rural youth aged 22 to 30 years?

VII. Is there a correlation between SSBs consumption and MetS components amongst Ellisras rural youth aged 22-30 years.

1.5. HYPOTHESES OF THE STUDY

I. Hypothesis 1: The prevalence of SSBs consumption will be high amongst Ellisras rural youth aged 22 to 30 years compared to other studies worldwide.

II. Hypothesis 2: The prevalence of MetS components (WC, FBG and HDL-C) will be higher among ELS rural youth aged 22 to 30 years compared other studied worldwide.

III. Hypothesis 3: All the MetS components (HDL-C, FBG, WC, SBP, DBP) will be associated with the consumption of SSBs amongst the ELS rural youth aged 22 to 30 years.

IV. Hypothesis 4: ELS rural youth aged 22 to 30 years will be at a higher risk of developing MetS compared to those studied in other parts of the world.

V. Hypothesis 5: All obesity (BMI, WHtR, WC and NC) could identify MetS amongst Ellisras rural youth aged 22 to 30 years compared to those studied worldwide.

VI. Hypothesis 6: All the obesity indices will be correlated with MetS components among Ellisras rural youth aged 22 to 30 years.

VII. Hypothesis 7: All the MetS will be correlated with SSBs consumption among Ellisras rural youth aged 22 to 30 years.

1.6. SCIENTIFIC CONTRIBUTION

This study is aimed at providing and adding new ideas to the existing scientific knowledge regarding the association between the consumption of SSBs and MetS; and the best obesity indices better identify MetS in Ellisras youth and the world at large. Thus, this will add improved knowledge and enhanced understanding of the association and obesity indices that better identify MetS. Results of the study will be presented to the community with the motive to educate them on the harmful effect of non-communicable diseases on health. Moreover, the results might encourage rural youth to live a healthy lifestyle to avoid the risk of metabolic syndrome and other related diseases. Additionally, the result will be presented at a Faculty Research Day to peers, this will provide the opportunity to network and gain exposure to new ways of conducting research that might be more productive and beneficial for rural communities in South Africa.

1.7. STRUCTURE OF THE DISSERTATION

1. Chapter 1 – Problems and aim of the study

2. Chapter 2 – Literature review

3. Chapter 3 – Materials and methods

4. Chapter 4 – Results and Discussion

5. Chapter 5 – Introduction, summary, conclusion, and recommendations

6. Peer-reviewed articles published in International Journals were compiled as an addendum.

1.8. REFERENCES

Alberti, K.G.M.M., Eckel, R.H., Grundy, S.M., Zimmet, P.Z., Cleeman, J.I., Donato, K.A., Fruchart, J.C., James, W.P.T., Loria, C.M. and Smith Jr, S.C. (2009). Harmonizing the metabolic syndrome: a joint interim statement of the international diabetes federation task force on epidemiology and prevention; national heart, lung, and blood institute; American heart association; world heart federation; international atherosclerosis society; and international association for the study of obesity. *Circulation*, 120(16):1640–1645.

Akram, M. and Hamid, A. (2013). Mini review on fructose metabolism. *Obesity Research and Clinical Practice*, 7(2):e89–e94.

Audain, K.A., Levy, L. and Ellahi, B. (2019). Sugar sweetened beverage consumption in the early years and implications for type 2 diabetes: A sub-Saharan Africa context. *Proceedings of the Nutrition Society*, 78(4):547–553.

Avena, N.M., Rada, P. and Hoebel, B.G. (2008). Evidence for sugar addiction: behavioral and neurochemical effects of intermittent, excessive sugar intake. *Neuroscience and Biobehavioral Reviews*, 32(1):20–39.

Barrio-Lopez, M.T., Martinez-Gonzalez, M.A., Fernandez-Montero, A., Beunza, J.J., Zazpe, I. and Bes-Rastrollo, M. (2013). Prospective study of changes in sugar-sweetened beverage consumption and the incidence of the metabolic syndrome and its components: the SUN cohort. *British Journal of Nutrition*, 110(9):1722–1731.

Brownbill, A.L., Miller, C.L. and Braunack-Mayer, A.J. (2018). The marketing of sugar-sweetened beverages to young people on Facebook. *Australian and New Zealand Journal of Public Health,* 42(4):354–360.

Deshpande, G., Mapanga, R.F. and Essop, M.F. (2017). Frequent sugar-sweetened beverage consumption and the onset of cardiometabolic

diseases: cause for concern?. *Journal of the Endocrine Society*, 1(11):1372–1385.

Erzse, A., Marais, N.C., Hofman, K.J. and Christofides, N.J. (2019). Evidence for high sugar content of baby foods in South Africa. *South African Medical Journal*, 109(5):328–332.

Euromonitor International. 2015. Soft drinks in South Africa. Euromonitor Passport database. Retrieved from: www. euromonitor.com (Accessed 12 Mar 2019).

Feeley, A., Pettifor, J.M. and Norris, S.A. (2009). Fast-food consumption among 17-year-olds in the Birth to Twenty cohorts. *South African Journal of Clinical Nutrition*, 22(3):188–123.

Grundy, S.M. (2008). Metabolic syndrome pandemic. *Arteriosclerosis, Thrombosis, and Vascular Biology*, 28(4):629–636.

Imamura, F., O'Connor, L., Ye, Z., Mursu, J., Hayashino, Y., Bhupathiraju, S.N. and Forouhi, N.G. (2015). Consumption of sugar-sweetened beverages, artificially sweetened beverages, and fruit juice and incidence of type 2 diabetes: systematic review, meta-analysis, and estimation of population attributable fraction. *BMJ*, 351(h357):1–8.

Knopp, R.H., Paramsothy, P., Retzlaff, B.M., Fish, B., Walden, C., Dowdy, A., Tsunehara, C., Aikawa, K. and Cheung, M.C. (2005). Gender differences in lipoprotein metabolism and dietary response: basis in hormonal differences and implications for cardiovascular disease. *Current Atherosclerosis Reports*, 7(6):472–479.

Koo, W.W. and Taylor, R.D. (2012). 2012 Outlook of the US and World Sugar Markets, 2011–2021 (No. 1187-2016-93538). https://ageconsearch.umn.edu/record/128037.

Kumar, G., Onufrak, S., Zytnick, D., Kingsley, B. and Park, S. (2015). Self-reported advertising exposure to sugar-sweetened beverages among US youth. *Public Health Nutrition,* 18(7):1173–1179.

Liu, S., Manson, J.E., Buring, J.E., Stampfer, M.J., Willett, W.C. and Ridker, P.M. (2002). Relation between a diet with a high glycemic load and plasma concentrations of high-sensitivity C-reactive protein in middle-aged women. *The American Journal of Clinical Nutrition*, 75(3):492–498.

Malik, V.S., Hu, B., Walter, A.P., and Willet, W.C. (2013). Sugar-sweetened beverages and weight gain in children and adults: A systematic review and meta-analysis. *American Journal of Clinical Nutrition*. 98(4):1084–1102.

Malik, V.S. and Hu, F.B. (2019). Sugar-sweetened beverages and cardiometabolic health: an update of the evidence. *Nutrients*, 11(8):1840.

Manyema, M., Veerman, L.J., Tugendhaft, A.D., Labadarios, A.D. and Hofman, K. J. (2016). Modelling the potential impact of a sugar-sweetened beverage tax on stroke mortality, costs and health-adjusted life years in South Africa. *Bio Medical Central Public Health*, 16(405):112.

Misra, A., Soares, M.J., Mohan, V., Anoop, S, Abhishek, V., Vaidya, R. and Pradeepa, R. (2018). Body fat, metabolic syndrome, and hyperglycemia in South Asians. *Journal of Diabetes and its Complications*, 32:1068–1075.

Mortality and causes of death in South Africa, 2014: Findings from death notification / Statistics South Africa. Pretoria: Statistics South Africa, 2015. https://www.statssa.gov.za › P030932015. (Accessed 17 March 2021).

Nnyepi, M.S., Gwisai, N., Lekgoa, M. and Seru, T. (2015). Evidence of nutrition transition in Southern Africa. *Proceedings of the Nutrition Society*, 74(4):478–486.

Okop, K.J., Lambert, E.V., Alaba, O., Levitt, N.S., Luke, A., Dugas, L., Dover, R.V.H., Kroff, J., Micklesfield, L.K., Kolbe-Alexander, T.L. and Warren, S. (2019). Sugar-sweetened beverage intake and relative weight gain among South African adults living in resource-poor communities: longitudinal data from the STOP-SA study. *International Journal of Obesity*, 43(3):603–614.

Oldewage-Theron, W. and Egal, A. (2018). The effect of consumption of soy foods on metabolic syndrome in women: a case study from peri-urban

Qwa-Qwa, South Africa. *South African Journal of Clinical Nutrition*, 1(1):1–6.

Pérez-Martínez, P., Mikhailidis, D.P., Athyros, V.G., Bullo, M., Couture, P., Covas, M.I., de Koning, L., Delgado-Lista, J., Díaz-López, A., Drevon, C.A. and Estruch, R. (2017). Lifestyle recommendations for the prevention and management of metabolic syndrome: an international panel recommendation. *Nutrition Reviews*, 75(5):307–326.

Rudd, R. (2010). Sugary drink facts: Evaluating sugary drink nutrition and marketing to youth. Centre http://www.sugarydrinkfacts.org/resources/SugaryDrinkFACTS_Report.pdf (Accessed 12 December 2020).

Sekgala, M.D., Monyeki, K.D., Mogale, A., Mchiza Z.J., Parker, W., Choma, S.R., and Makgopa, H.M. (2018). The risk of metabolic syndrome as a result of lifestyle among Ellisras rural youth. *Journal of Human Hypertension*. 32(8):572–584.

Shin, S., Kim, S.A., Ha, J. and Lim, K. (2018). Sugar-sweetened beverage consumption in relation to obesity and metabolic syndrome among Korean adults: a cross-sectional study from the 2012–2016 Korean national health and nutrition examination survey (KNHANES). *Nutrients*, 10(10):1467.

Tugendhaft, A., Manyema, M., Veerman, L.J., Chola, L., Labadarios, D. and Hofman, K.J. (2016). Cost of inaction on sugar-sweetened beverage consumption: implications for obesity in South Africa. *Public Health Nutrition*, 19(13):2296–2304.

Vorster, H.H., Kruger, A., Wentzel-Viljoen, E., Kruger, H.S. and Margetts, B.M. (2014). Added sugar intake in South Africa: findings from the Adult Prospective Urban and Rural Epidemiology cohort study. *The American Journal of Clinical Nutrition,* 99(6):1479–1486.

Winpenny, E.M., Penney, T.L., Corder, K., White, M. and van Sluijs, E.M.F. (2017). Changes in consumption of added sugars from age 13 to 30 years: a systematic review and meta-analysis of longitudinal studies. *Obesity Reviews*, 18(11):1336–1349.

World Health Organisation. 2015. Noncommunicable diseases fact sheet 335. Retrieved from. http://www.who.int/mediacentre/factsheets/fs355/en/.(Accessed from 21 February 2021).

World Health Organization (WHO). 2017. South Africa country profile. Available from: http://www.who.int/nmh/countries/zaf_en.pdf?ua=1.(Accessed 12 April 2021).

World Health Organization (WHO). 2018. Non communicable diseases. From: https://apps.who.int › iris › rest › bitstreams ›. (Accessed 16 June 2021).

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2.5. References

2.1. INTRODUCTION

Metabolic syndrome is a cluster of abnormalities related with metabolic health that increases the chances of CVDs and T2DM (Alberti et al., 2009). On the other hand, this syndrome was reported to lack the global standard definition (Grungy, 2008; Alberti et al., 2009). Therefore, this has led to many organisations using different MetS diagnostic criteria that are based on the presence of one, two, three or all of the MetS risk factors (Grungy, 2008; Alberti et al., 2009). Thus, this has resulted in the same population having both high or low MetS prevalence or being over or under-diagnosed of the risk (Grungy, 2008). Indeed, this highlights the need for a global standard MetS definition.

There is the growing prevalence of MetS worldwide and this is no exception to African countries and South African rural areas. Sekgala et al. (2018) reported the prevalence of MetS to be 23.1%, with males being 8.6% and females being 36.8 % in the Ellisras rural area. The growing prevalence of MetS might have resulted from westernisation, advancement in technology, and urbanisation which have caused a huge impact on the nutritional transition (Nnyepi et al., 2015; Tugendhaft et al., 2016).

The nutritional transition had not only impacted the epidemiological transition but also promoted the adaptation to a western diet (WHO(a), 2018). The western diet is characterised by a high consumption of alcohol, high saturated fats intake, high salts intake, and high sugar consumption particularly in the form of SSBs (Chen et al., 2018; WHO(a), 2018; Kopp, 2019). Sugar-sweetened beverages are a major source of added sugar and contain small or no nutritional content (Manyema et al., 2016; Hernandez-F et al., 2021).

Nowadays, in rural settings of SA, it is popular for the consumption of SSBs because of the expansion of supermarkets and spaza shops into informal urban and rural areas (Tugendhaft et al., 2016). This factor fuels SSBs availability, easy access, purchase ,therefore, increased consumption (Voster et al., 2014; Tugendhaft et al.,

2016). According to Okop et al. (2019) consumption of SSBs in rural adults of South Africa have increased between 2005 and 2010 ranging from 33 to 63% for women and 25 to 56% for men. Moreover, it has been reported that the SSBs market targets mostly adolescents and youth (Brownbill et al., 2018). Of significant concern is the association of increased consumption of SSBs with adverse metabolic health outcomes (Imamura et al., 2015).

Various studies have reported the link between the risk of MetS and high consumption of SSBs (Barrio-Lopez et al., 2013; Manyema et al., 2014; Seo et al., 2019). Of note, high consumption of SSBs not only increases the risk of MetS but in addition other risk factors associated with the disruption of metabolic health function and regulation. Therefore, screening of health risk factors and assessment of dietary intake (SSBs) is significant in identifying adverse health outcomes and those at early stages or at increased risk of developing MetS. Furthermore, researching about this matter could help add improved knowledge and create informed awareness of the health risk factors of a high consumption of SSBs. And this might promote the practice of living healthy lifestyles which is significant in reducing health complications associated with MetS and ensuring healthy rural communities.

2.2. METABOLIC SYNDROME

Metabolic syndrome is the grouping of interconnected metabolic health abnormalities that include high TG, reduced HDL-C, high BP, excess WC, and high FBG (Alberti et al., 2009). Other metabolic abnormalities such as prothrombotic state, proinflammatory state, sleep apnea and NAFL disease also add to the components and complications of MetS (Kassi et., 2011). Metabolic syndrome is the driving force of CVDs and T2DM and doubles their progression and risk (Gundy, 2008). Its prominent basic underlying risk factors are abdominal obesity and insulin resistance (Kassi et al., 2011).

Various organisations define MetS differently using different diagnostic criteria that are either constructed on the occurrence of one, two, three or all the MetS components. The World Health Organisation (WHO) definition of Mets is constructed on insulin resistance which is the major determinant of MetS used for diagnosis together with any two or more additional components (Grungy, 2008). The National Cholesterol Education Programme Adult Treatment Panel III (NCEP: ATP III) requires the occurrence of any three of the five defining MetS components (Alberti et al., 2009). The American Association of Clinical Endocrinologists (AACE) definition considers elevated BP, impaired glucose tolerance (IGT), obesity, elevated TG, and reduced HDL-C (Alberti et al., 2009) but was not precise on the required number of diagnosing criteria to be used (Parikh and Mohan, 2012). The European Group for Study of Insulin Resistance (EGIR) is an amendment of the WHO definition which uses elevated plasma insulin (> 75^{th} percentile) plus any other two of the MetS components (Parikh and Mohan, 2012). The International Diabetes Federation (IDF) had issued a global consensus definition for MetS which focused on the race and gender of a population and its essential component which is abdominal obesity and any two of the MetS components (Parikh and Mohan, 2012). The Joint Interim Statement is the statement released in 2009 by IDF in conjunction with other various organisations, it considers any three of the five defining MetS components (Alberti et al., 2009) The commonly used criteria for the estimation of the prevalence of MetS in most systematic reviews, meta-analysis (Faijer-Westerink et al., 2020) and

epidemiological studies (Grungy, 2008) are the NCEP: ATP, WHO, IDF JIS. See **Table 2.1:** Definition of MetS by various organisations.

Table 2.2.1: Definition of metabolic syndrome by various organizations.

	(Parikh and Mohan, 2012)	NCEP ATP III (2001) Parikh and Mohan, 2012)	Parikh and Mohan, 2012)	AACE (Grundy et al., 2004)	EGIR (Parikh and Mohan, 2012)	JIS (Alberti et al., 2009) Statement
Essential Components	Insulin resistance	Central obesity	Central obesity	None	Insulin resistance	any three of the below
Clinical Measurers						
Insulin resistance	Insulin resistance is defined as IGT, IFG, T2DM or ↓ hyperinsulinemia, euglycemic conditions and any two that follows below	None but any three of the subsequent three/ more features below	None	None	Raised plasma insulin (>75th percentile) plus any two that follows below	None
Bodyweight	Males: waist to hip ratio >0.90; females: waist to hip ratio >0.85 and/or BMI >30 kg/m^2	WC ≥102 cm in men or ≥88 cm in women	Increased WC (ethnic and gender-specific) and any of the following two features	BMI ≥ $25kg/m^2$	WC ≥ 94 cm among men and ≥80 cm among women	Increased WC (population-specific and gender-specific)
Lipids	TG ≥150 mg/dL (≥1.7 mmol/L) and/or	High TG ≥150 mg/dL	High TG ≥1 50 mg/dL or history of treatment for lipid abnormality	High TG ≥ mg/dL (1.69 ml/L)	Raised TG ≥ 150 mg/dL	Elevated ≥ 1.7 mmol/L or drug treatment for elevated TG
	↓ HDL-C <35 mg/dL (<0.9 mmol/L) for men or <39 mg/dL (1.0 mmol/L) for women	↓ HDL-C <40 mg/dL among men or <50 mg/dL among women	↓HDL-C <40 mg/dL in men or <50 mg/dL in women or history of treatment of lipid abnormality	↓ HDL-C <40 mg/dL (1.04 mmol/L) men & <50 mg/dL (1.29 mmol/L)	↓ HDL-C both for men and women	↓HDL-C (1.0 mmol/L) for males and 1.3 mmol/L or drug treatment for ↓HDL-C
Blood pressure	Antihypertensive medication/≥140 Hg≥ systolic 90 mm	≥130/85 mm Hg	High ≥130 mm Hg systolic or ≥85 mm Hg diastolic or on hypertension treatment	≥130/85 mm Hg	≥140/90 mm/Hg/ Antihypertensive treatment	≥130 mm/ ≥85 Hg or antihypertensive treatment
Glucose	IGT, IFG, or T2DM	≥110mg/dL (includes diabetes)	≥100 mg/dL or previously diagnosed with DM2	Between 110 and 126 mg/dL	Elevated Plasma glucose, IFG or IGT	Elevated FBG (≥ 5.5 mmol/L) or treatment thereof
Other	Microalbuminuria urinary albumin excretion rate ≥ 20 µgm/minute or albumin/creatine ratio ≥ 30 µgm/mg.	Proinflammatory state and prothrombotic state	None	Sedentary Lifestyle, advanced age, Polycystic ovary syndrome, history on the Family/Ethnic group /elevated risk of type 2 diabetes, hypertension, or CVD,	None	None

↓=reduced; IFG=impaired fasting glucose; IGT= impaired glucose tolerance; TG= triglycerides; HDL-C= high-density-lipoprotein-cholesterol; WC= Waist circumference; BMI=body mass index; T2DM= type 2 diabetes mellitus.

Table 2.2.2: The ethnic group, age, and gender-specific WC cut-offs are suggested below by various organisations and researchers:

Ethnic group	Waist circumference cut off points		References	Age
	Male	Female		
Caucasians	>94 cm–102 cm	>80 cm–88 cm	(Han et al., 1995; WHO, 2000)	20–59 years
Europids	>94 cm	>80 cm	(Alberti et al., 2006; Zimmet and Alberti, 2006)	-
South Asians, Chinese and Japanese	>90 cm	>80 cm	(Alberti et al., 2006; Zimmet and Alberti, 2006)	-
Americans	>102 cm	>88 cm	(NCEP, 2001)	-
Africans	>91 cm	>84 cm	(Hoebel et al., 2013)	24-45 years

2.2.1. The effect of using different metabolic syndrome definitions

The effect of using different MetS criteria might result in over or underestimating the risk of MetS in a population being diagnosed because when two or more criteria are used the prevalence might be higher or lower or comparable. In the systematic reviews and meta-analyses conducted by Faijer-Westerink et al. (2020) in sub-Saharan Africa, when the JIS criterion is used the prevalence was higher (23.9%) but when WHO was used the prevalence tended to be lower (11,1%), moreover when the IDF and the NCEP-ATP III definition was used comparable findings were found (18.0% and 17.1%) respectively. A similar trend was reported in the Northwest Ethiopia study focusing on patients attending Tertiary hospitals where when the IDF and NCEP-ATP III definition was used the prevalence of MetS was 53.5% and 66.7 respectively (Biadgo et al., 2018). In the Ellisras rural area, the prevalence of MetS

was 10% when the JIS was used; 11.2% with the IDF definition and 7.9% with the ATP III definition meanwhile among females the MetS prevalence was 25% when the JIS was used, 21.2% with the IDF definition and 16, 8% with the ATP III definition (Sekgala et al., 2018). However, when the WHO definition was used the prevalence appeared to be 59.1% (Sekgala et al., 2018).

The Joint Interim Statement is a combination of various criteria from different organisation thus, it clears off the use of many criteria, reduces inconsistencies and also it specifies the gender and the race of a population (Alberti et al., 2009). And hence, it will be used in the current study to define MetS. Of significant concern is that the cut of points of waist circumference from the white population is used for sub-Saharan Africa (SSA) due to limited data in the harmonised definition (Gradidge and Crowther, 2017).

According to Gradidge and Crowther. (2017) the WC of African women is higher thus the use of the current cut off waist circumference may not be suitable. Moreover, though the WC is used widely as the simplest and alternative index for screening, it has limitations that it cannot be used in overweight/obese individuals as it is affected by inhalation and fullness (distention of the abdomen) (Saka et al., 2014; Tal et al., 2019) Therefore, this explains why numerous reports have proposed ideal cut-off values for all men and on black South African women (Motala et al., 2011; Peer et al., 2016).

2.2.2. Prevalence of metabolic syndrome

Globally

Globally there is alarming rise in MetS prevalence (Oldewage-Theron and Egal, 2018) with an estimation of 20-25% among the adult individuals (Alberti et al., 2006). In the United State of America (USA), a cross-sectional study by Hirode and Wong. (2020) reported a MetS prevalence of 19.5% among those aged 20-39 years and 48.6% in those aged 60 years and above when NCEP: ATP III criteria was used. Moreover, the prevalence was reported to be higher among Hispanic white (36.3%) compared to Asian individuals (36.0%) (Hirode and Wong, 2020).

Africa

A few studies have reported on the prevalence of MetS in African countries (Solomon and Mulugeta, 2019; Faijer-Westerink et al., 2020) although other regions indicated higher incidence. Southern Africa was reported to have the highest prevalence, where it was followed by East Africa, West Africa and Central (Faijer-Westerink et al., 2020). South Africa was reported to have the increased prevalence of MetS than other African countries including Tunisia, Ethiopia, and Nigeria (Oldewage-Theron and Egal, 2018).

South Africa

South Africa is a diverse country with different ethnic groups, socio-cultural backgrounds, socio-economic statuses, and technological development and these might result in a difference in the prevalence of MetS (SALC, 2015). In the Free State (FS) province, the prevalence of MetS was reported to be 15% among pregnant women attending antenatal care clinics at a tertiary hospital (Baloyi and Mokwena, 2020). In the Eastern Cape (EC) province, Buffalo city municipality, it was reported to be 21.8%; with 15.6% being males and 24.8% being females (Owolabi et al., 2017), in the Western Cape (WC) province, Boland district, the prevalence of the MetS among women (46.3%) was higher compared to men (29.3%) (Kruger and Nell, 2017). In Kwa-Zulu Natal (KZN) province, Ubombo district, the prevalence of MetS was reported to be 22.1%, higher in women (25.0%) than in men (10.5%) (Motala et al., 2011). In the Limpopo province, Ellisras rural area, Sekgala et al. (2018) reported the prevalence of MetS to be 23.1%, with males 8.6% and females 36.8 %.

Risk factors associated with metabolic syndrome encompasses both the non-modifiable and modifiable risk factors are indicated in Figure 2.2.4.3.

2.2.3. Non-modifiable risk factors

2.2.3.1. Age

Age is emerging as an important underlying risk factor that is implicated in the aetiology of many diseases including MetS (Grundy et al., 2004; Wu et al., 2017). In a recent study by Saklayen. (2018) MetS prevalence was reported to increase with age. Another study conducted in the USA reported a higher prevalence of MetS especially in individuals aged 60 and above years compared to those aged 20-39

years (Hirode and Wong, 2020). Of concern is that the presence of one component of MetS early in life increases the risk of development of MetS and CVDs later in life (Nolan et al., 2017). In essence, ageing is correlated with increased risk of MetS progression which however depicts a linear relationship (Motala et al., 2011). This could be attributed to the fact that ageing is coupled with changes in metabolic processes and deterioration in the function of the body (Van Beek et al., 2016). According to the study conducted in an urban area of Cape Town, the peak age at which one can develop MetS is 55-64 years in women and 65-74 years amongst men (Peer et al., 2016).

2.2.3.2. Gender

Disparities have been reported about differences in the prevalence of MetS in both genders (Kruger and Nell, 2017; Solomon and Mulugeta 2019), thus gender plays an important role in exposing individuals to different risk factors. This might be rooted in the definition of the MetS where the WC and HDL-C of both men and women differ (Alberti et al., 2009). In many studies, the prevalence of MetS was reported to be higher in females than in males (Kruger and Nell, 2017; Solomon and Mulugeta 2019). However, a cross-sectional study from the USA reported contradicting findings where a higher prevalence of MetS was reported in males than in females (Hirode and Wong, 2020). Moreover, it was reported that below the age of 50 years, the prevalence of MetS is higher in males than in females and after the age of 50 years the prevalence seems to be higher in females than in males (Kuk and Ardern, 2010; Pucci et al., 2017). The difference in the prevalence of MetS in females concerning age might be attributed to the fact that ageing in females is accompanied by the decrease in the concentration of the hormones that offer protection against cardiometabolic diseases especially after reaching menopause (Kuk and Ardern, 2010).

2.2.3.3. Region

The prevalence of MetS was reported to be higher in urban areas than in rural areas of developing countries (Saklayen, 2018; Faijer-Westerink et al., 2020). A Chinese study also reported a higher incidence of MetS in an urban area 8 to 10.6% than in a rural area 4.9 to 5.3%. This was supported by the study by Peer et al. (2015) who also reported a higher prevalence of MetS among the urban black population compared to the rural population. Misra and Khurana. (2008) explained that this

could be attributed to changes in lifestyle habits that are associated with urbanization, such as increased energy intake and reduced physical activity (Misra and Khurana, 2008). Faijer-Westerink et al. (2020) further explained that rural communities are further located away from towns and cities where urbanisation occurs the most. Thus, the changes in lifestyle and diseases will be observed more in the urban areas than in rural areas. In contrast, the study based in the USA reported that rural areas had a higher prevalence of MetS than in urban areas (Trivedi et al., 2013). The differences could have resulted in the fact that developing countries including SA are experiencing a gradual rise in epidemiological transition resulting from nutritional transition whereas the USA has been experiencing the transitions for a longer period now (Dalal et al., 2011).

2.2.3.4. Heredity/Genetics

The genetic material was also reported to have a huge impact on the development of MetS where genetic factors were addressed in linkage studies, genome-wide association studies and multiple candidate gene association studies (Stancakova and Laasko, 2014; Zafar et al., 2018). However, most studies typically investigated the combination of individual MetS components instead of MetS per se because of its complexity (Stancakova and Laasko, 2014). A linkage study conducted among 2467 subjects, 387 families and 1082 subjects from sibship provided evidence for linkage on chromosome 2. In this study, clustering of MetS-related phenotype that was found on chromosome 2 compromised of serum uric acid, homeostatic model assessment index, subscapular skinfold, HDL-C, BMI, WtHR, plasminogen activator inhibitor-1 antigen (Tang et al., 2003; Stancakova and Laasko, 2014). Moreover, a total of 157 loci were reported to be associated with lipids and lipoprotein levels, where 71 loci were related to the levels of HDL-C and 39 of them were related to TG (Willer et al., 2013) which are all risk factors of MetS.

2.2.4. Modifiable risk factors

2.2.4.1. Lifestyle factors

Lifestyle factors are factors such as physical inactivity, psychological stress, alcohol intake, smoking, socioeconomic status, and diet (MRC, 2006). These factors contribute to the development of different individual MetS components.

- Smoking

Studies have reported evidence on the association of smoking and MetS (Sun et al., 2012; Slagter et al., 2013) especially among active smokers had who had a 26% increased risk of MetS compared with non-smokers. This probably resulted from the consumption of smokeless tobacco (snuff) which is more popular in females (Gupta et al., 2013). Audrain-McGovern et al. (2011) and Ridker et al. (2003) further indicated that possible association might result from nicotine within cigarettes which stimulate hormones that are linked with increased levels of an inflammatory biomarker such as C-reactive protein.

- Alcohol

While some studies reported beneficiary effects of alcohol in reduction of CVDs especially when it is consumed in light or moderate amounts (Pérez-Martínez et al., 2017) other studies reported an increased risk in MetS when consumed in large amounts (Park et al 2003; Schroder et al., 2007; Taylor et al., 2009). The correlation between alcohol intake and MetS results from the adverse effect that alcohol probably has on BP, TG and HDL-C concentration, insulin sensitivity and abdominal obesity (Schroder et al., 2007; Taylor et al., 2009; Perez-Martinez et al., 2017). In the Ellisras rural area, binge alcohol drinking was not significantly associated with MetS but only with its component HDL-C (Monyeki et al., 2020).

- Physical activity

Physical activity is regarded as one of the significant preventive measures for diseases (Myers et al., 2019; Zaiac-Gawlak et al., 2021). This mostly results from its ability to protect against cardiometabolic risk factors (Myers et al., 2019). It was reported that long term regular exercise lowers the risk of MetS, particularly in concentrations of TG and increases HDL-C concentration (Zaiac-Gawlak et al., 2021). In contrast, Turi et al. (2016) reported that participants with lower levels of physical activity in leisure time were likely to have the occurrence of hypercholesterolemia, diabetes mellitus and metabolic syndrome.

- Diet

Diet emerges as the most significant mediator of nutrition-related chronic diseases globally (WHO(b), 2018). Diet plays an important role in providing essential nutrition and energy in the body, but it was also reported to be one of the root contributors to

the progression of non-communicable diseases (Chen et al., 2018; Kopp, 2019). However, the intake of western diet disrupts energy balance resulting in either nutrient excess/ deficiency, metabolism dysregulation, inducing cellular stress which is linked with various risk factors of MetS (Cordain et al., 2005; Chen et al., 2018). Evidence from experimental trials and observational studies has indicated that regular consumption of SSBs contributes to the rising prevalence of overweight and obesity which is significantly linked with the onset of metabolic diseases (Hu, 2013; Imamura et al., 2015).

2.2.4.2. Obesity and metabolic syndrome

- Body composition

Body composition is defined as the distribution and quantity of muscle and the other compartment of adipose tissue.

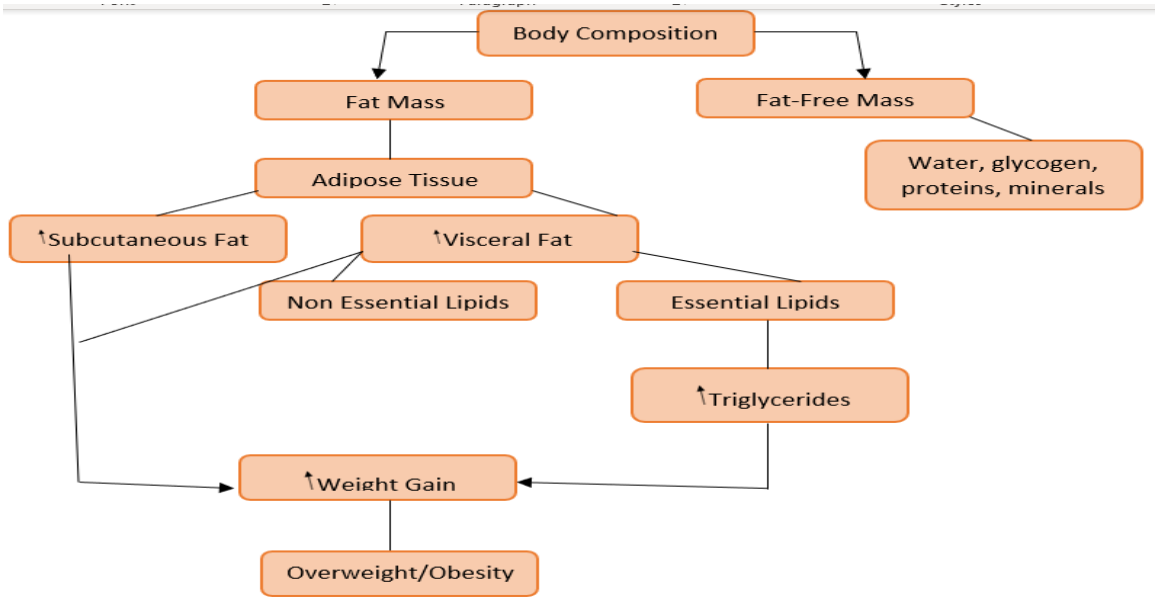

Figure 2.2.4.2.1: The compartment of body composition and how increased body fat can cause overweight/obesity (Heymsfield and Cefalu, 2013).

Obesity is defined as the abnormal or excessive accumulation of fat which may impair health (Sorrie et al., 2017) that results from a disruption in energy balance (Hall et al., 2012). The WHO defines overweight as BMI of ≥ 25 kg/m^2 and obesity as BMI of ≥30 kg/m^2 (WHO(b), 2018). Obesity was indicated to be the reason behind the increasing prevalence of MetS and the number of non-communicable diseases

such as T2DM, many kinds of cancers, hypertension, heart diseases and high cholesterol-related diseases (WHO(a), 2018). Obesity is multifactorial but childhood and adulthood poverty, physical activity, dietary behaviour, genetic susceptibility and attitude towards obesity (Faber and Kruger, 2005; Steyn and Mchiza, 2014; Okop et al., 2016; WHO(a), 2018) etc were also among the factors responsible for its onset. It has become a worldwide pandemic with projected 1.3 billion overweight or obese adults by 2030 (Kelly et al., 2008). In SA, people living in urban areas were reported to be at increased risk of obesity and related disorders, however, this was more evident in black South African women compared to men and the corresponding white population (Puoane et al., 2002). Okop et al. (2016) also reported that black African women living in urban townships and some rural communities are the most affected by obesity. Balgoon et al. (2019) reported that in the Kingdom of Saudi Arabia, female students with BMI $\geq 25\ kg/m^2$ had an increased risk of developing MetS. However, a study conducted among South African women found the association between decreased abdominal subcutaneous fat with a higher risk of MetS (Gradidge, 2017).

- Types of methods to assess body composition

Measurements or assessments of body composition can help determine the health status of an individual or population. The quantity and distribution of fat in the body may be a significant indicator of health risk (Ackland et al., 2012). Therefore, precise, and reliable methods are required to accurately measure body composition (Ackland et al., 2012).

Other various techniques that have been proposed to assess body fat such as anthropometric/obesity indices which are inexpensive, non-invasive, widely, and easily used in both epidemiological and clinical research studies (Sen and Mondal, 2013; Shrestha, 2018). These anthropometric/obesity indices are known to be the best determinants of metabolic health complications such as insulin resistance, hypertension, dyslipidaemia, CVDs and MetS (Fan et al., 2016; Alziedan et al., 2019). They include BMI, WC, NC and WHtR which were reported to have both strengths and limitations (Luo et al., 2017; Tal et al., 2019).

Body mass index was reported to be a good indicator of overall obesity and known to correlate positively with metabolic conditions but at the same time, it cannot

discriminate between fat mass and fat-free mass (Shrestha et al., 2018; Tal et al., 2019). Both WC and WHtR are normally used as the simplest and alternative indices to assess central/abdominal obesity and are known to precisely reflect the visceral fats which are strongly linked to metabolic complications (Fan et al., 2016; Shrestha et al., 2018). The WC was reported to invade participants privacy, affected by fullness (distention of the abdomen after meals) and inhalation (Tal et al., 2019) whereas WHtR still requires more validation and research (Baioumi, 2019). The NC emerges as a promising and relevant technique to measure fat distribution due to its simplicity and ability to identify measures of MetS (Alzeidan et al., 2019). Moreover, NC was found to correlate positively with BMI, WC, WHtR in identifying measures of MetS however, is not suitable for persons with goitre (Luo et al., 2017, Patil et al., 2017).

Other advanced technologically techniques or methods to measure body fat include magnetic resonance imaging, dual-energy x-ray absorptiometry (DXA) and computed tomography (CT), bioelectrical impendence (BI) (Rodrigues et al., 2001, Kuriyan, 2018). These techniques were also reported as an excellent indicator of total and regional body adiposity (Rodrigues et al., 2001; Kuriyan, 2018) and excellent screening tool for cardiometabolic risk (Amato et al., 2013). However, their limitation lies in that they may not be applicable in large population studies because they are expensive, time-consuming, requires highly skilled and trained personnel to operate them and most are used in a laboratory environment (Wagner and Heyward, 1999; Rodrigues et al., 2001; Amato et al., 2013).

On the other side, skinfold methods are widely used and have high accuracy in assessing adipose tissue (Pérez-Chirinos Buxadé et al., 2018). Though it was also reported to inaccurately measure obese individuals, it was also indicated to have a strong correlation with other techniques such as magnetic resonance imaging (MRI), BI (Pérez-Chirinos Buxadé et al., 2018) ultrasound (Amato et al., 2013; Kuriyan, 2018) to accurately estimates actual body fat.

2.2.4.3. Type 2 diabetes mellitus and metabolic syndrome

Type 2 diabetes mellitus is characterised by the weakening of the β=cell dysfunction resulting from programmed cell death, increased apoptosis, and reduction in cell mass (Inaishi and Saisho 2020). However, this results in hyperglycaemia because of

the reduced insulin action or insulin secretion (Cerf, 2020). Its major pathophysiology factor is thought to be insulin resistance; however, apoptosis was also reported to be its major risk factor (Tomita, 2016). Moreover, T2DM is multifactorial thus it can also result from defective insulin secretion, obesity-associated insulin resistance (Tomita, 2016). Both nutritional transition and advancement in technology were reported to increase the prevalence of T2DM in Africa (Audain et al., 2019). In SA the prevalence of T2DM was reported to be 5.5% (Bradshaw et al., 2007). It has been projected to rise by 41.4 million rates by 2035 (Zhang et al., 2010) in Africa. Type 2 diabetes mellitus is also reported as an important underlying factor of MetS (Tomita, 2016). However, MetS, in turn, is one of the risk factors for T2DM and both double the risk of patients acquiring atherosclerotic and CDVs complications (Einarson et al., 2018). It was indicated that MetS is very common in individuals with T2DM, and it is associated with micro-and macrovascular conditions (Pheiffer et al., 2018). Oftentimes, T2DM is undiagnosed, and this tends to aggravate CVDs risk (Pheiffer et al., 2018).

2.2.4.4. Hypertension and metabolic syndrome

Hypertension is elevated BP within the arteries and is defined as 140/90 mmHg (WHO, 2013). Hypertension is one of the most imperative modifiable risk factors of CVDs (Jongen et al., 2019) its prevalence was reported to be the highest in both SA and other low-and middle-income countries (Jongen et al., 2019). Globally, 18% of deaths are attributable to blood pressure, followed by raised blood glucose, and overweight and obesity (Lim et al., 2012). The prevalence of hypertension in SSA ranges from 25.4% to 41.1% being men and 27.2 % to 38.7 % being women (Gebreyes et al., 2018). The same study observed a higher prevalence of hypertension in urban areas compared to rural areas which seem to increase with age. Similar findings were also reported in Nigeria with higher hypertension prevalence rates of 32.7% for urban residents and 12.9% for rural dwellers. According to the South African National Survey (SANS), the prevalence rate of hypertension was 18% men and 13% women (He and MacGregor, 2007). Hypertension causes are also multifactorial ranging from lack of physical activity, alcohol consumption, high salt intake, being overweight (Jongen et al., 2019). Jongen et al. (2019) further explained that the high prevalence rate of hypertension is attributed to low awareness (19.0%-56.0%) and control (4.0-33.0%). However, it

was reported that improved knowledge of hypertension was associated with enhancing compliance to the usage of antihypertensive medication and disease control (Busari et al., 2010; Boateng et al., 2017).

The MAP is another parameter to measure hypertension after SBP and DBP. It is defined as the average of SBP and DBP influenced by cardiac output and systematic vascular resistance throughout one cardiac cycle (Sesso et al., 2000). The MAP was reported to be of great importance compared to SBP because of its vital role in maintaining proper organ perfusion (Vedel et al., 2016; DeMers and Wachs, 2021). It is therefore important to maintain MAP at a minimum of 60 mmHg to ensure sufficient perfusion of vital organs (DeMers and Wachs, 2021) since any deviation whether below or above 60 mmHg for a prolonged period can result in life-threatening conditions. The life-threatening conditions include blood clots, heart attack, stroke, consciousness, ischemia, infarction and leading to neural death (Vedel et al., 2016). The MAP was reported to be used extensively in clinical settings to offer information regarding diagnoses of hypertension from the calculated SBP and DBP readings (DeMers and Wachs, 2021). The MAP can be calculated using the following equation (Sesso et al., 2000):

$$MAP = DBP + 1/3 \times (SBP - DBP).$$

2.2.4.2. Dyslipidaemia and metabolic syndrome

Dyslipidaemia is described as raised blood lipids levels such as TC, low-density lipoprotein cholesterol (LDL-C), TG and HDL-C, apolipoprotein A and apolipoprotein B above optimum levels (Anderson et al, 2013; Ntusi, 2018). Dyslipidaemia is also among the major modifiable risk factor of CVDs (Ntusi, 2018). The WHO reported the prevalence of raised total cholesterol among adults to be 39% (≥5.0 mmol/L), with 40% being females and 37% being males (WHO, 2008). In SA, Gauteng province, a retrospective study was conducted among black patients attending Dr George Mukhari Hospital (Khine and Marais, 2016). A significant burden and high prevalence of dyslipidaemia were reported amongst these patients (Khine and Marais, 2016). Furthermore, 9% of patients were observed to have extreme hypercholesterolaemia (TG >12 mmol/L) and 5 % of patients were observed to have severe hypercholesterolaemia (TG > 7 mmol/L) (Khine and Marais, 2016). Treatment of dyslipidaemia was indicated to be the route that can decrease mortality and

morbidity of CVDs (Grundy et al., 2004). In turn, this treatment was reported to also benefit individuals without CVDs (Grundy et al., 2004). Furthermore, this treatment was reported to reduce the risk of heart diseases over five years by 30% (Grundy et al., 2004). The most common lipid in West Africans and African Americans with MetS was low HDL-C with normal TG levels (Sumner et al., 2010). It was reported that elevated plasma triglycerides levels, reduced HDL-C, and increased proportion of small dense LDL-C particles were linked with excess visceral adipose tissue accumulation (Blaton, 2007). This suggests that overweight and obesity may be important markers of dyslipidaemia. Moreover, both MetS and dyslipidaemia may be used as a screening tool for CVDs since they are both primary risk factors (Blaton, 2007).

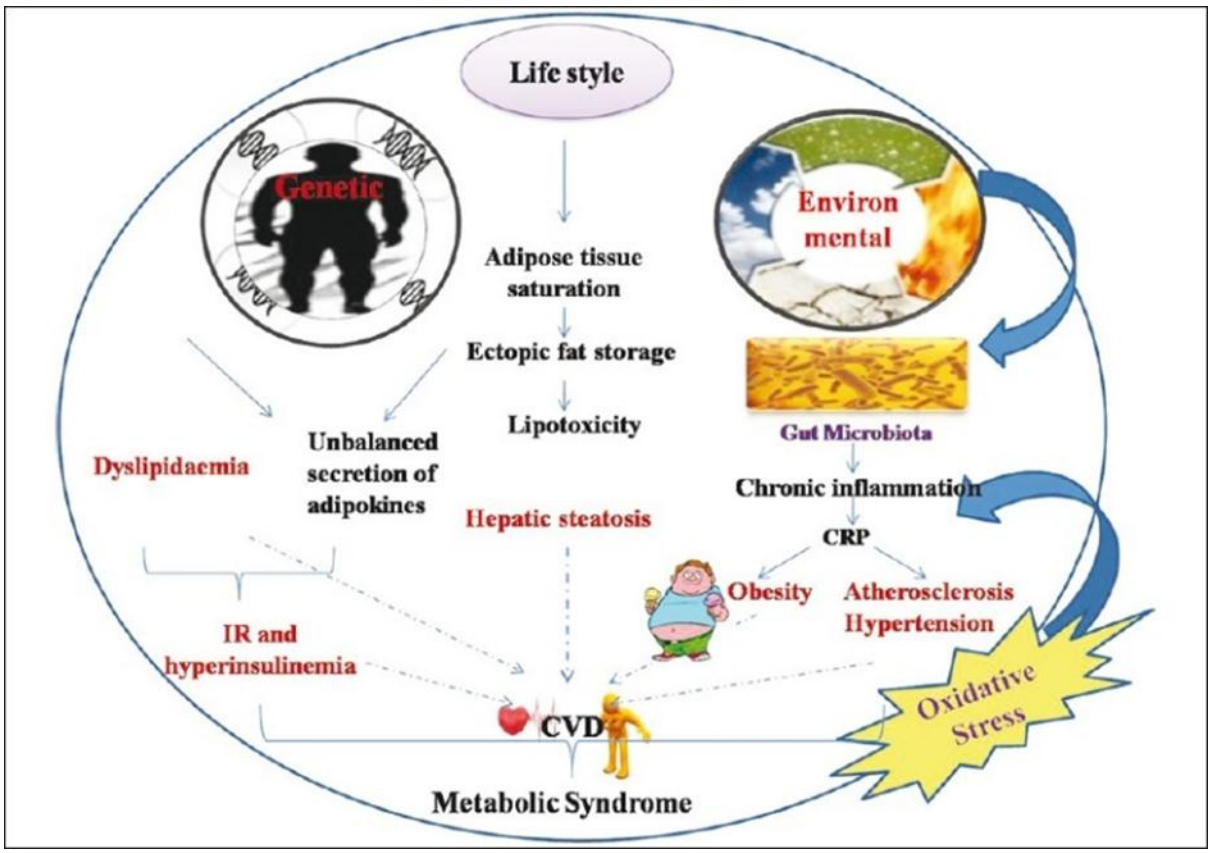

Figure 2.2.4.3: The modifiable and non-modifiable risk factors of metabolic syndrome (Grundy et al., 2004).

2.2.5. Models used to predict metabolic syndrome

The goodness of fit is a model that makes use of discrepancy measures or some fit statistics that include deviance, residuals of chi-square to compare the observed data with the expected data (Kery and Royle, 2016). On the other hand, confirmatory factor analysis (CFA) tests if models fit the data (Alhija, 2010). The CFA is mostly applied when one wants to measure new and existing measures, to develop new measures and contrast validity, to test measurements invariance across groups or populations and examine the effect of the model (Harrington, 2009). The major important role of the CFA is evaluating the connection between the observed/indicators variables and unobserved/latent variables (Harrington, 2009). In the current study, CFA is used to test the MetS single-factor models as defined by TG, FBG, MAP on selected obesity indices that include WHtR, WC, NC, BMI. In this regard, the MetS variable is treated as an unobserved or latent (unknown) variable where variables such as TG, FBG and MAP are used to identify it (Pladevall et al., 2006; Hu and Bentler, 1999). Additionally, the CFA was reported to be sensitive to sample size thus it depends on other factors such as Akaike's information criterion (AIC), comparative fit index (CFI), turker lewis index (TLI), goodness-of-fit index (GFI) and root mean square of approximation (RMSEA) to assist in how well the model fits the data (Hu and Bentler, 1999; Akaike, 1973). The model with the lowest AIC is regarded as the best model (Akaike, 1973). Consequently, a model with TLI>0.95, CFI>0.95 and RMSEA<0.06 is also considered a good model-data fit (Hu and Bentler, 1999).

2.2.6. Recommendations for the control and prevention of the metabolic syndrome

Obesity is strongly related to the disruption in energy balance (DeBoer, 2019) and MetS. Thus, restriction of a diet rich in energy and encouragement of increased physical activity could increase energy expenditure which is significant in maintaining a healthy and balanced body weight (DeBoer, 2019). Subsequently, this will result in increased insulin sensitivity thereby reducing the risk of MetS (Perez-Martinez et al., 2017). A study by Perez-Martinez et al. (2017) further indicated that there is no single type of diet that can help maintain body weight or weight loss. However, the Mediterranean diet such as the one rich in vegetables, fruits, legumes, less red meat, less saturated fat to name a few was regarded to be a diet that can help

improve a metabolic health profile and decrease the prevalence and incidence of MetS and its components (Perez-Martinez et al., 2017; DeBoer, 2019). Risky modifiable lifestyle behaviour and habits emerge as a significant mediator to the rising prevalence of MetS (Freely and Norris, 2014; WHO, 2017). Therefore, stopping smoking, decrease in alcohol consumption, high consumption of SSBs, salts, processed food etc. should be primarily included in the intervention programmes to help in efforts for both prevention and treatment of MetS which in turn would encourage healthy lifestyle habits (Perez-Martinez et al., 2017).

2.3. SUGAR-SWEETENED BEVERAGES

Sugar-sweetened beverages are non-alcoholic beverages with excessive energy that fails to fulfil the nutritional needs of the body (Manyema et al., 2016). They are often available as ready to consume since little or no preparation before consumption is required (Hernández-F et al., 2021). They are naturally sweet, pleasurable, and addictive when being consumed and often results in overconsumption resulting from increased cravings (Avena et al., 2008; Lustig et al., 2012). These features are likely to disrupt the energy balance in the body which result from the affected satiety centres in the brain (Akhram and Hamid, 2013). They contain artificial flavourings, preservatives, acid, caffeine, carbon dioxide to some extent and sweeteners like added sugar as their major constituent (Buglass, 2014).

Added sugars are sugars that are added by a cook to the beverages while serving at the table and during manufacturing or processing (Akhram and Hamid, 2013). They are sweetened with sucralose and aspartame, contain additives, and also exist in the form of syrups such as high-fructose corn syrup, glucose, sucrose, fructose, galactose, lactose, and maltose (Pepin et al., 2019; Solomi et al., 2019). These are added to provide energy and satisfy the consumers taste buds (Akhram and Hamid, 2013). These added sugars form part of carbohydrates which is the central and primary source of the energy in the diet (Aller et al., 2011).

Carbohydrates form part of the three main groups of food or macronutrients (Szalay, 2017). They are made of sugar monomers that occur naturally which are either combined to form complex carbohydrates or exist as simple carbohydrates (Aller et al., 2011). Complex carbohydrates are carbohydrates with thousands of monosaccharides units bonded by glycosidic bonds to form longer chains of sugar

molecules (Niaz et al., 2020). They include starches (oligosaccharides and polysaccharides) and fibres and are normally known to provide lasting energy since they take time to digest (Aller et al., 2011; Clemens et al., 2016). Simple carbohydrates are the smallest basic units of carbohydrates that have shorter sugar chains thus, easy to digest (Szalay, 2017). They include monosaccharides and disaccharides which normally undergo the process of polymerisation to form complex sugars and are often called free sugars (Scapin et al., 2020).

Monosaccharides are the simplest carbohydrate sugar molecules that are absorbed without being digested such as galactose, fructose, and glucose (Scapin et al., 2020)**.** While disaccharides are defined as the combination of two monosaccharides that is broken down before being absorbed such as sucrose, maltose, and lactose (Niaz et al., 2020). These sugars were indicated to exert different effects on hunger, satiety, energy expenditure and energy intake which all bring about different physiological effects in the body (Aller et al., 2011).

2.3.1. Carbohydrates (sugars) that are normally added in sweetened beverages include:

2.3.1.1. Glucose

Glucose is a moderately sweet and important monosaccharide that is also known as dextrose (Bralow and Bralow, 2017). This sugar is the primary source of energy for most body tissues hence denoted as blood sugar which flows throughout the body (Basciano et al., 2005). It is generally preferred by red blood cells and central nervous system tissues particularly the brain as the source of energy (Akhram and Hamid, 2013). Moreover, much energy that is produced within the skeletal and heart muscles originates from glucose (Akhram and Hamid, 2013). All the sugar that an individual consumes is first converted to glucose by the body to be used immediately or stored for later use by the muscle cells or in the liver as glycogen (Basciano et al., 2005). Once glucose is absorbed, it rapidly raises blood glucose because it has the highest glycaemic index compared to other simple sugars (Tey et al., 2017; Solomi et al., 2019). For the process of metabolism to be initiated, glucose depends on the glucokinase or hexokinase enzyme (Basciano et al., 2005). Shortage of glucose stimulates the process of gluconeogenesis to produce glucose from the liver (Akhram and Hamid, 2013).

2.3.1.2. Fructose

Fructose is a highly sweet and prevalent monosaccharide that naturally occurs in fruits (pears, apples, mango grapes etc), honey, and agave. Because of its sweet taste and attractive features, it is frequently used as a sweetener (Szalay, 2017). As opposed to glucose, fructose is not the preferred energy source for the brain and the muscle (Basciano et al., 2005). Its metabolism is indicated in figure 2.3.1 and it differs from that of glucose because it only takes place in the liver where the enzyme fructokinase is stimulated to initiate metabolism (Basciano et al., 2005). It's a sugar that has minimal effect on the blood because it has the lowest glycaemic index (Sun and Empire, 2012). However, this is the reason why fructose has a short-term effect on satiety, it does not result in the suppression of orexigenic hormone and ghrelin hormone (Goran et al., 2015).

2.3.1.3. Sucrose

Sucrose, a disaccharide composed of one glucose and fructose unit each, is a prevalent natural sweetener typically harvested from either sugar cane or sugar beets and refined to a white crystalline end product (Kent, 2007; Bralow and Bralow, 2017). Its commonly known as table sugar (Basciano et al., 2005). Sucrose is a disaccharide that is formed during the process of photosynthesis in plants thus, it is naturally found in vegetables, fruits, the sap of various plants and nectar and is widely used as a natural sweetener (Szalay, 2017). Sucrose is known as the most cariogenic sugar and it is involved in the process of dental caries. Its metabolism process is initiated by the enzyme fructosidase (Basciano et al., 2005).

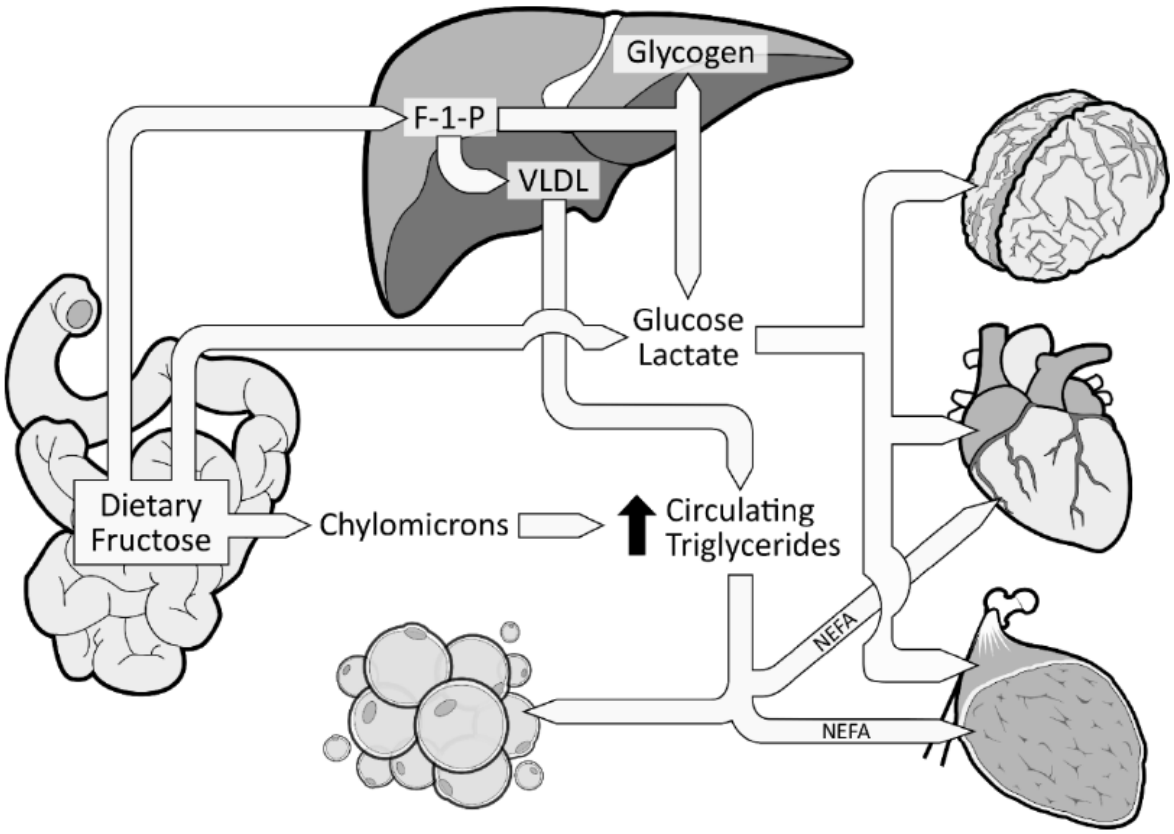

Figure 2.3.1: Dietary fructose metabolism in the body (Pepin et al., 2019).

2.3.2. Trends in sugar-sweetened beverages globally, South Africa

Globally, the consumption of SSBs is on the rise and ranges from 9.5 gallons per person per year in 1997 to 11.4 gallons in 2010 (Audain et al., 2019). In the USA, SSBs consumption remains high, and, in some groups, it nearly exceeds the recommendation intakes by the WHO (WHO, 2015) of 10% daily calories and the Dietary Guidelines for Americans (DGA, 2015). The National Health and Nutrition Examination Survey (NHANES) data had issued a report between 2011 and 2014 among USA adults (Hirode and Wong, 2020). The report indicated that the Americans adults consumed an average of 145 kcal/day from SSB, which correspond to 6.5% of their total calories. Also, excessive levels were found amongst non-Hispanic black and Hispanic men and women and mostly in younger age groups (Hirode and Wong, 2020).

Although in the USA and other high-income countries consumption of SSBs remain at steady levels or declining, in the lower- and middle-income countries there is a gradual increase in the consumption levels (Malik and Hu, 2019).

Malik and Hu. (2019) further reported that the increase is due to the growth in SSBs marketing and nutritional transition experienced by lower-and-middle income countries (Malik and Hu, 2019). This is supported by a survey of data among adults conducted in 187 countries (Singh et al., 2015). It was observed that the consumption of SSBs was higher in upper-middle countries and lower-middle-income countries compared to low-income countries (Singh et al., 2015). Another observation was that in high-income countries such as the USA, lower socioeconomic status (SES) groups had higher levels of SSBs consumption compared to higher SES (Malik and Hu, 2019). Additionally, a South African study conducted among socio-economically disadvantaged (low-income) three communities, namely, two urban townships (Khayelitsha and Langa) in the WC province, and one rural community (Mount Frere) in the EC province (Okop et al., 2019) found similar findings. The study reported an increase in the intake of SSBs (>10 servings/week) (Okop et al., 2019). These areas were reported to be most affected by poverty due to the high unemployment rate and being away from the market (Voster et al., 2014). However, the above factors may encourage communities to buy non-nutritive food rich in fats, salts and sugar especially added sugar (Voster et al., 2014) while exposing themselves to the risk of malnutrition.

South Africa was ranked seventh globally in sugar consumption with SSBs sales doubled from 3.0 to 6.0 billion litres annually between 2002 and 2016 (Koo and Taylor, 2012; Manyema et al., 2014; and Euromonitor, 2015). Tugendhaft et al. (2016) has also projected that by 2017, South African adults may be consuming an average of 200 ml of SSB which correspond to 6 teaspoons of sugar daily per person. This is of great concern since increased consumption of SSBs has been associated with adverse metabolic health complications (Imamura et al., 2015). The consumption of SSBs in rural adults of South Africa has increased from 2005 and 2010 and ranging from 33 to 63% for women and 25 to 56% for men (Okop et al., 2019). However, Essman et al. (2021) reported a decrease in the intake of taxed beverages by 9.0 g (31%), 39 kcal (33%), and 117 ml (37%) per capita per day, respectively. But the intake of untaxed beverages increased by 5.3 g (36%), 30 kcal (29%), and 339 ml (58%) per capita per day, respectively (Essman et al., 2021). This indicates that the taxing of SSBs can play a very important role in reducing adverse health effects associated with the intake of SSBs in SA.

In SA, most data on SSBs consumption are on children and adolescents as opposed to youth, adults, and elders (Temple and Steyn, 2013). A descriptive study survey based in Cape Town (CT) conducted among 9–13 school-aged children reported increased carbonated drinks consumption. A daily 730 g consumption of carbonated drinks which is equivalent to a sugar intake of 40-80 g each day was observed among school-age children (Louwrens et al., 2010). Another study conducted in the EC and WC province among 6-9-year children reported consumption of sugar between 22 g and 57 g respectively (Temple and Steyn, 2013). In adolescents and adults (above 10 years) sugar consumption in the urban area of South Africa was stated to be 12.3% of total energy intake, which is over > 10% of total energy intake recommendation by WHO (WHO, 2015). MacIntyre et al. (2012) also found that men who had a high consumption of added sugar, also consumed more soft drinks, fruits and bread, whereas women who had a high consumption of added sugar consumed more soft drinks and bread. This suggests that SSBs are taken in between or with meals which is worrisome.

The Cardiovascular Risk Study in Black South Africans (CRIBSA) conducted a study among urban adults aged 18–60 years living in four CT townships also provided valuable data on dietary sugar (Jaffer et al., 2011). The study reported that men consumed roughly 52g/day, while women consumed 51g/day in the youngest group while 38 g/day of dietary sugar was consumed in the oldest group. In this regard, the above reports show very limited recent data on SSBs or added sugar, especially in rural youth or youth generally. It shows that in the future, SSB consumption trends might probably change and be parallel to that of high-income countries especially in rural areas (Tugendhaft et al., 2016). This might result from an adaptation to the western diet in this setting because of nutritional transition (Tugendhaft et al., 2016). Moreover, it suggests that the variability in the consumption of sugar might be raised by factors such as socioeconomic status, the desire to eat healthy, gender and age (Temple and Steyn, 2013). It also remains controversial whether the consumption of SSBs is higher among females or in males.

Frequently consumed sources of added sugar in South Africa amongst other things in both rural and urban areas include sweetened squash/ concentrates (to which water is added), carbonated/soft drinks, 100% fruit juice, tea and coffee with either full cream milk or powdered milk added (Nel and Steyn, 2002; Temple and Steyn,

2013; Ronguest-Ross et al., 2015). Another South African study on street food and drinks, has found carbonated drinks to be the second commonly purchased SSBs after fruit juices (Ronguest-Ross et al., 2015).

In a South African study conducted among university students, carbonated soft drinks and juice concentrates were reported to be most frequently consumed where one-third of juice concentrate was consumed daily while 29.5% of carbonated soft drinks were consumed on weekends (Narain et al., 2017; Nakhooda and Wiles 2020; Keller et al., 2020). Nakhooda and Wiles. (2020) indicated price and preference for sweetness as the factors that promote the purchase and increased consumption of SSBs.

2.3.3. Association of sugar-sweetened beverages and metabolic syndrome

Discrepancies have been reported on the association between SSBs consumption and MetS. Association between high consumption of SSBs and MetS was reported by (Narain et al., 2017). Additionally, the SUN prospective study of 6 years duration also reported that an increase in SSBs consumption was associated with the risk of developing four of the five defining criteria of MetS such as central obesity, high blood pressure, hypertriacylglycerolaemia and impaired fasting glucose (Barrio-Lopez et al., 2013). By contrast, Pienovi et al. (2018) did not find an association between total consumption of certain SBs and MetS but only found an association of MetS component WC at the intake above 400 mL/d of SSBs, but not for hypertriglyceridemia, low low-density lipoprotein, high blood pressure, or high fasting glucose. Supporting findings were also observed in the Korean cross-sectional study, where higher SSBs consumption (≥1 serving/day) was not associated with MetS including its components (Shin et al., 2018).

Observational studies showed that not all types of SSBs are associated with the risk of developing MetS (Imamura et al., 2015; Imamura et al., 2019). This has been reported in previous substitution studies that have shown that substituting SSBs with water, milk, artificially-sweetened beverage (ASB), plain tea or coffee for SSBs was associated with a lower risk of weight gain, obesity and T2DM (de Koning et al., 2011; Pan et al., 2013; Zheng et al., 2015; Imamura et al., 2019). A study conducted in Costa Rica had reported a positive relationship between a reduction of 29% risk of MetS after a decrease in SSBs consumption and substitution with fresh fruit juice

(Pienovi et al., 2018). Baliunas et al. (2009) and Jiang et al. (2014) also reported that adults who consume 2-3 daily servings of coffee or tea were more likely to experience a reduction of 15-25% risk of T2DM across 8 European populations. It has been reported that fruit juice, water, milk, plain tea or coffee consists of various bioactive compounds such as vitamins, folate, minerals, potassium, antioxidants, and anti-inflammatory effects which are well known to protect against diseases (Higashi et al., 2009).

2.3.4. Association, mechanism of sugar-sweetened beverages with individual metabolic syndrome components

2.3.4.1. Sugar-sweetened beverages and type 2 diabetes mellitus

Evidence from several studies has shown the role of SSBs in the aetiology of T2DM (Malik and Hu, 2012; Malik and Hu 2019). Malik and Hu. (2012) indicated that individuals consuming one or two SSBs daily had a 25% increased risk of T2DM development. Additionally, Malik and Hu. (2019) in a meta- observed that one serving of SSBs per day was associated with increased risk of T2DM. Malik et al. (2010) and Liu et al. (2002) had indicated a possible pathway through which large quantities of SSBs consumption led to T2DM. The possible pathway involves the β-cell dysfunction which results in glucose intolerance, insulin resistance and inflammatory biomarkers (Malik et al, 2010; Liu et al., 2002). Moreover, sugar molecules contained in the SSBs were also reported to cause rapid blood glucose spikes due to moderate to a high glycaemic index (Atkinson et al., 2008; Tey et al., 2017; Solomi et al., 2019). It must be noted that this occurs independently of weight gain or obesity (Malik et al., 2010; Weeratunga et al., 2014). Consequently, lowering SSBs intakes should become the public health focus to help reduce the increased risk of T2DM (Bleich et al., 2018).

2.3.4.2. Sugar-sweetened beverage and obesity

Clear evidence has been provided on the association between obesity and SSBs (Malik and Hu 2019). Sugar-sweetened beverages act on the brain to promote overconsumption by initiating the action of the hormone ghrelin (hunger hormone) and inhibiting the hormone leptin that is responsible for the feeling of fullness (Lustig et al., 2012; Akhram and Hamid, 2013). Sugar-sweetened beverages usually contain little or no nutritive value (vitamin and minerals, fibres etc) to compensate for the added calories consumed, thus will result in extra calories in the body (Manyema et

al., 2016). Moreover, oftentimes SSBs appears appealing and tasty and has little satiety thus will promote overindulgence resulting also in increased energy intake (Temple and Steyn 2013).

Glucose is one of the constituents of SSBs that have a high GI (Akhram and Hamid, 2013) thus consumption of SSBs will increase blood sugar activating the insulin hormone to promote its uptake by the body cells (Lustig et al., 2012). However, this action normally causes the blood sugar to drop increasing hunger and encouraging an over intake of food or beverages (Malik and, Hu 2019). Similar to glucose, fructose also forms part of the SSBs constituent, however, it does not trigger the hormones involved in controlling food or beverage intakes but promotes the process of lipogenesis which results in accumulation and deposition of triglycerides in the abdomen (Sun and Empire. 2012; Herman and Samuel, 2016).

A study conducted by Okop et al. (2019) on South African adults living in resource-poor communities has reported an increase in body weight following SSBs consumption. It was reported that adults who consumed an average of 10 servings of SSBs per week were found to have a relative weight gain in follow up of 4-5 years. A similar finding was also reported in the Tehran Lipid and Glucose Study were the “participants in the higher SSBs quartile had a 35% higher risk of abdominal obesity (OR:1.35, 95%:1.12-1.61) and 22% higher risk of general obesity (OR: 1.22, 95% CI: 1.00–1.48) compared with those in the lowest quartile of SSBs consumption (Mirmiran et al., 2015). This indicates that actually, weight gain results from a disruption in energy balance especially from increased energy intake of sugar in SSBs which is strongly implicated in the onset of obesity (Temple and Steyn, 2013). In contrast, according to Kaiser et al. (2013) and Poppit. (2015) no association between SSBs intake and weight gain was reported. However, this remains inconclusive and warrants further investigation.

This suggests that sugar causes weight gain mostly as a result of increased energy intake and less energy expenditure. This means, sugar, especially in SSBs, is strongly implicated in obesity onset therefore reducing its intake can help prevent obesity and related conditions, which include T2DM, CVDs and cancer of the colon and breast (Essman et al., 2021).

2.3.4.3. Sugar-sweetened beverages and hypertension

Fructose is the only sugar molecule contained in the SSBs which triggers the production of uric acid in the liver (Lustig et al., 2012) through the depletion of adenosine triphosphate (ATP) (Johnson et al., 2009). This usually takes place when the intake of fructose surpasses the capacity of the liver to release lactate and glucose for a prolonged period in the muscle (Tappy and Rosset, 2017). Therefore, the production of the uric acid in the liver might result in the reduction of the endothelial nitric oxide which as well might be involved in the link between SSBs and coronary heart diseases (CHD) (Richette and Bardin, 2009; Richette et al., 2014; Malik and Hu, 2019).

Subsequently, hyperuricemia is the mediator of the association between SSBs consumption and hypertension through endothelial dysfunction also by activation of the renin-angiotensin system, vascular oxidative stress, and renal disease development (Richette and Bardin, 2009; Richette et al., 2014). This was reported in the animal experiments and clinical trial studies, that high sugar consumption, especially fructose, may result in acute and chronic elevations of serum uric acid concentrations (Feig, 2012). Thereby leading to activation of the renin-angiotensin system, which consequently further reduces nitric oxide production (Feig et al., 2006; Feig et al., 2008).

Moreover, hyperuricemia is correlated with the progression of gout (Choi and Curhan, 2008) subsequently, both hyperuricemia and gout are implicated in the development of hypertension, T2DM, kidney disease, NAFLD, dyslipidaemia, CVDs and MetS (Nakagawa et al., 2005; Richette et al., 2009; Richette and Bardin, 2009) as shown in figure 2.3.4. On the other hand, reduced nitric acid production which is a vasodilator is associated with elevated blood pressure (Perez-Pozo et al., 2010). Additionally, elevated fructose molecules might promote sodium and water reabsorption, this action enhances the activity of the sympathetic nervous system (Komnenov et al., 2019).

Additionally, sex hormones were reported to play a role in the development of hypertension. Oestrogen was reported to play a role in activating the protein kinase c pathway which is responsible for vascular smooth muscle relaxation and contraction (Ebbeling et al., 2012). However, this might increase nitric oxide production

(Ebbeling et al., 2012) and the activation of the renin-angiotensin system which both are involved in increasing blood pressure leading to the onset of hypertension. Maris et al. (2005) conducted a study in male and female rats and fed them with fructose for 9 weeks. It was observed that female sex hormones were protective against hypertension or hyperinsulinemia (Maris et al., 2005). This may in part explain why young females are less likely to develop hypertension.

Although a significant body of evidence reported an association between high intake of SSBs and hypertension through various mechanisms (Brown et al. 2011; Kim et al. 2012; Malik et al. 2014), it remains uncertain if the association only results from the SSBs consumption or other mechanism. High salt intake accompanied by a high intake of SSBs was also one of the proposed mechanisms for the association of hypertension and high consumption of SSBs (He et al. 2008; Grimes et al., 2013). However, in the multicentre randomised study, it was reported that a reduction in the consumption of SSBs and sugars resulted in a reduction in BP levels (Chen et al., 2010).

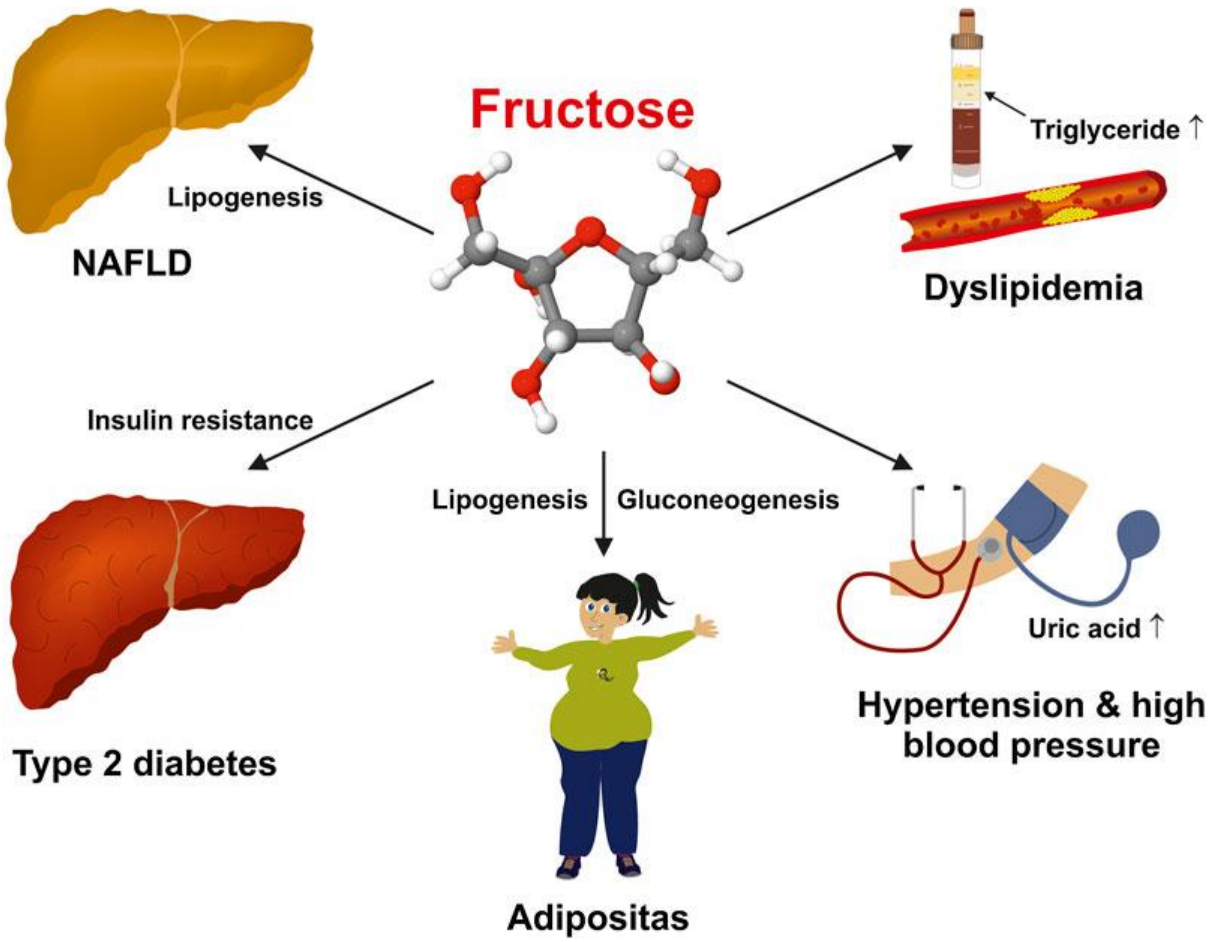

Figure 2.3.4: The fructose and its associated risk factors **(**Richette and Bardin, 2009).

2.3.4.4. Sugar-sweetened beverages and dyslipidaemia

Studies have reported that excessive SSBs consumption adversely affects blood lipids (Akhram and Hamid, 2013; Goran et al., 2015; Xi et al., 2015). An adverse change in lipoprotein concentration such as elevated TG and HDL-C was reported to be associated with regular consumption of SSBs such as sodas and fruit juice which is simultaneously related to increased incidence of dyslipidaemia (Haslam et al., 2020). The liver is a tissue where fructose metabolism occurs. When consumed in moderate amount, fructose molecule is converted into glucose, lactate, and fatty acids to serve as a source of energy for body cells (Sun and Empire, 2012). Meanwhile, when consumed in excess, it likely results in increased atherogenic dyslipidaemia, insulin resistance and hepatic *de novo* lipogenesis. This occurs when hepatic lipids increase the production and secretion of very-low-density lipoprotein (VLDLs) resulting in accumulation of VAT and deposition of ectopic fat (Stanhope and Havel, 2008; Teff et al., 2009). This might result in elevated concentration of postprandial triglycerides and small dense LDL-C cholesterol and decreased levels of HDL-C (Akhram and Hamid 2013; Goran et al., 2015; Xi et al., 2015)

Similar to hypertension, SSBs showed the possibility of influencing the development of dyslipidaemia also through sex hormones which exhibit different effects in both genders. The possible explanation could result from the difference in hormonal response and disease implication following consumption of SSBs (Knopp et al., 2005). In females, oestrogen stimulates the renin-angiotensin system which is responsible for increasing the levels of TG levels and lipoprotein following consumption of SSBs thus resulting in fat transportation in the blood (Knopp et al., 2005). In males, androgen (testosterone) has a different effect compared to oestrogen, it stimulates adipose tissue to enhance the deposition and accumulation of visceral fat thereby causing insulin resistance which may lead to T2DM and dyslipidaemia over time (Knopp et al., 2005; Yao et al., 2018).

2.3.4. Mechanism of sugar-sweetened beverages and metabolic syndrome.

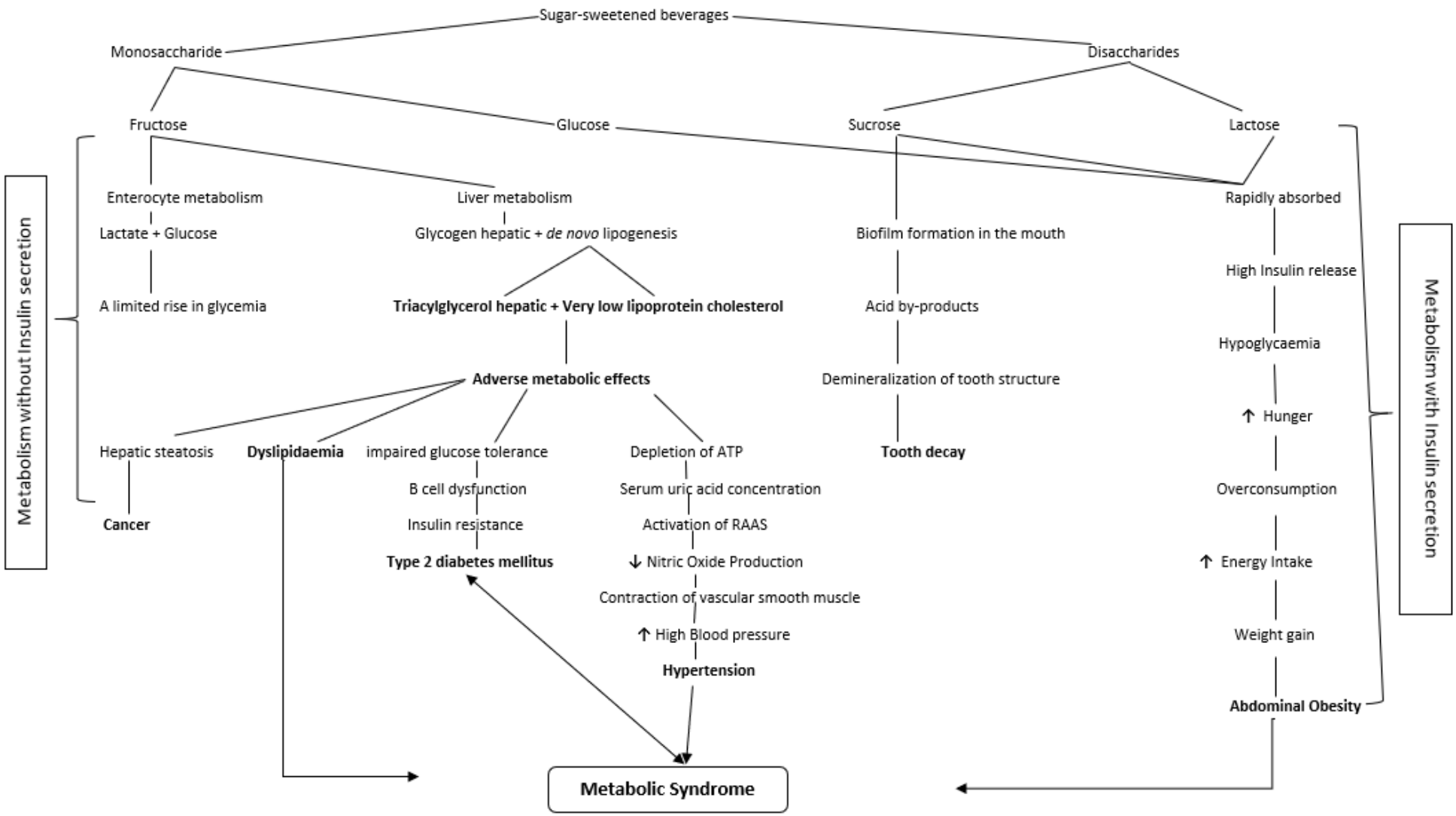
Sugar-sweetened beverages
Monosaccharide
Disaccharides
Fructose
Glucose
Sucrose
Lactose
Metabolism without Insulin secretion
Enterocyte metabolism
Liver metabolism
Rapidly absorbed
Lactate + Glucose
Glycogen hepatic + de novo lipogenesis
Biofilm formation in the mouth
High Insulin release
A limited rise in glycemia
Triacylglycerol hepatic + Very low lipoprotein cholesterol
Acid by-products
Hypoglycaemia
Adverse metabolic effects
Demineralization of tooth structure
↑ Hunger
Hepatic steatosis
Dyslipidaemia
impaired glucose tolerance
Depletion of ATP
Tooth decay
Overconsumption
Cancer
B cell dysfunction
Serum uric acid concentration
Insulin resistance
Activation of RAAS
↑ Energy Intake
Type 2 diabetes mellitus
↓ Nitric Oxide Production
Contraction of vascular smooth muscle
Weight gain
↑ High Blood pressure
Hypertension
Abdominal Obesity
Metabolism with Insulin secretion
Metabolic Syndrome

Table 2.3.4: The pathways in which monosaccharides and disaccharides may cause the development of metabolic syndrome (Malik and Hu 2019).

2.3.5. Recommended level or daily intake level for sugar-sweetened beverages

Sugars are part of the carbohydrates and form an important part of our diet. The Institute of Medicine (IM) instructs that 25% of sugar be the daily recommended energy (DRI, 2006). The WHO advises that the recommended daily added sugar intake be no more than 10% energy (WHO, 2003). The European Food Safety Authority (EFSA) also recommended the added sugars <10% intake of daily energy (WHO, 2003). The South African Food-Based Dietary Guidelines (SAFBDG) is ≤ 55g which is equivalent to 6-10% of total energy intake (Steyn et al., 2003). The American Heart Association (AHA) recently suggested an added sugar of upper limit of 100 calories (420 kJ, 25 g) per day or 100 calories for women and (630 kJ, 37.5 g) or 150 calories for men which corresponds to approximately 5-6% of dietary energy (Johnson et al., 2009).

Table 2.3.5.1: Shows added sugar daily recommended limit by various organisations.

Organisations	IM (DRI, 2006)	WHO (WHO, 2003)	EFSA (WHO, 2003)	AHA (Johnson et al., 2009)	SA-FBDG (Steyn et al., 2003)
Daily energy/added sugar intake	< 25%	< 10%	<10 %	≤ 100 calories (420 kJ, 25 g) for women ≤ 150 calories (630 kJ, 37.5 g) for men	≤ 55g

2.3.6. Factors that drive people to consume sugar-sweetened beverages

2.3.6.1. Advertisement of sugar-sweetened beverages

Many developing countries including SA are experiencing westernisation, urbanisation and nutritional transition which fuels the adoption of a western diet (Nnyepi et al., 2015; Tungendhaft et al., 2016). Adaptation to the western diet occurs through exposure to various means of marketing. This is the aspect of SSBs markets and producers who see these countries as an opportunity where they can grow and

expand their sales (Rude, 2010). Various ways of marketing include promoting of SSBs through advertisement on the radio, cinema, televisions, magazines, newspapers, internets ads, games, and social media platforms (Rude, 2010; Emond et al., 2015; Kumar et al., 2015). This suggests that on daily basis both children and adults may be exposed to various types of advertisements (Temple and Steyn, 2013). Television was reported to be a powerful marketing tool in developed countries (Dijikstra et al., 2005; Guran and Bekeret., 2011) followed by internet marketing (Temple and Steyn, 2013). It has been reported that long hours of watching TV were associated with decreased intake of fruits and vegetables but increased in SSBs and fast-food consumption (Coon and Tucker, 2011; Andreyeya et al., 2011).

2.3.6.2. Availability, affordability, and accessibility of sugar-sweetened beverages

Widely available and affordable energy-dense food and beverages are the aspects of the nutritional transition occurring in South Africa (Tugendhaft et al., 2016). Voster et al. (2014) reported that factors such as cost of food, lifestyle habits, changing environment, taste, convenience, and dietary behaviour influences the purchase and intake of sugary products. This results from the expansion of supermarket and spaza shops into informal urban and rural areas which however promotes easy access, purchase then consumption (Tugendhaft et al., 2016). A Mexican study found that frequent visits and easy accessibility to convenience stores, small grocery stores, soft drinks and other food stores were associated with higher purchases of taxed beverages or SSBs (Hernandez-F et al., 2021). Ruel et al. (2010) and D'Souza and Jolliffe. (2013) reported that increased cost of healthy food may promote purchase and consumption of cheap food rich in high calories. This was evident in a South African study reporting on food prices (Temple and Steyn, 2013; Voster et al., 2014). The study showed that poor people were pressurised to buy beverages with more sugar than fruit and vegetables because of low cost. This indicates that socio-economic status also plays a significant role in the purchase and consumption of SSBs where poor households/low socio-economic status often falls victim.

2.3.6.3. Nutritional knowledge of sugar-sweetened beverages

Nutritional knowledge and education are amongst factors that promote early frequent SSBs consumption (Audain et al., 2019). In the context of Africa, little has been reported on the level of consumers knowledge regarding frequent SSBs consumption and the adverse health effect that may result in thereof (Audain et al., 2019). In South African peri-urban areas, an inverse association between the level of a mother's education and students carbonated drinks consumption frequency was reported (Audain et al., 2014).

2.3.7. Types of methods used to assess sugar-sweetened beverages

Various methods have been suggested to assess the dietary intakes information of participants (Baik et al., 2013; Shim et al., 2014; Corella and Ordovas, 2015). These dietary intake methods are used to assess diet and diseases associated with diet, monitor the populations' usual intake, and help provide dietary guidance to individuals who need it (Shim et al., 2014; Naska et al., 2017). Shim et al. (2014) have reported that dietary nutrient assessment inaccuracy can hinder the correct dietary-related diseases prediction. However, the dietary intake assessment inaccuracy seems to lead to several inconsistencies reported in most studies especially when using either food frequency questionnaire (FFQ) or twenty-four-hour dietary recall (24-HDR) (Kipnis et al., 2003; Shim et al., 2014; Freedman et al., 2015). Other studies have reported that to overcome measurement errors adjusting with energy must be applied to improve measurement bias (Freedman et al., 2014; Freedman et al., 2015). While other studies have reported that adjusting with energy weakens or does not improve the measurement bias (Kipnis et al., 2003; Schatzkin et al., 2003). In addition, others suggested the use of biomarkers to a surrogate error made by other dietary intake assessments methods (Combs et al., 2013; Baik et al., 2013). The above findings indicate the existence of controversies and however, needs further studies for investigation.

Table 2.3.7: Types of methods to assess dietary intakes.

	24-hour dietary recall (Shim et al., 2014)	Dietary record (Shim et al., 2014)	Dietary history (Shim et al., 2014)	Food frequency questionnaire (Shim et al., 2014)	Biomarker (Tasevska et al., 2005; Shim et al., 2014; Corella and Ordovas 2015)
Methods	A trained interviewer using an open-ended questionnaire to collect dietary data	A trained interviewer uses both open and closed questionnaire	Uses open-ended questionnaire -Self-administered questionnaires	A trained/self-interviewer uses open-ended questions to collect dietary data	-Measurements made by collecting urine, plasma or serum, teeth, hair and nails samples
Collected data	Dietary data information collected over the past 24 hours	Dietary data information collected over a relatively long period	Dietary data information collected throughout a particular period	Dietary data information collected over a month, 6 months or 1 year	Dietary data information collected over hours, days, weeks, months, and years
Strengths	Literacy not needed Detailed intake of data offered -Can be used in large epidemiology studies -Can be used to provide dietary guidance	-Ability to measure actual dietary intake	-Detailed dietary intake provided -no recall biases -no requirements of interviewers	Actual dietary data easily measured -Suitable for epidemiological studies -Cost-effective	-Free from bias and errors - Independent of memory -No need to describe the type and the quantity of food consumed by the subject -It can be used to surrogate dietary intake methods errors
Limitations	-Recall and interviewers bias likelihood by the participants -Requires trained interviewer -Requires more than one day to measure usual intake -Poor reflection of individuals usual intake -Cannot indicate an individual's day-to-day long term inter variability	Not appropriate for epidemiological studies -Time-consuming and costly	-Requirements of multiple days to measure actual intakes -Underreporting possibility -It is costly and consumes time -Requires high motivation and literacy -possible changes in dietary intakes	-Requires exact research and study groups -Closed-ended questionnaire usage -Possibility of recall bias by the participants -Consumes time	--Affected by absorption and metabolism after consumption -It cannot be used alone to collect dietary data -Affected by homeostasis or diseases -Inter-individual factors such as age, gender, alcohol intake, tobacco smoking, physical activity -Storage and the collection of the collected specimen -Cannot be used to provide dietary recommendations -Cannot be used to adjust subjects' dietary habits

Furthermore, the SSBs data is often divided into categories depending on how the study classifies it. In, the study by Barrio-Lopez et al. (2013) the SSBs consumption differences were grouped into quintiles of change, for example, quintile 1 was considered as the participants who had decreased their consumption while quintile 5 were the participants who increased most of their consumption. The study additionally regarded the first quintile as the reference category (Barrio-Lopez et al., 2013). In the study conducted by Shin et al. (2018) SSBs data were categorised into four groups according to the frequency of SSBs consumption such as non-SSBs drinkers, less than 2 times/week, 3–6 times/week, and more than once a day. However, percentiles and quartiles are also used to categorises SSBs data. The percentile is described as the set of data that is divided into 100 equal groups by the use of 99 points such that each group consist of 1% of the data that is organised in ascending or descending order (Mishra et al., 2019). On the other hand, quartiles are defined as the points that separate the data set into four equal groups that are organised in ascending and descending order such that each group consist of a quarter of a data (Mishra et al., 2019). Likewise, the first quartile which is the lowest is considered the 25% percentile, while the second is considered the 50% percentile, the third quartile as the 75% percentile and last the 100% percentile as the fourth quartile which is the highest (Mishra et al., 2019). The quartiles and percentiles would be used in the current study to divide SSBs data.

2.4. SUMMARY

Controversy remains about the prevalence of MetS stated in the literature because some studies found higher and some lower prevalence of MetS depending on the type of definition they used. Shift into unhealthy lifestyle behaviours and choices such as increased consumption of SSBs also forms part of the primary risk factors for ever-increasing MetS prevalence. The risk of developing MetS especially in rural communities might be influenced by the gradual increase of SSBs. This results from easy access and availability of SSBs at the spaza shops and exposure through media advertisement, low cost of SSBs and lack of income. Consumption of SSBs is commonly associated with a disruption in energy balance which is the root cause of metabolic disarrangement in an individual. Thus, an increase in the consumption of SSBs is associated with an increased risk of developing Mets. However, screening of MetS risk factors through the use of obesity indices such as NC, BMI, WC and WHtR could assist in predicting individuals at risk of developing MetS. Moreover, this might help in providing novel data for intervention studies to implement programmes or campaigns that are aimed at preventing and managing non-communicable diseases in which MetS play a major role.

2.5. REFERENCES

Ackland, T.R., Lohman, T.G., Sundgot-Borgen, J., Maughan, R.J., Meyer, N.L., Stewart, A.D. and Müller, W. (2012). Current status of body composition assessment in sport. *Sports Medicine*, 42(3):227–249.

Akaike, H. (1973). Information theory and an extension of the maximum likelihood principle. Pp. 267-281 in 2nd International Symposium on Information Theory, Tsahkadsor, Armenia, USSR, September 2-8, 1971, eds. BN Petrov and F. Csáki. Budapest: Akadémiai Kiadó. Bankevich, A., S. Nurk, D. Antipov, AA Gurevich, M. Dvorkin, AS Kulikov, VM Lesin, et al. 2012. SPAdes: A new genome assembly algorithm and its applications to single. *Systematics and Evolution of the Arundinoideae and Micrairoideae (Poaceae)*, 18(1):139.

Akram, M. and Hamid, A. (2013). Mini review on fructose metabolism. *Obesity Research and Clinical Practice*, 7(2):e89–e94.

Alberti, K.G.M.M., Eckel, R.H., Grundy, S.M., Zimmet, P.Z., Cleeman, J.I., Donato, K.A., Fruchart, J.C., James, W.P.T., Loria, C.M. and Smith Jr, S.C. (2009). Harmonizing the metabolic syndrome: a joint interim statement of the international diabetes federation task force on epidemiology and prevention; national heart, lung, and blood institute; American heart association; world heart federation; international atherosclerosis society; and international association for the study of obesity. *Circulation*, 120(16):1640–1645.

Alberti, K.G.M.M., Zimmet, P. and Shaw, J. (2006). Metabolic syndrome—a new world-wide definition. A consensus statement from the international diabetes federation. *Diabetic Medicine*, 23(5):469–480.

Alhija, F.A.N. (2010). Factor analysis: An overview and some contemporary advances. *International Encyclopedia of Education*, 3:162–170.

Aller, E.E., Abete, I., Astrup, A., Martinez, J.A. and Baak, M.A.V. (2011). Starches, sugars and obesity. *Nutrients*, 3(3):341–369.

Alzeidan, R., Fayed, A., Hersi, A.S. and Elmorshedy, H. (2019). Performance of neck circumference to predict obesity and metabolic syndrome among adult Saudis: a cross-sectional study. *BMC Obesity*, 6(1):1–8.

Amato, M.C., Guarnotta, V. and Giordano, C. (2013). Body composition assessment for the definition of cardiometabolic risk. *Journal of Endocrinological Investigation*, 36(7):537–543.

Anderson, T.J., Grégoire, J., Hegele, R.A., Couture, P., Mancini, G.J., McPherson, R., Francis, G.A., Poirier, P., Lau, D.C., Grover, S. and Genest Jr, J. (2013). 2012 update of the Canadian Cardiovascular Society guidelines for the diagnosis and treatment of dyslipidemia for the prevention of cardiovascular disease in the adult. *Canadian Journal of Cardiology*, 29(2):151–167.

Andreyeva, T., Kelly, I.R. and Harris, J.L. (2011). Exposure to food advertising on television: associations with children's fast food and soft drink consumption and obesity. *Economics and Human Biology*, 9(3):221–33.

Atkinson, F.S., Foster-Powell, K. and Brand-Miller, J.C. (2008). International tables of glycemic index and glycemic load values. *Diabetes Care*, 31(12):2281–2283.

Audain, K.A., Kassier, S.M. and Veldman, F.J. (2014). Adolescent food frequency and socio-economic status in a private urban and peri-urban school in Hilton, KwaZulu-Natal. *South African Journal of Clinical Nutrition*, 27(4):201–207.

Audain, K.A., Levy, L. and Ellahi, B. (2019). Sugar sweetened beverage consumption in the early years and implications for type 2 diabetes: A sub-Saharan Africa context. *Proceedings of the Nutrition Society*, 78(4):547– 553.

Audrain-McGovern, J. and Benowitz, N.L. (2011). Cigarette smoking, nicotine, and body weight. *Clinical Pharmacology and Therapeutics*, 90(1):164–168.

Avena, N.M., Rada, P. and Hoebel, B.G. (2008). Evidence for sugar addiction: behavioral and neurochemical effects of intermittent, excessive sugar intake. *Neuroscience and Biobehavioral Reviews*, 32(1):20–39.

Baik, I., Cho, N.H., Kim, S.H. and Shin, C. (2013). Dietary information improves cardiovascular disease risk prediction models. *European Journal of Clinical Nutrition*, 67(1):25–30.

Baioumi, A.Y.A.A. (2019). Comparing Measures of Obesity: Waist Circumference, Waist-Hip, and Waist-Height Ratios. In Nutrition in the Prevention and Treatment of Abdominal Obesity (pp. 29-40). Academic Press.

Balgoon, M.J., Al-Zahrani, M.H., Alkhattabi, N.A. and Alzahrani, N.A. (2019). The correlation between obesity and metabolic syndrome in young female university students in the Kingdom of Saudi Arabia. Diabetes & Metabolic Syndrome: *Clinical Research and Reviews*, 13(4):2399–2402.

Baliunas, D.O., Taylor, B.J., Irving, H., Roerecke, M., Patra, J., Mohapatra, S. and Rehm, J. (2009). Alcohol as a risk factor for type 2 diabetes: a systematic review and meta-analysis. *Diabetes Care*, 32(11):2123–2132.

Baloyi, S.M. and Mokwena, K. (2020). Metabolic syndrome among pregnant women attending an antenatal care clinic at a tertiary hospital in the Free State province, South Africa. *In Obstetrics and Gynaecology Forum*, 30(1):14–18.

Barrio-Lopez, M.T., Martinez-Gonzalez, M.A., Fernandez-Montero, A., Beunza, J.J., Zazpe, I. and Bes-Rastrollo, M. (2013). Prospective study of changes in sugar-sweetened beverage consumption and the incidence of the metabolic syndrome and its components: the SUN cohort. *British Journal of Nutrition*, 110(9):1722–1731.

Basciano, H., Federico, L. and Adeli, K. (2005). Fructose, insulin resistance, and metabolic dyslipidemia. *Nutrition and Metabolism*, 2(1):11–4.

Biadgo, B., Melak, T., Ambachew, S., Baynes, H.W., Limenih, M.A., Jaleta, K.N., Tachebele, B., Melku, M. and Abebe, M. (2018). The prevalence of metabolic syndrome and its components among type 2 diabetes mellitus patients at a tertiary hospital, northwest Ethiopia. *Ethiopian Journal of Health Sciences*, 28(5): 645–654.

Blaton, V. (2007). How is the metabolic syndrome related to the dyslipidemia? *The Journal of International Federation of Clinical Chemistry*, 18(1):15–22.

Bleich, S.N., Vercammen, K.A., Koma, J.W. and Li, Z. (2018). Trends in beverage consumption among children and adults, 2003-2014. *Obesity*, 26(2):432–441.

Boateng, D., Wekesah, F., Browne, J.L., Agyemang, C., Agyei-Baffour, P., Aikins, A.D.G., Smit, H.A., Grobbee, D.E. and Klipstein-Grobusch, K. (2017). Knowledge and awareness of and perception towards cardiovascular disease risk in sub-Saharan Africa: A systematic review. *PloS One*, 12(12):1–21.

Bralow, V. and Bralow, S. 2017. Sucrose, fructose, and glucose. Bralow Medical group. https://bralowmedicalgroup.com/sucrose-glucose-fructose/1-2. (Accessed 16 November 2020).

Brown, I.J., Stamler, J., Van Horn, L., Robertson, C.E., Chan, Q., Dyer, A.R., Huang, C.C., Rodriguez, B.L., Zhao, L., Daviglus, M.L. and Ueshima, H. (2011). Sugar-sweetened beverage, sugar intake of individuals, and their blood pressure: international study of macro/micronutrients and blood pressure. *Hypertension*, 57(4):695–701.

Brownbill, A.L., Miller, C.L. and Braunack-Mayer, A.J. (2018). The marketing of sugar-sweetened beverages to young people on Facebook. *Australian and New Zealand Journal of Public Health,* 42(4):354–360.

Buglass, A.J. (2014). Chemical composition of beverages and drinks. In Handbook of Food Chemistry: 1–62. Germany: Springer.

Busari, O.A., Olanrewaju, T.O., Desalu, O.O., Opadijo, O.G., Jimoh, A.K., Agboola, S.M., Busari, O.E. and Olalekan, O. (2010). Impact of patients and knowledge, attitude and practices on hypertension on compliance with antihypertensive drugs in a resource-poor setting.*TAF-Preventive Medicine Bulletin*, 9(2):87–92.

Cerf, M.E. (2020). Beta Cell Physiological Dynamics and Dysfunctional Transitions in Response to Islet Inflammation in Obesity and Diabetes. *Metabolites*, 10(11):452.

Chen, L., Caballero, B., Mitchell, D.C., Loria, C., Lin, P.H., Champagne, C.M., Elmer, P.J., Ard, J.D., Batch, B.C., Anderson, C.A. and Appel, L.J. (2010). Reducing consumption of sugar-sweetened beverages is associated with reduced blood pressure: a prospective study among United States adults. *Circulation*, 121(22):2398–2406.

Chen, Y., Michalak, M. and Agellon, L.B. (2018). Focus: Nutrition and Food Science: Importance of Nutrients and Nutrient Metabolism on Human Health. *The Yale Journal of Biology and Medicine*, 91(2):95–103.

Choi, H.K. and Curhan, G. (2008). Soft drinks, fructose consumption, and the risk of gout in men: prospective cohort study. *BMJ*, 336(7639):309–312.

Clemens, R.A., Jones, J.M., Kern, M., Lee, S.Y., Mayhew, E.J., Slavin, J.L. and Zivanovic, S. (2016). Functionality of sugars in foods and health. *Comprehensive Reviews in Food Science and Food Safety*, 15(3):433–470.

Combs Jr, G.F., Trumbo, P.R., McKinley, M.C., Milner, J., Studenski, S., Kimura, T., Watkins, S.M. and Raiten, D.J. (2013). Biomarkers in nutrition: new frontiers in research and application. *Annals of the New York Academy of Sciences*, 1278(1):1.

Coon, K.A. and Tucker, K.L. (2002). Television and children's consumption patterns. *Minerva Pediatr*, 54(5):423– 436.

Cordain, L., Eaton, S.B., Sebastian, A., Mann, N., Lindeberg, S., Watkins, B.A., O'Keefe, J.H. and Brand-Miller, J. (2005). Origins and evolution of the Western diet: health implications for the 21st century. *The American Journal of Clinical Nutrition*, 81(2), 81(2):341–354.

Corella, D. and Ordovás, J.M. (2015). Biomarkers: background, classification and guidelines for applications in nutritional epidemiology. *Nutricion Hospitalaria*, 31(3):177–188.

D'Souza, A. and Jolliffe, D. (2013). Conflict, food price shocks, and food insecurity: The experience of Afghan households. *Food Policy*, 42:32–47.

Dalal, S., Beunza, J.J., Volmink, J., Adebamowo, C., Bajunirwe, F., Njelekela, M., Mozaffarian, D., Fawzi, W., Willett, W., Adami, H.O. and Holmes, M.D. (2011). Non-communicable diseases in sub-Saharan Africa: what we know now. *International Journal of Epidemiology*, 40(4):885–901.

de Koning, L., Malik, V.S., Rimm, E.B., Willett, W.C. and Hu, F.B. (2011). Sugar-sweetened and artificially sweetened beverage consumption and risk of type 2 diabetes in men. *The American Journal of Clinical Nutrition*, 93(6):1321–1327.

DeBoer, M.D. (2019). Assessing and managing the metabolic syndrome in children and adolescents. *Nutrients*, 11(8):1788.

DeMers, D. and Wachs, D. (2020). Physiology mean arterial pressure. StatPearls [Internet].

Dietary Guidelines for Americans (DGA) 2015–2020. Available online: http://health.gov/dietaryguidelines/2015/ guidelines/.(Accessed on 7 August 2019).

Dietary Reference Intakes. 2006. The Essential Guide to Nutrient Requirements http://www.nap.edu/catalog/11537.html. (Accesses 05 August 2020).

Dijkstra, M., Buijtels, H.E. and Van Raaij, W.F. (2005). Separate and joint effects of medium type on consumer responses: a comparison of television, print, and the Internet. *Journal of Business Research*, 58(3):377–386.

Ebbeling, C.B., Feldman, H.A., Chomitz, V.R., Antonelli, T.A., Gortmaker, S.L., Osganian, S.K. and Ludwig, D.S. (2012). A randomized trial of sugar-sweetened beverages and adolescent body weight. *New England Journal of Medicine*, 367:1407–1416.

Einarson, T.R., Acs, A., Ludwig, C. and Panton, U.H. (2018). Prevalence of cardiovascular disease in type 2 diabetes: a systematic literature review of scientific evidence from across the world in 2007–2017. *Cardiovascular Diabetology*, 17(1):1–19.

Emond, J.A., Sargent, J.D. and Gilbert-Diamond, D. (2015). Patterns of energy drink advertising over US television networks. *Journal of Nutrition Education and Behavior*, 47(2):20–126.

Essman, M., Taillie, L.S., Frank, T., Ng, S.W., Popkin, B.M. and Swart, E.C. (2021). Taxed and untaxed beverage intake by South African youth after a national sugar-sweetened beverage tax: A before-and-after study. *PLoS Medicine,* 18(5):e1003574.

Euromonitor International. 2015. Soft drinks in South Africa. Euromonitor Passport database. Available: Retrieved from: www. euromonitor.com. (Accessed 11 September, 2020).

Expert Panel on Detection, E. (2001). Executive summary of the third report of the National Cholesterol Education Program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (adult treatment panel III). *JAMA*, 285(19):2486–2497.

Faber, M. and Kruger, H.S. (2005). Dietary intake, perceptions regarding body weight, and attitudes toward weight control of normal weight, overweight, and obese black females in a rural village in South Africa. *Ethnicity and Diseases*, 15(2):238–245.

Faijer-Westerink, H.J., Kengne, A.P., Meeks, K.A. and Agyemang, C. (2020). Prevalence of metabolic syndrome in sub-Saharan Africa: A systematic review and meta-analysis. *Nutrition, Metabolism and Cardiovascular Diseases*, 30(4), :547–565.

Fan, H., Li, X., Zheng, L., Chen, X., Wu, H., Ding, X., Qian, D., Shen, Y., Yu, Z., Fan, L. and Chen, M. (2016). Abdominal obesity is strongly associated with Cardiovascular Disease and its Risk Factors in Elderly and very Elderly Community-dwelling Chinese. *Scientific Reports*, 6(1):1–9.

Feeley, A., Pettifor, J.M. and Norris, S.A. (2009). Fast-food consumption among 17-year-olds in the Birth to Twenty cohorts. *South African Journal of Clinical Nutrition*, 22(3):188–123.

Feig, D.I. (2012). The role of uric acid in the pathogenesis of hypertension in the young. *The Journal of Clinical Hypertension*, 14(6):346–352.

Feig, D.I., Kang, D.H. and Johnson, R.J. (2008). Uric acid and cardiovascular risk. *New England Journal of Medicine*, 359(17):1811–1821.

Feig, D.I., Kang, D.H., Nakagawa, T., Mazzali, M. and Johnson, R.J. (2006). Uric acid and hypertension. *Current Hypertension Reports*, 8(2):111–115.

Freedman, L.S., Commins, J.M., Moler, J.E., Arab, L., Baer, D.J., Kipnis, V., Midthune, D., Moshfegh, A.J., Neuhouser, M.L., Prentice, R.L. and Schatzkin, A. (2014). Pooled results from 5 validation studies of dietary self-report instruments using recovery biomarkers for energy and protein intake. *American Journal of Epidemiology,* 180(2):172–188.

Freedman, L.S., Commins, J.M., Moler, J.E., Willett, W., Tinker, L.F., Subar, A.F., Spiegelman, D., Rhodes, D., Potischman, N., Neuhouser, M.L. and Moshfegh, A.J. (2015). Pooled results from 5 validation studies of dietary self-report

instruments using recovery biomarkers for potassium and sodium intake. *American Journal of Epidemiology*, 181(7):473–487.

Gebreyes, Y.F., Goshu, D.Y., Geletew, T.K., Argefa, T.G., Zemedu, T.G., Lemu, K.A., Waka, F.C., Mengesha, A.B., Degefu, F.S., Deghebo, A.D. and Wubie, H.T. (2018). Prevalence of high bloodpressure, hyperglycemia, dyslipidemia, metabolic syndrome and their determinants in Ethiopia: Evidence from the National NCDs STEPS Survey, 2015. *PloS One*, 13(5):e0194819.

Goran, M.I.; Tappy, L.; Lê, K.A. (2015). Dietary Sugars and Health; CRC Press, Boca Raton, FL, USA: Taylor & Francis Group.

Gradidge, P.J.L. and Crowther, N.J. (2017). Metabolic syndrome in black South African women. *Ethnicity and Disease*, 27(2):189.

Grimes, C.A., Riddell, L.J., Campbell, K.J. and Nowson, C.A. (2013). Dietary salt intake, sugar-sweetened beverage consumption, and obesity risk. *Paediatrics*, 131(1), 14–21.

Grundy, S.M. (2008). Metabolic syndrome pandemic. *Arteriosclerosis, Thrombosis, and Vascular Biology,* 28(4):629–636.

Grundy, S.M., Cleeman, J.I., Bairey Merz, C.N., Brewer, H.B., Clark, L.T., Hunninghake, D.B., Pasternak, R.C., Smith, S.C., Stone, N.J. and Coordinating Committee of the National Cholesterol Education Program. (2004). Implications of recent clinical trials for the national cholesterol education program adult treatment panel III guidelines. *Journal of the American College of Cardiology*, 44(3):20–732.

Gupta, R., Gupta, N. and Khedar, R.S. (2013). Smokeless tobacco and cardiovascular disease in low- and middle-income countries. *Indian Heart Journal*, 65(4):369–377.

Guran T, Bekeret A. International epidemic of childhood obesity and television viewing. (2011). *Minerva Pediatrica*, 63:483–90.

Hall, K.D., Heymsfield, S.B., Kemnitz, J.W., Klein, S., Schoeller, D.A. and Speakman, J.R. (2012). Energy balance and its components: implications for

body weight regulation. *The American Journal of Clinical Nutrition*, 95(4), 989–994.

Harrington, D. (2009). *Confirmatory factor analysis*. Oxford University Press:3–21.

Haslam, D.E., Peloso, G.M., Herman, M.A., Dupuis, J., Lichtenstein, A.H., Smith, C.E. and McKeown, N.M. (2020). Beverage consumption and longitudinal changes in lipoprotein concentrations and incident dyslipidemia in US adults: the Framingham heart study. *Journal of the American Heart Association,* 9(5):e014083.

He, F.J. and MacGregor, G.A. (2007). Salt, blood pressure and cardiovascular disease. *Current Opinion in Cardiology*, 22(4):298–305.

He, F.J., Marrero, N.M. and MacGregor, G.A. (2008). Salt intake is related to soft drink consumption in children and adolescents: a link to obesity?. *Hypertension*, 51(3), 629–634.

Herman, M.A. and Samuel, V.T. (2016). The sweet path to metabolic demise: fructose and lipid synthesis. *Trends in Endocrinology and Metabolism*, 27(10):719–730.

Hernández-F, M., Figueroa, J.L. and Colchero, M.A. (2021). Association between density of stores and purchases of ultra-processed food and sugar-sweetened beverages in Mexico. *Health and Place*, 68:102528.

Heymsfield, S.B. and Cefalu, W.T. (2013). Does body mass index adequately convey a patient's mortality risk?. *Jama*, 309(1):87–88.

Higashi, Y., Noma, K., Yoshizumi, M. and Kihara, Y. (2009). Endothelial function and oxidative stress in cardiovascular diseases. *Circulation Journal*, 73(3):411–418.

Hirode, G. and Wong, R.J. (2020). Trends in the prevalence of metabolic syndrome in the United States, 2011-2016. *Jama*, 323(24):2526–2528.

Hoebel, S., Malan, L. and De Ridder, J.H. (2013). Determining ethnic-, gender-, and age-specific waist circumference cut-off points to predict metabolic syndrome: the Sympathetic Activity and Ambulatory Blood Pressure in Africans (SABPA) study. *Journal of Endocrinology, Metabolism and Diabetes in South Africa*, 18(2):88–96.

Hu, F.B. (2013). Resolved: there is sufficient scientific evidence that decreasing sugar-sweetened beverage consumption will reduce the prevalence of obesity and obesity-related diseases. *Obesity Reviews*, 14(8):606–619.

Hu, L.T. and Bentler, P.M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural equation modeling: *A Multidisciplinary Journal*, 6(1):1–55.

Imamura, F., O'Connor, L., Ye, Z., Mursu, J., Hayashino, Y., Bhupathiraju, S.N. and Forouhi, N.G. (2015). Consumption of sugar sweetened beverages, artificially sweetened beverages, and fruit juice and incidence of type 2 diabetes: systematic review, meta-analysis, and estimation of population attributable fraction. *BMJ*, 351:h3576.

Imamura, F., Schulze, M.B., Sharp, S.J., Guevara, M., Romaguera, D., Bendinelli, B., Salamanca-Fernández, E., Ardanaz, E., Arriola, L., Aune, D. and Boeing, H. (2019). Estimated substitution of tea or coffee for sugar-sweetened beverages was associated with lower type 2 diabetes incidence in case–cohort analysis across 8 European Countries in the EPIC-InterAct Study. *The Journal of Nutrition*, 149(11):1985–1993.

Inaishi, J. and Saisho, Y. (2020). Beta-Cell Mass in Obesity and Type 2 Diabetes, and Its Relation to Pancreas Fat: A Mini-Review. *Nutrients*, 12(12):3846.

Jaffer, N., Steyn, N.P. and Peer, N. (2011). Dietary data from the CRIBSA study. Unpublished Master's thesis. University o Cape Town. Cape Town.

Jiang, X., Zhang, D. and Jiang, W. (2014). Coffee and caffeine intake and incidence of type 2 diabetes mellitus: a meta-analysis of prospective studies. *European Journal of Nutrition,* 53(1):25–38.

Johnson, R.K., Appel, L.J., Brands, M., Howard, B.V., Lefevre, M., Lustig, R.H., Sacks, F., Steffen, L.M. and Wylie-Rosett, J. (2009). Dietary sugars intake and cardiovascular health: a scientific statement from the American Heart Association. *Circulation*, 120(11):1011–1020.

Jongen, V.W., Lalla-Edward, S.T., Vos, A.G., Godijk, N.G., Tempelman, H., Grobbee, D.E., Devillé, W. and Klipstein-Grobusch, K. (2019). Hypertension in a

rural community in South Africa: what they know, what they think they know and what they recommend. *BMC Public Health*, 19(1):1–10.

Kaiser, K.A., Shikany, J.M., Keating, K.D. and Allison, D.B. (2013). Will reducing sugar-sweetened beverage consumption reduce obesity? Evidence supporting conjecture is strong, but evidence when testing effect is weak. *Obesity Reviews*, 14(8):620–633.

Kassi, E., Pervanidou, P., Kaltsas, G. and Chrousos, G. (2011). Metabolic syndrome: definitions and controversies. *BMC Medicine*, 9(1):1–13.

Kelly, T., Yang, W., Chen, C.S., Reynolds, K. and He, J. (2008). Global burden of obesity in 2005 and projections to 2030. *International Journal of Obesity*, 32(9):1431–1437.

Kenny, D.A. (2012). Multiple latent variable models: Confirmatory factor analysis. Retrieved from: http://davidkenny.net>mfactor. (Accessed 2 January 2021).

Kent, J.A. 2007. Sugar and other sweeteners. In Kent and Riegel's Handbook of Industrial Chemistry and Biotechnology. 11th edition. Springer, Boston, MA:1657–1693.

Kéry, M. and Royle, J.A. (2016). Chapter 6-Modeling abundance with counts of unmarked individuals in closed populations: Binomial N-mixture models. *Applied Hierarchical Modeling in Ecology*:293–312.

Khine, A.A. and Marais, A.D. (2016). High prevalence of primary dyslipidaemia in black South African patients at a tertiary hospital in northern Gauteng, South Africa. *South African Medical Journal*, 106(7):724–729.

Kim, Y.H., Abris, G.P., Sung, M.K. and Lee, J.E. (2012). Consumption of sugar-sweetened beverages and blood pressure in the United States: the national health and nutrition examination survey 2003-2006. *Clinical Nutrition Research*, 1(1):85–93.

Kipnis, V., Subar, A.F., Midthune, D., Freedman, L.S., Ballard-Barbash, R., Troiano, R.P., Bingham, S., Schoeller, D.A., Schatzkin, A. and Carroll, R.J. (2003). Structure of dietary measurement error: results of the OPEN biomarker study. *American Journal of Epidemiology*, 158(1):14–21.

Knopp, R.H., Paramsothy, P., Retzlaff, B.M., Fish, B., Walden, C., Dowdy, A., Tsunehara, C., Aikawa, K. and Cheung, M.C. (2005). Gender differences in lipoprotein metabolism and dietary response: basis in hormonal differences and implications for cardiovascular disease. *Current Atherosclerosis Reports*, 7(6):472–479

Komnenov, D., Levanovich, P.E. and Rossi, N.F. (2019). Hypertension associated with fructose and high salt: renal and sympathetic mechanisms. *Nutrients*, 11(3):569.

Koo, W.W. and Taylor, R.D. (2012). *2012 Outlook of the US and World Sugar Markets, 2011-2021* (No. 1187-2016-93538).

Kopp, W. (2019). How western diet and lifestyle drive the pandemic of obesity and civilization diseases. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy*, 12:2221–2236.

Kruger, M.J. and Nell, T.A. (2017). The prevalence of the metabolic syndrome in a farm worker community in the Boland district, South Africa. *BMC Public Health*, 17(1):1-10.

Kuk, J.L. and Ardern, C.I. (2010). Age and sex differences in the clustering of metabolic syndrome factors: association with mortality risk. *Diabetes Care*, 33(11):2457–2461.

Kumar, G., Onufrak, S., Zytnick, D., Kingsley, B. and Park, S. (2015). Self-reported advertising exposure to sugar-sweetened beverages among US youth. *Public Health Nutrition*, 18(7):1173–1179.

Kuriyan, R. (2018). Body composition techniques. *The Indian Journal of Medical Research*, 148(5):648.

Lim, S.S., Vos, T., Flaxman, A.D., Danaei, G., Shibuya, K., Adair-Rohani, H., AlMazroa, M.A., Amann, M., Anderson, H.R., Andrews, K.G. and Aryee, M., (2012). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *The Lancet*, 380(9859):2224–2260.

Liu, S., Manson, J.E., Buring, J.E., Stampfer, M.J., Willett, W.C. and Ridker, P.M. (2002). Relation between a diet with a high glycaemic load and plasma concentrations of high-sensitivity C-reactive protein in middle-aged women. *The American Journal of Clinical Nutrition*, 75(3):492–498.

Louwrens, H., Venter, I. and Otty, C. (2010). Soft drink consumption of Grade 4 and Grade 7 learners in the Wynberg area, City of Cape Town, South Africa and the factors influencing the consumption. *Journal of Consumer Sciences*, 38:1–11.

Luo, Y., Ma, X., Shen, Y., Xu, Y., Xiong, Q., Zhang, X., Xiao, Y., Bao, Y. and Jia, W. (2017). Neck circumference as an effective measure for identifying cardio-metabolic syndrome: a comparison with waist circumference. *Endocrine*, 55(3):822–830.

Lustig, R.H., Schmidt, L.A. and Brindis, C.D. (2012). The toxic truth about sugar. *Nature*, 482(7383):27–29.

MacIntyre, U.E., Venter, C.S., Kruger, A. and Serfontein, M. (2012). Measuring micronutrient intakes at different levels of sugar consumption in a population in transition: the Transition and Health during Urbanisation in South Africa (THUSA) study. *South African Journal of Clinical Nutrition*, 25(3):22–130. `

Malik, V.S., Popkin, B.M., Bray, G.A., Després, J.P., Willett, W.C. and Hu, F.B. (2010). Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: a meta-analysis. *Diabetes Care*, 33(11):2477–2483.

Malik, V.S. and Hu, F.B. (2012). Sweeteners and risk of obesity and type 2 diabetes: the role of sugar-sweetened beverages. *Current Diabetes Reports*, 12(2):195–203.

Malik, V.S., Pan, A., Willett, W.C. and Hu, F.B. (2013). Sugar-sweetened beverages and weight gain in children and adults: a systematic review and meta-analysis. *The American Journal of Clinical Nutrition*, 98(4):1084–1102.

Malik, A.H., Akram, Y., Shetty, S., Malik, S.S. and Njike, V.Y. (2014). Impact of sugar-sweetened beverages on blood pressure. *The American Journal of Cardiology*, 113(9):1574–1580.

Malik, V.S. and Hu, F.B. (2019). Sugar-sweetened beverages and cardiometabolic health: an update of the evidence. *Nutrients*, 11(8):1840.

Manyema, M., Veerman, L.J., Chola, L., Tugendhaft, A., Sartorius, B., Labadarios, D. and Hofman, K.J. (2014). The potential impact of a 20% tax on sugar-sweetened beverages on obesity in South African adults: a mathematical model. *Plos One*, 9(8):e105287.

Manyema, M., Veerman, L.J., Tugendhaft, A., Labadarios, D. and Hofman, K.J. (2016). Modelling the potential impact of a sugar-sweetened beverage tax on stroke mortality, costs and health-adjusted life years in South Africa. *BMC Public Health*, 16(1):1–10.

Maris, M.E., Melchert, R.B., Joseph, J. and Kennedy, R.H. (2005). Gender differences in blood pressure and heart rate in spontaneously hypertensive and Wistar-Kyoto rats. *Clinical and Experimental Pharmacology and Physiology,* 32(1-2):35–39.

Medical Research Council-Technical report. 2006. Available at: www.mrc.ac.za/noncomm/cdl1995-2005.pdf. (Accessed 14 February 2020).

Mirmiran, P., Yuzbashian, E., Asghari, G., Hosseinpour-Niazi, S. and Azizi, F. (2015). Consumption of sugar sweetened beverage is associated with the incidence of metabolic syndrome in Tehranian children and adolescents. *Nutrition and Metabolism*, 12(1):1–9.

Mishra, P., Pandey, C.M., Singh, U., Gupta, A., Sahu, C. and Keshri, A. (2019). Descriptive statistics and normality tests for statistical data. *Annals of Cardiac Anaesthesia*, 22(1):67.

Misra, A. and Khurana, L. (2008). Obesity and the metabolic syndrome in developing countries. *The Journal of Clinical Endocrinology and Metabolism*, 93:s9–s30.

Monyeki, K.D., Siweya, H.J., Kemper, H.C., Kengne, A.P., Musinguzi, G., Nkwana, M.R., Mothiba, T., Malatji, T., Baloyi, S.M.A., Malema, R. and Leach, L. (2020). The Relationship between Binge Drinking and Metabolic Syndrome Components amongst Youth Aged 21 to 31 Years: Ellisras Longitudinal

Study. *International Journal of Environmental Research and Public Health*, 17(20):7484.

Motala, A.A., Esterhuizen, T., Pirie, F.J. and Omar, M.A. (2011). The prevalence of metabolic syndrome and determination of the optimal waist circumference cutoff points in a rural South African community. *Diabetes Care*, 34(4):1032–1037.

Myers, J., Kokkinos, P. and Nyelin, E. (2019). Physical activity, cardiorespiratory fitness, and the metabolic syndrome. *Nutrients*, 11(7):1652.

Nakagawa, T., Tuttle, K.R., Short, R.A. and Johnson, R.J. (2005). Hypothesis: fructose-induced hyperuricemia as a causal mechanism for the epidemic of the metabolic syndrome*. Nature Clinical Practice Nephrology*, 1(2):80–86.

Narain, A., Kwok, C.S. and Mamas, M.A. (2017). Soft drink intake and the risk of metabolic syndrome: A systematic review and meta-analysis. *International Journal of Clinical Practice*, 71(2):e12927.

Naska, A., Lagiou, A. and Lagiou, P. (2017). Dietary assessment methods in epidemiological research: current state of the art and future prospects. *F1000Research*, 6:926.

Nel, J.H. and Steyn, N.P. (2002). Report on South African food consumption studies undertaken amongst different population groups (1983-2000): average intakes of foods most commonly consumed. Department of Health.

Niaz, K., Khan, F. and Shah, M.A. (2020). Analysis of carbohydrates (monosaccharides, polysaccharides). *In Recent Advances in Natural Products Analysis*:621–633.

Nnyepi, M.S., Gwisai, N., Lekgoa, M. and Seru, T. (2015). Evidence of nutrition transition in Southern Africa. *Proceedings of the Nutrition Society*, 74(4).478–486.

Nolan, P.B., Carrick-Ranson, G., Stinear, J.W., Reading, S.A. and Dalleck, L.C. (2017). Prevalence of metabolic syndrome and metabolic syndrome components in youth: A pooled analysis. *Preventive Medicine Reports*, 7:211–215.

Ntusi, N. (2018). Dyslipidaemia in South Africa. SAMJ: *South African Medical Journal*, 108(4):256–257.

Okop, K.J., Lambert, E.V., Alaba, O., Levitt, N.S., Luke, A., Dugas, L., Dover, R.V.H., Kroff, J., Micklesfield, L.K., Kolbe-Alexander, T.L. and Warren, S. (2019). Sugar-sweetened beverage intake and relative weight gain among South African adults living in resource-poor communities: longitudinal data from the STOP-SA study. *International Journal of Obesity*, 43(3):603–614.

Okop, K.J., Mukumbang, F.C., Mathole, T., Levitt, N. and Puoane, T. (2016). Perceptions of body size, obesity threat and the willingness to lose weight among black South African adults: a qualitative study. *BMC Public Health*, 16(1):1–13.

Oldewage-Theron, W. and Egal, A. (2018). The effect of consumption of soy foods on metabolic syndrome in women: a case study from peri-urban Qwa-Qwa, South Africa. *South African Journal of Clinical Nutrition*, 1(1):1–6.

Owolabi, E.O., Ter Goon, D., Adeniyi, O.V., Adedokun, A.O. and Seekoe, E. (2017). Prevalence and correlates of metabolic syndrome among adults attending healthcare facilities in Eastern Cape, South Africa. *The Open Public Health Journal*, 10(1):148–159.

Pan, A., Malik, V.S., Hao, T., Willett, W.C., Mozaffarian, D. and Hu, F.B. (2013). Changes in water and beverage intake and long-term weight changes: results from three prospective cohort studies. *International Journal of Obesity*, 37(10):1378–1385.

Parikh, R.M. and Mohan, V. (2012). Changing definitions of metabolic syndrome. *Indian Journal of Endocrinology and Metabolism*, 16(1):7.

Park, Y.W., Zhu, S., Palaniappan, L., Heshka, S., Carnethon, M.R. and Heymsfield, S.B. (2003). The metabolic syndrome: prevalence and associated risk factor findings in the US population from the Third National Health and Nutrition Examination Survey, 1988-1994. *Archives of Internal Medicine*, 163(4):427–436.

Patil, C., Deshmukh, J., Yadav, S., Patil, S. and Sheikh, A. (2017). Neck circumference: A novel anthropometric tool for screening obesity in adults. *International Journal of Collaborative Research on Internal Medicine and Public Health*, 9(7):711–720.

Peer, N., Lombard, C., Steyn, K. and Levitt, N. (2015). High prevalence of metabolic syndrome in the Black population of Cape Town: the Cardiovascular Risk in Black South Africans (CRIBSA) study. *European Journal of Preventive Cardiology*, 22(8):1036–1042.

Peer, N., Steyn, K. and Levitt, N. (2016). Differential obesity indices identify the metabolic syndrome in Black men and women in Cape Town: the CRIBSA study. *Journal of Public Health*, 38(1):175–182.

Pepin, A., Stanhope, K.L. and Imbeault, P. (2019). Are fruit juices healthier than sugar-sweetened beverages? A review. *Nutrients*, 11(5):1006.

Pérez-Chirinos Buxadé, C., Solà-Perez, T., Castizo-Olier, J., Carrasco-Marginet, M., Roy, A., Marfell-Jones, M. and Irurtia, A. (2018). Assessing subcutaneous adipose tissue by simple and portable field instruments: Skinfolds versus A-mode ultrasound measurements. *PLoS One*, 13(11):e0205226.

Pérez-Martínez, P., Mikhailidis, D.P., Athyros, V.G., Bullo, M., Couture, P., Covas, M.I., de Koning, L., Delgado-Lista, J., Díaz-López, A., Drevon, C.A. and Estruch, R. (2017). Lifestyle recommendations for the prevention and management of metabolic syndrome: an international panel recommendation. *Nutrition Reviews*, 75(5):307–326.

Pheiffer, C., Pillay-van Wyk, V., Joubert, J.D., Levitt, N., Nglazi, M.D. and Bradshaw, D. (2018). The prevalence of type 2 diabetes in South Africa: a systematic review protocol. *BMJ Open*, 8(7):e021029.

Pienovi, L., Bustos, P. and Amigo, H. (2018). Certain Selected Sugar-Sweetened Beverages and Metabolic Syndrome. *Nutrition Today*, 53(6):300–305.

Pladevall, M., Singal, B., Williams, L.K., Brotons, C., Guyer, H., Sadurni, J., Falces, C., Serrano-Rios, M., Gabriel, R., Shaw, J.E. and Zimmet, P.Z. (2006). A

single factor underlies the metabolic syndrome: a confirmatory factor analysis. *Diabetes Car*e, 29(1):113–122.

Poppitt, S.D. (2015). Beverage consumption: are alcoholic and sugary drinks tipping the balance towards overweight and obesity? *Nutrients*, 7(8):6700–6718.

Pucci, G., Alcidi, R., Tap, L., Battista, F., Mattace-Raso, F. and Schillaci, G. (2017). Sex-and gender-related prevalence, cardiovascular risk and therapeutic approach in metabolic syndrome: A review of the literature. *Pharmacological Research*, 120:34–42.

Puoane, T., Steyn, K., Bradshaw, D., Laubscher, R., Fourie, J., Lambert, V. and Mbananga, N. (2002). Obesity in South Africa: the South African demographic and health survey. *Obesity Research*, 10(10):1038–1048.

Richette, and Bardin, T. (2009). Gout. The Lancet. https://www.thelancet.com › lancet › article › fulltext. (Accessed 15 September 2019).

Richette, P., Perez-Ruiz, F., Doherty, M., Jansen, T.L., Nuki, G., Pascual, E., Punzi, L., So, A.K. and Bardin, T. (2014). Improving cardiovascular and renal outcomes in gout: what should we target? *Nature Reviews Rheumatology*, 10(11):654–661.

Ridker, P.M., Buring, J.E., Cook, N.R. and Rifai, N. (2003). C-reactive protein, the metabolic syndrome, and risk of incident cardiovascular events: an 8-year follow-up of 14 719 initially healthy American women. *Circulation*, 107(3):391–397.

Rodrigues, M.N., Silva, S.C.D., Monteiro, W.D. and Farinatti, P.D.T.V. (2001). Comparison of body fat estimation by bioelectric impedance, skinfold thickness, and underwater weighing*. Revista Brasileira De Medicina Do Esporte*, 7(4):125–131.

Ronquest-Ross, L.C., Vink, N. and Sigge, G.O. (2015). Food consumption changes in South Africa since 1994. *South African Journal of Science*, 111(9-10):01–12.

Rudd, R. (2010). Sugary drink facts: Evaluating sugary drink nutrition and marketing to youth. Centre

http://www.sugarydrinkfacts.org/resources/SugaryDrinkFACTS_Report.pdf (Accessed 12 December 2020).

Ruel, M.T., Garrett, J.L., Hawkes, C. and Cohen, M.J. (2010). The food, fuel, and financial crises affect the urban and rural poor disproportionately: a review of the evidence. *The Journal of Nutrition*, 140(1):170S–176S.

Saka, M., Türker, P., Ercan, A., Kızıltan, G. and Baş, M. (2014). Is neck circumference measurement an indicator for abdominal obesity? A pilot study on Turkish Adults. *African Health Sciences*, 14(3):5705–75.

Saklayen, M.G. (2018). The global epidemic of the metabolic syndrome. *Current Hypertension Reports*, 20(2):1–8.

Scapin, T., Fernandes, A.C. and Proença, R.P.D.C. (2017). Added sugars: Definitions, classifications, metabolism, and health implications. *Revista de Nutrição*, 30:663–677.

Schatzkin, A., Kipnis, V., Carroll, R.J., Midthune, D., Subar, A.F., Bingham, S., Schoeller, D.A., Troiano, R.P. and Freedman, L.S. (2003). A comparison of a food frequency questionnaire with a 24-hour recall for use in an epidemiological cohort study: results from the biomarker-based Observing Protein and Energy Nutrition (OPEN) study. *International Journal of Epidemiology,* 32(6):1054–1062.

Schröder, H., Morales-Molina, J.A., Bermejo, S., Barral, D., Mándoli, E.S., Grau, M., Guxens, M., de Jaime Gil, E., Álvarez, M.D. and Marrugat, J. (2007). Relationship of abdominal obesity with alcohol consumption at population scale. *European Journal of Nutrition*, 46(7):369–376.

Sekgala, M.D., Monyeki, K.D., Mogale, A., Mchiza, Z.J., Parker, W., Choma, S.R. and Makgopa, H.M. (2018). The risk of metabolic syndrome as a result of lifestyle among Ellisras rural youth. *Journal of Human Hypertension*, 32(8):572–584.

Sen, J. and Mondal, N. (2013). Fat mass and fat-free mass as indicators of body composition among Bengalee Muslim children. *Annals of Human Biology*, 40(3):286–293.

Seo, E.H., Kim, H. and Kwon, O. (2019). Association between total sugar intake and metabolic syndrome in middle-aged Korean men and women. *Nutrients*, 11(9):2042.

Sesso, H.D., Stampfer, M.J., Rosner, B., Hennekens, C.H., Gaziano, J.M., Manson, J.E. and Glynn, R.J. (2000). Systolic and diastolic blood pressure, pulse pressure, and mean arterial pressure as predictors of cardiovascular disease risk in men. *Hypertension*, 36(5):801–807.

Shim, J.S., Oh, K. and Kim, H.C. (2014). Dietary assessment methods in epidemiologic studies. *Epidemiology and Health*, 36:e2014009

Shin, S., Kim, S.A., Ha, J. and Lim, K. (2018). Sugar-sweetened beverage consumption in relation to obesity and metabolic syndrome among Korean adults: a cross-sectional study from the 2012–2016 Korean national health and nutrition examination survey (KNHANES). *Nutrients*, 10(10):1467.

Shrestha, N. (2018). Neck circumference as an indicator of overweight and obesity in youth. *American Journal of Applied Mathematics and Statistics*, 6(5):176–180.

Singh, G.M., Micha, R., Khatibzadeh, S., Shi, P., Lim, S., Andrews, K.G., Engell, R.E., Ezzati, M., Mozaffarian, D. and Global Burden of Diseases Nutrition and Chronic Diseases Expert Group (NutriCoDE). (2015). Global, regional, and national consumption of sugar-sweetened beverages, fruit juices, and milk: a systematic assessment of beverage intake in 187 countries. *PloS One*, 10(8): e0124845.

Slagter, S.N., van Vliet-Ostaptchouk, J.V., Vonk, J.M., Boezen, H.M., Dullaart, R.P., Kobold, A.C.M., Feskens, E.J., van Beek, A.P., M van derKlauw, M. and Wolffenbuttel, B.H. (2013). Associations between smoking, components of metabolic syndrome and lipoprotein particle size. *BMC Medicine*, 11(1):1–15.

Solomi, L., Rees, G.A. and Redfern, K.M. (2019). The acute effects of the non-nutritive sweetener's aspartame and acesulfame-K in UK diet cola on glycaemic response. *International Journal of Food Sciences and Nutrition*, 70(7):894–900.

Solomon, S. and Mulugeta, W. (2019). Disease burden and associated risk factors for metabolic syndrome among adults in Ethiopia. *BMC Cardiovascular Disorders*, 19(1):1–8.

Sorrie, M.B., Yesuf, M.E. and GebreMichael, T.G. (2017). Overweight/obesity and associated factors among preschool children in Gondar City, Northwest Ethiopia: a cross-sectional study. *PloS One*, 12(8):e0182511.

South Africa Information, (1999/2015). South African Languages and Culture (SALC). Available at: https://www.sa-venues.com/sa_languages_and_culture.htm (Accessed on 17 March 2020).

Stančáková, A. and Laakso, M. (2014). Genetics of metabolic syndrome. *Reviews in Endocrine and Metabolic Disorders*, 15(4): 243–252.

Stanhope, K.L. and Havel, P.J. (2008). Endocrine and metabolic effects of consuming beverages sweetened with fructose, glucose, sucrose, or high-fructose corn syrup. *The American Journal of Clinical Nutrition*, 88(6): 733S–1737S.

Steyn, N.P., Mchiza, Z., Hill, J., Davids, Y.D., Venter, I., Hinrichsen, E., Opperman, M., Rumbelow, J. and Jacobs, P. (2014). Nutritional contribution of street foods to the diet of people in developing countries: a systematic review. *Public Health Nutrition*, 17(6):1363–1374.

Steyn, N.P., Myburgh, N.G. and Nel, J.H. (2003). Evidence to support a food-based dietary guideline on sugar consumption in South Africa. *Bulletin of the World Health Organization,* 81:599–608.

Sumner, A.E., Zhou, J., Doumatey, A., Imoisili, O.E., Amoah, A., Acheampong, J., Oli, J., Johnson, T., Adebamowo, C. and Rotimi, C.N. (2010). Low HDL-cholesterol with normal triglyceride levels is the most common lipid pattern in West Africans and African Americans with metabolic syndrome: implications for cardiovascular disease prevention. *CVD Prevention and Control*, 5(3):75–80.

Sun, K., Liu, J. and Ning, G. (2012). Active smoking and risk of metabolic syndrome: a meta-analysis of prospective studies. *Plos One*, 7(10):e47791.

Sun, S.Z. and Empie, M.W. (2012). Fructose metabolism in humans–what isotopic tracer studies tell us. *Nutrition and Metabolism*, 9(1):1–15.

Szalay, J. 2017. What are carbohydrates? From - Live Science. https://www.livescience.com › topics › carbohydrates. (Accessed 12 May 2021).

Tal, S., Litovchik, I., Klar, M.M., Maresky, H.S., Grysman, N., Wiser, I., Vitkon-Barkay, I., Marcus, G., Tzuman, O., Pereg, D. and Rum, V. (2019). The association between neck adiposity and long-term outcome. *PloS One*, 14(4):e0215538.

Tang, W., Miller, M.B., Rich, S.S., North, K.E., Pankow, J.S., Borecki, I.B., Myers, R.H., Hopkins, P.N., Leppert, M. and Arnett, D.K. (2003). Linkage analysis of a composite factor for multiple metabolic syndrome: the National Heart, Lung, and Blood Institute Family Heart Study. *Diabetes*, 52(11):2840–2847.

Tappy, L. and Rosset, R. (2017) Fructose metabolism from a functional perspective: implications for athletes. *Sports Medicine*, 47(1):23–32.

Taylor, B., Irving, H.M., Baliunas, D., Roerecke, M., Patra, J., Mohapatra, S. and Rehm, J. (2009). Alcohol and hypertension: gender differences in dose–response relationships determined through systematic review and meta-analysis. *Addiction*, 104(12):1981–1990.

Teff, K.L., Grudziak, J., Townsend, R.R., Dunn, T.N., Grant, R.W., Adams, S.H., Keim, N.L., Cummings, B.P., Stanhope, K.L. and Havel, P.J. (2009). Endocrine and metabolic effects of consuming fructose-and glucose-sweetened beverages with meals in obese men and women: influence of insulin resistance on plasma triglyceride responses. *The Journal of Clinical Endocrinology and Metabolism*, 94(5):1562–1569.

Temple, N.J. and Steyn, N.P. (2013). Sugar and health: a food-based dietary guideline for South Africa. *South African Journal of Clinical Nutrition*, 26:S100–S104.

Tey, S.L., Salleh, N.B., Henry, J. and Forde, C.G. (2017). Effects of aspartame-, monk fruit-, stevia-and sucrose-sweetened beverages on postprandial

glucose, insulin and energy intake. *International Journal of Obesity*, 41(3):450–457.

Tomita, T. (2016). Apoptosis in pancreatic β-islet cells in Type 2 diabetes. *Bosnian Journal of Basic Medical Sciences*, 16(3):162.

Trivedi, T., Liu, J., Probst, J.C. and Martin, A.B. (2013). The metabolic syndrome: are rural residents at increased risk? *The Journal of Rural Health*, 29(2):188–197.

Tugendhaft, A., Manyema, M., Veerman, L.J., Chola, L., Labadarios, D. and Hofman, K.J. (2016). Cost of inaction on sugar-sweetened beverage consumption: implications for obesity in South Africa. *Public Health Nutrition*, 19(13):2296–2304.

Turi, T.C., Codogno, J.S., Fernandes, R.A. and Monteiro, H.L. (2016). Low levels of physical activity and metabolic syndrome: cross-sectional study in the Brazilian public health system. *Ciência and Saúde Coletiva*, 21(4):1043–1050.

Van Beek, J.H., Kirkwood, T.B. and Bassingthwaighte, J.B. (2016). Understanding the physiology of the ageing individual: computational modelling of changes in metabolism and endurance. *Interface Focus*, 6(2):20150079.

Vedel, A.G., Holmgaard, F., Rasmussen, L.S., Paulson, O.B., Thomsen, C., Danielsen, E.R., Langkilde, A., Goetze, J.P., Lange, T., Ravn, H.B. and Nilsson, J.C. (2016). Perfusion Pressure Cerebral Infarct (PPCI) trial-the importance of mean arterial pressure during cardiopulmonary bypass to prevent cerebral complications after cardiac surgery: study protocol for a randomised controlled trial. *Trials*, 17(1):1–11.

Vorster, H.H., Kruger, A., Wentzel-Viljoen, E., Kruger, H.S. and Margetts, B.M. (2014). Added sugar intake in South Africa: findings from the Adult Prospective Urban and Rural Epidemiology cohort study. *The American Journal of Clinical Nutrition,* 99(6):479–1486.

Wagner, D.R. and Heyward, V.H. (1999). Techniques of body composition assessment: a review of laboratory and field methods. *Research Quarterly for Exercise and Sport*, 70(2):135–149.

Weeratunga, P., Jayasinghe, S., Perera, Y., Jayasena, G. and Jayasinghe, S. (2014). Per capita sugar consumption and prevalence of diabetes mellitus–global and regional associations. *BMC Public Health*, 14(1):1–6.

Willer, C.J., Schmidt, E.M., Sengupta, S., Peloso, G.M., Gustafsson, S., Kanoni, S., Ganna, A., Chen, J., Buchkovich, M.L., Mora, S. and Beckmann, J.S. (2013). Discovery and refinement of loci associated with lipid levels. *Nature Genetics*, 45(11):1274.

World Health Organization. 2000. Global strategy for the prevention and control of noncommunicable diseases. Geneva. https://www.afro.who.int > site > default > files. (Accessed 27 May 2020).

World Health Organization. and Consultation, F.E. (2003). Diet, nutrition and the prevention of chronic diseases. *World Health Organ Tech Rep Ser*, 916:1–57.Retrieved from: http://whqlibdoc.who.int › trs › WHO_TRS_916. Accessed 18 February 2019).

World Health Organization. 2008. Global Health Observatory data. Cholesterol From:http://www.who.int/gho/ncd/risk_factors/cholesterol_prevalence/en/ (Accessed 12 May 2020).

World Health Organization. 2013. Global action plan for the prevention and control of noncommunicable diseases 2013-2020. From: https://www.who.int › Publications › i › item. (Accessed January 2021).

World Health Organization. 2017. South Africa country profile. Available from: http://www.who.int/nmh/countries/zaf_en.pdf?ua=1.(Accessed 12 April 2021).

World Health Organization. 2018b. Non communicable diseases. From: https://apps.who.int › iris › rest › bitstreams ›. (Accessed 16 June 2021).

World Health Organization(b). Obesity and overweight. Fact sheet. 2018. From: http://www.who.int/news-room/fact-sheets/detail/obesity-andoverweight. (Accessed 12 October 2019).

Wu, H.F., Tam, T., Jin, L., Lao, X.Q., Chung, R.Y.N., Su, X.F. and Zee, B. (2017). Age, gender, and socioeconomic gradients in metabolic syndrome: biomarker

evidence from a large sample in Taiwan, 2005–2013. *Annals of Epidemiology*, 27(5):315–322.

Xi, B., Huang, Y., Reilly, K.H., Li, S., Zheng, R., Barrio-Lopez, M.T., Martinez-Gonzalez, M.A. and Zhou, D. (2015). Sugar-sweetened beverages and risk of hypertension and CVD: a dose–response meta-analysis. *British Journal of Nutrition*, 113(5):709-717.

Yao, Q.M., Wang, B., An, X.F., Zhang, J.A. and Ding, L. (2018). Testosterone level and risk of type 2 diabetes in men: a systematic review and meta-analysis. *Endocrine Connections*, 7(1):220-231.

Zafar, U., Khaliq, S., Ahmad, H.U., Manzoor, S. and Lone, K.P. (2018). Metabolic syndrome: an update on diagnostic criteria, pathogenesis, and genetic links. *Hormones*, 17(3):299–313.

Zając-Gawlak, I., Pelclová, J., Groffik, D., Přidalová, M., Nawrat-Szołtysik, A., Kroemeke, A., Gába, A. and Sadowska-Krępa, E. (2021). Does physical activity lower the risk for metabolic syndrome: a longitudinal study of physically active older women. *BMC Geriatrics*, 21(1):1–9.

Zhang, P., Zhang, X., Brown, J., Vistisen, D., Sicree, R., Shaw, J. and Nichols, G. (2010). Global healthcare expenditure on diabetes for 2010 and 2030. *Diabetes Research and Clinical Practice,* 87(3):293–301.

Zheng, M., Allman-Farinelli, M., Heitmann, B.L. and Rangan, A. (2015). Substitution of sugar-sweetened beverages with other beverage alternatives: a review of long-term health outcomes. *Journal of the Academy of Nutrition and Dietetics*, 115(5):767–779.

Zimmet, P.Z. and Alberti, K.G.M. (2006). Introduction: Globalization and the non-communicable disease epidemic. *Obesity*, 14(1):1–3.

CHAPTER 3

RESEARCH METHODOLOGY

3.1. Introduction

3.2. Geographical area of the study

3.3. Sample methods and research design

3.4. Measurements

3.5. Quality control

3.6. Statistical analysis

3.7. References

3.1. INTRODUCTION

This chapter outlines the geographical area, sampling methods, and the research design of the study. Moreover, the discussion of the ethical approval issues, data collections measurements and procedures and finally the data analysis followed.

3.2. GEOGRAPHICAL AREA OF THE STUDY

Ellisras, currently known as Lephalale, is a deeply rural area in Limpopo Province, South Africa, located adjacent to Botswana borders. Ellisras has 42 settlements with estimated 140 240 people dwelling in and 43002 households (Lephalale Gov, 2018). The villages are approximately 70 km away from the Ellisras town (231 40S 271 44W). The main source of employment for Ellisras residents is the Matimba and Medupi electricity power station and Iscor coal mine, a smaller portion of the population is involved in education and civil service while the residual is involved in the rearing of cattle and subsistence farming (Lephalale Gov, 2018). Unemployment, poverty, and low life expectancy remain a dilemma in most South African rural areas with Ellisras being no exception (Bradshaw and Steyn, 2001; Lephalale Gov, 2018). The Ellisras area is located as shown in figure 3.2.1.

Figure 3.2.1: Limpopo Province map showing the location of the Ellisras (Lephalale) area and neighbouring places (HAD, 2015).

3.3. SAMPLING METHODS (POPULATION) AND STUDY DESIGN

The Ellisras Longitudinal Study (ELS) is a longitudinal study investigating the lifestyle factors and causes of non-communicable diseases, through continuous periodic surveys and standard data collection. The study focuses on Ellisras rural areas and its main objective is to identify non-communicable diseases in the area. The ELS was originally established in 1996 and the follow-up data which the current study used was collected in 2013 and 2015 November/December (Monyeki et al., 1999; Monyeki et al., 2000; Daniel et al., 2019). The ELS initially used a cluster sampling method to recruit the participants (Monyeki et al., 1999; Monyeki et al., 2000). In brief, 69 schools were randomly selected within the Ellisras area. The data collection was undertaken at 22 schools (10 pre-schools and 12 primary schools) where birth records of children were attained from the principals of each school. Only those records that were verified against health clinic records were used to determine the age of each potential participant (Monyeki et al., 1999; Monyeki et al., 2000). Each of the 22 selected schools was assigned a grade with the expectation that most of the children in a particular age category (3–10 years) would be found in that grade (Monyeki et al., 1999; Monyeki et al., 2000).

In this current cross-sectional study, which used a quantitative method, a total of 624 participants were recruited. Thirty-one (31) participants did not meet inclusion criteria thus were excluded and the exclusion criteria included: pregnant or lactating females, females on menstruation, those who did not fast before the blood collection, those with missing and incomplete values, those who failed to provide a consent form, and those on medication for diabetes, hypertension, and dyslipidaemia, those who exercised, consumed alcohol, or smoked prior to measurements. Most of the above factors were reported to have an impact on lipids profiles, for example, after meals, TG and lipids levels remain elevated for a couple of hours. On the other hand, pregnancy is associated with the fluctuation of cholesterol and TG levels across the trimesters (Saebra et al., 2015). Moreover, menstruation is associated with fluctuations in hormones which will ultimately affects lipids levels. The inclusion criteria consisted of all the participants who fall between the ages of 22 to 30 years old without the exclusion criteria mentioned above.

A total of 593 (301 females and 292 males) rural black youth aged 22-30 years enrolled.

The sample size (n= 593) was calculated using the STATA software programme at a statistical power of 0.95 based on a 5% margin of error and a MetS prevalence of 4.8% among the black South African population (Owolabi et al., 2017).

3.3.1. Ethical consideration

This study is a sub-study of the current ongoing ELS, and both the studies were granted ethical approval before the survey by the Turfloop Ethics Research Committee of the University of Limpopo, (Project number: TREC/323/2017:IR ELS and the current study, project identification (ID): TREC/97/2020: PG). School principals and Tribal authorities granted permission to use school halls or community halls for all the data collection periods. The Witpoort Hospital also granted permission to store blood samples after their collection. Medical Science Unit, Department of Pathology and Medical Science laboratory at the University of Limpopo permitted to use the laboratory and for analysis of blood profile.

3.4. MEASUREMENTS

A detailed outline of the data collection procedures for the data collection has been previously described (Monyeki et al., 2002; Monyeki et al., 2008; Monyeki et al., 2009) and all measurements were done according to standard protocols using validated types of equipments and questionnaire. To ensure that the participants fully know and understand what is required of them, the principal investigator and trained field workers clearly explained all the measurement procedures.

3.4.1. Anthropometric measurements

All the anthropometric measurements were conducted by trained and experienced field workers on all the study participants using standard procedures set by the International Society for the Advancement of Kinanthropometry (ISAK) (Norton and Olds, 1996).

3.4.1.1. Body mass index (body weight and height)

The participants were asked to be in light clothing, without shoes and in an anatomic position (Monyeki et al., 1999). Weight was measured using a portable electronic scale (Precision Health Scale, A & D Company, Japan) to the nearest 0.1kg. Height was measured using a stadiometer on a standing position (Monyeki et al., 1999) with feet placed together, heels, buttocks and shoulders touching the vertical plane of the stadiometer (Leicester height 87 measure, Seca, Birmingham, UK). The headboard of the stadiometer was then lowered onto the head of the participants and measurements were taken to the nearest 0.1 cm. The BMI was determined using height (m^2) and weight (kg) values. BMI was calculated as weight (kg)/(height(m))^2. The BMI categories and cut off points are shown below in table 3.4.1.1.

Table 3.4.1.1: BMI categories and cut off points (Must et al., 1999).

BMI cut off points	BMI categories
<18 kg/m^2	Underweight
18.5-24.9 kg/m^2	Normal
30.0 kg/m^2	Overweight
>30.0 kg/m^2	Obese

3.4.1.2. Waist circumference

The WC was measured using a flexible steel tape (Lufkin, Cooper Tools, Apex NC, USA) to the nearest 0,1 cm, while participants were in light clothing and a standing position (Monyeki et al., 1999). The measurements were taken at the middle point between the lowest rib and iliac crest at the end of each gentle expiration (Monyeki et al., 1999, Anothaisintawee et al., 2019). The WC risk categories and cut-off are shown below in table 3.4.1.2.

Table 3.4.1.2: Waist circumference risk categories and cut-off points (WHO, 2008).

Metabolic Risk Category	Males: WC	Females: WC
Normal	</= 94 cm	</=80 cm
Increased risk	>94 cm	>80 cm
Greatly increased risk	>102 cm	>88 cm

3.4.1.3. Neck circumference

Neck circumference (NC) was taken with the use of a flexible tape (Delta surgical SA (PTY) Ltd., Johannesburg, Gauteng, South Africa) while the participants head was in a Frankfurt horizontal plane position (Luo et al., 2017). The measurements were taken to the nearest 0.1 cm in a standing position. The flexible tape was then placed perpendicular to the long axis of the neck and around the inferior margin of the below the Adams' apple in men having large Adam's apple (Patil et al., 2017). The cut-off points of NC are ≥37 cm for men and ≥34 cm for women (Saka et al., 2014).

3. 4.1.4. Waist to height ratio

The waist to height ratio (WHtR) was calculated by the division of WC (cm) by height. (m) (Hsieh and Yoshinaga, 1995; Yoo, 2016;). The WHtR cut off points was suggested to be 0.5 cm which can be applied to different genders and races (Ashwell et al., 2012; Yoo, 2016).

Table 3.4.1.4.1. Waist to height ratio classification and cut off points (Nedea, 2020).

WHtR Classification	Females	Males

Extremely slim	≤ 0.34	≤ 0.34
Slim	0.35 – 0.41	0.35 – 0.42
Healthy	0.42 – 0.48	0.43 – 0.52
Overweight	0.49 – 0.53	0.53 – 0.57
Very overweight	0.54 – 0.57	0.58 – 0.62
Obese	≥ 0.58	≥ 0.63

A. Neck circumference

B. Waist Circumference

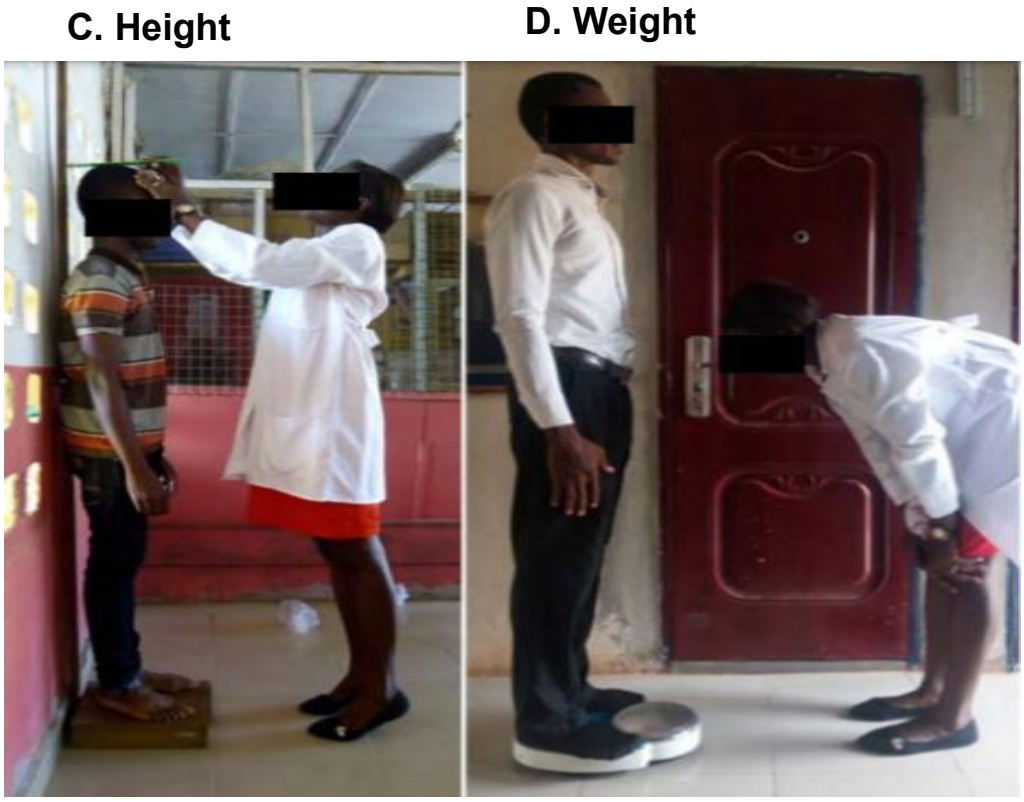

Figure 3.4.1.1: Anthropometric measurements (A, C, D, Jervas, 2018; B, www.shutterstock.com)

3.4.2. Blood pressure and mean arterial pressure

The SBP and DBP readings were taken after 5 minutes of rest, using an Omron electronic micronta (Omron Healthcare Europe B.V, Hoofddorp, Netherlands) monitoring kit (Monyeki et al., 2006). The bladder of the device contains an electronic infrasonic transducer that monitors the BP and pulse rate showing them on the screen at the same time (Monyeki et al., 2006). This versatile instrument has been designed for clinical purposes and research (Monyeki et al., 2006). To measure BP readings of a participant's the right arm was supported on a prop at a heart level in a relaxed position with an appropriate cuff size placed over the brachial artery of the right arm. The participants were seated with feet on the floor and the measurements were taken 3 times at a 5-minute interval. The average of three BP (SBP and DBP) readings were calculated. The MAP is the average of SBP and DBP

influenced by cardiac output and systematic vascular resistance throughout one cardiac cycle (Sesso et al., 2000). The MAP is an indication of blood pressure and was calculated using the following equation (Sesso et al., 2000):

MAP = DBP + 1/3 × (SBP − DBP). Blood pressure and MAP classifications are shown below in table 3.4.2.

Table 3.4.2: Blood pressure and mean arterial pressure definition and classification (Kundu et al., 2017).

Category	Systolic	Diastolic	MAP
Optimal	<120-129 and/or	<80	<93.33
Normal	120-139 and/or	80-84	93.33-99.00
High normal	130-139 and/or	85-89	99.01-105.67
Grade 1 hypertension	140-159 and/or	90-99	105.68-199.00
Grade 2 hypertension	≥160-179 and/or	100-109	199.01-132.33
Grade 3 hypertension	≥180 and/or	≥110	≥132.34
Isolated systolic hypertension	≥140 and/or	<90	-

Figure 3.4.2: Blood pressure measurements.

3.4.3. Biochemical samples collection and analysis

3.4.3.1. Biochemical samples collection procedures

Participants were asked to fast for 8-10 hours before blood collection in the morning. Blood samples were collected by registered nurses from the Witpoort Hospital. The participant's arm was rested on a supporting prop. Natural latex gloves were used to avoid possible infection during the handling and collection of blood samples. Fasting venous blood samples were collected from the arm (antecubital vein) into vacutainer tubes (Vacutainer BDTM) using new sterilised needles for each participant. After the collection of blood samples, a cool box containing ice was immediately used to place the samples at (0-8^{0}C). The samples were then centrifuged for 15 minutes to obtain plasma and serum at 2500 rpm and later transported to the hospital and placed in a freezer at a temperature of -80^{0}C for later analysis. Haemolysed and clotted samples were discarded. The collected blood samples were used to measure fasting blood glucose samples and lipids samples (HDL-C and TG). All blood analyses were done at the Medical Science Unit of the Department of Pathology and Medical Science at the University of Limpopo.

- Biochemical analyses
    - Fasting blood glucose

Fasting plasma blood samples were collected and stored into a 4ml grey cap tube that contains sodium fluoride and oxalate to inhibit glycolytic enzymes action. Beckman LX20® auto analyser (Beckman coulter Fullerton, CA, USA) was used to measure the fasting blood plasma using an enzymatic method that uses glucose oxidase.

- Lipid profile

The HDL-C was measured using a unique detergent that solubilises only the HDL-C particles and releases HDL-C. Triglyceride levels were measured using enzymatic (lipase, glycerol kinase, glycerophosphate oxidase and horseradish peroxidase) spectrophotometric technique. All plasma lipid measurements were done following the AU480 Chemistry System from Beckman Coulter (Brea, Calif). The AU480 instrument was calibrated according to standard procedures. All measurements were

done three times and the percentage of the coefficient of variation (%CV) was calculated. Measurements were repeated when the CV > 5%.

Elevated WC	**Males WC ≥ 94 cm** **Females WC ≥ 80 cm**

Figure 3.4.3: Biochemical assessment

3.4.3.2. The criteria of metabolic syndrome are shown below in table 3.4.3.2.

Elevated blood pressure	Systolic BP ≥130 mmHg Diastolic BP ≥85 mmHg Or antihypertensive treatment
Elevated TG	≥150 mg/dl (1.7 mmol/L) Or drug treatment for elevated TG
Reduced HDL-C	Males HDL-C <40 mg/dl (1.03 mmol/L) Females HDL-C <50 mg/dl (1.29mmol/L) Or drug treatment for reduced HDL-C
Elevated fasting blood glucose	Fasting plasma glucose ≥100 mg/dl (5.6 mmol/L) Or treatment for high fasting blood glucose

Table 3.4.3.1: The criteria or definition of metabolic syndrome according to the joint interim statement (Alberti et al., 2009). It indicates that an individual is diagnosed with metabolic syndrome if having any three or more of the below features.

3.4.4. Dietary intake

The current study used only a 24h-recall questionnaire to collect SSBs data

3.4.3.1. Twenty-four (24)-hour recall questionnaire

In the current study, a trained and skilled Northern Sotho speaking fieldworker conducted an in-person interview on the SSBs data. The SSBs data was collected by a means of a validated 24-hour dietary recall questionnaire and food composition manuals method (Langehoven et al., 1991; Steyn et al., 2003). The food composition manuals were used to improve the accuracy of the data collection because they had pictures of actual types, portion sizes and weight of SSBs items. This accommodated both the interviewer and even those with low literacy to correctly identify and report the consumed SSBs over the previous 24-hrs (Shim and Kim, 2014). A booklet adapted from the Dietary Assessment and Education Kit was also used to obtain portion sizes (Steyn et al., 2006). To minimise the recall bias, the current study used well skilled and trained interviewers to collect SSBs data. Additionally, for each participant, a two-day 24-hour dietary recall questionnaire was administered where the interview took place twice a week to ensure potential variations in days. One on a weekday and one on weekends and the average of 2 days was calculated using both the 24-h recall questionnaire and food composition

with pictures shown in Figure 3.4.4.1. to facilitate easy identification of SSBs. The reported information on the type, portion sizes of SSBs by the participants were then reviewed, converted to actual weights, and coded with the appropriate food listed in the food composition database.

Examples of portion sizes and weight of SSBs: when participants chose tea and coffee, they were also required to specify whether used teacup which had a quantity of 180ml and/or used a mug which had a quantity of 250 ml. Participants had to indicate whether the mug or cup was, full cup~ 250g, ½ full cup~ 90g, full mug~ 125g, 1/2 full mug~250g. They also had to choose whether they used a teaspoon or a tablespoon and also indicate whether the spoon was level~4g teaspoon and 15g tablespoon or heaped~ 6g teaspoon and 25g tablespoon for sugar. For fruit juice, the participants had to indicate whether they used a cup (1/2 cup~90g, full cup~180g), mug (1/2 mug~~125g and full mug~250g) and glass (1/2 big glass~125g; ¾ big glass~187.5g; full big glass~250g; ½ small glass~62.5g; full small glass~125g).

The coded SSBs data were then analysed with Food finder dietary analysis software programme version 3 developed by the South African Medical Research Council. The food finder software was used to generate added sugar denoted as SSBs in the current study and simple sugars such as fructose, sucrose, lactose. To categorise SSB consumption, we considered the data distribution across SSBs quartiles consumption where SSBs were divided into four quartiles. High SSBs was defined as ≥55g/day intake and recommended limit as ≤ 55g/day sugar by South African-Food Based Dietary Guideline (SA-FBDG) (Steyn et al., 2003).

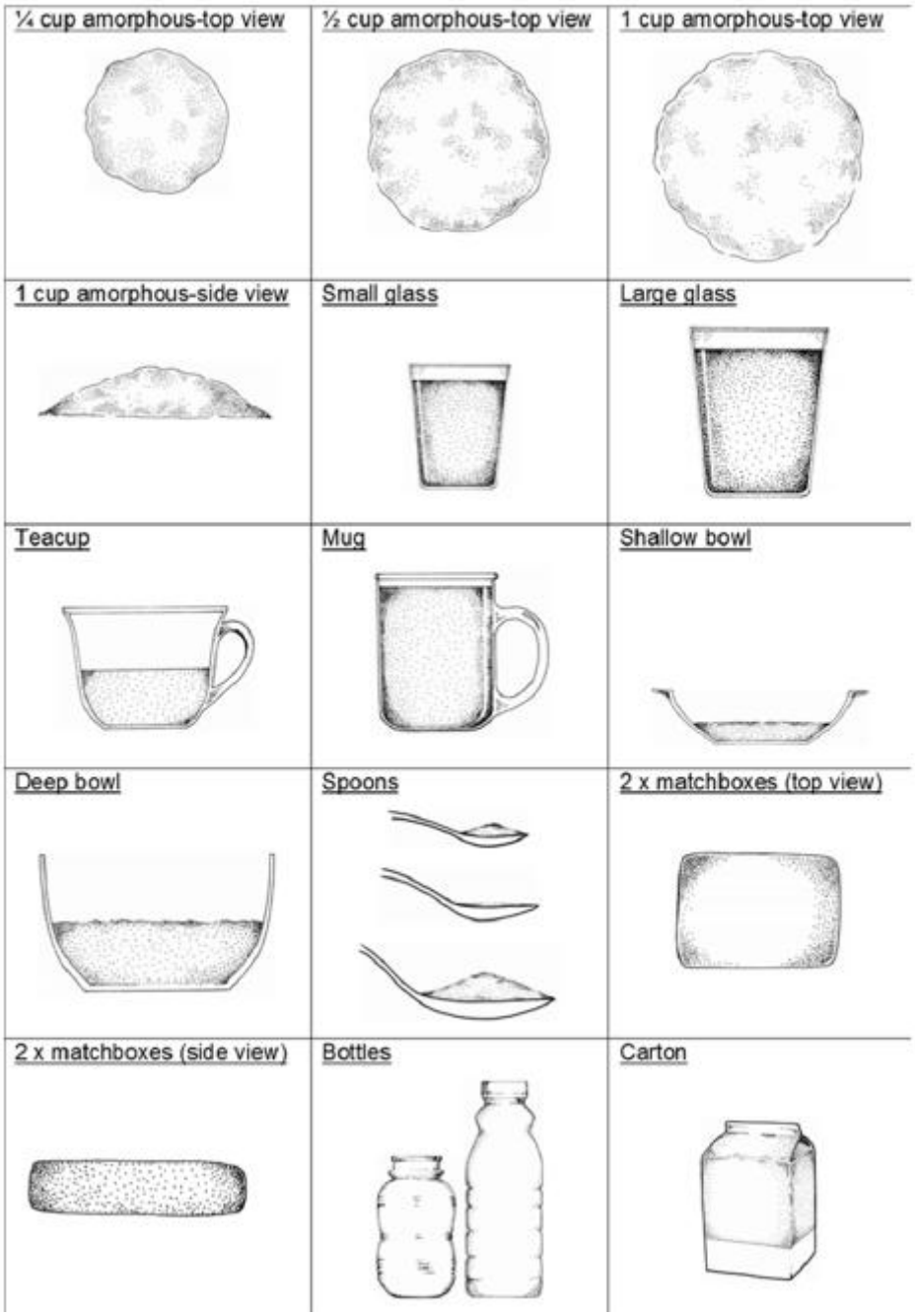

Figure: 3.4.3.1: Examples of sketches and measures used in the study (Steyn et al., 2020).

3.5. QUALITY CONTROL

The ISAK, was used as a standard procedure for all training of anthropometric and skinfolds measurement of participants (Norton and Olds, 1996). Fieldworkers underwent testing for the reliability of measurements as part of their training (Monyeki et al., 1999). This was done to achieve a technical error of measurement

within limits. The survey was carried out over three weeks by 16 fieldworkers each year. The training was conducted according to the three-level of criterion as per ISAK guidelines (Norton and Olds, 1996). In brief, the absolute and relative values for intra-tester and inter tester technical error measurements (%TEM) for all the skinfolds measurements ranged from 0.2 to 6 mm (0.4 to 6.8%), height measurements ranged from 0.04-4.16 cm (0.2-5.01%), bodyweight 0.01-0.02 kg and WC 0.0-3.4 cm (0-4%) (Monyeki et al, 1999; Monyeki et al., 2002). Blood samples were collected by registered nurses.

3.6. STATISTICAL ANALYSIS

3.6.1.The statistical package, significant level, and normality

The IBM statistical package for social sciences (SPSS) (IBM, Chicag0, USA) version 27.0 and Stata 15 software (StataCorp LP., College Station, TX, USA) was used to perform data analyses. The significance level was set at $p \leq 0.05$. All the variables were assessed for normality using the Shapiro–Wilk test and log transformation was done on non-normally distributed variables.

3.6.2. Descriptive statistics

Descriptive statistics were done for all the normally distributed variables and were presented as means and standard deviations. The descriptive statistics included biochemical variables, WC, age, BMI, WHtR, NC, sucrose, lactose, SSBs. The difference between gender was determined using a one-way analysis of variance (ANOVA) and the independent *t*-test.

3.6.3. Prevalence

The study used both the percentile and quartiles to categorise SSBs data. The cut-off points (19, 40, 56 and 104) and percentile (20, 50, 65, 90) were used to stratify SSBs into four quartiles Q1, Q2, Q3, Q4:(Q_{20}=19; Q_{50}=40; Q_{65}=56; Q_{90}=104). High SSBs was defined as ≥55g/day intake and recommended limit as ≤ 55g/day sugar by SA-FBDG which is equivalent to 6-10% of total energy intake (Steryn et al., 2003). The Joint interim statement by IDF and various organisations (Alberti et al., 2009) were used to classify MetS components as high or above the recommended limit. The chi-square test was to find the significant association between genders.

3.6.4. Bivariate Correlations

Pearson correlations were used to evaluate the correlation between obesity indices (NC, BMI, WC and WHtR) and MetS components (MAP, TG, FBG and HDL-C).

Spearman correlations were used to evaluate the correlation between the consumption of SSBs and MetS components (FBG, HDL-C, TG, SBP, DBP, and WC).

3.6.5. Regression coefficient

Binary logistic regression analysis was applied to determine the association between SSBs consumption and MetS components (DBP, SBP, TG, HDL-C, WC). Furthermore, a Cochran's and Mantel-Haenszel statistics test for trend was used to assess if there is a linear trend in the SSBs quartiles. The study additionally regarded the first SSBs quartile as the reference category.

3.6.6. Goodness-of-fit statistics for various factor models of metabolic syndrome.

Confirmatory factor analysis was used to test the single-factor models of MetS defined by MAP, FBG, TG and commonly selected obesity indices such as NC, BMI, WC and WHtR as indicators of MetS (Pladevall et al., 2006). The model was reported on the standardised regression weight (standardised factor loading). We built a single-factor model of MetS similar to that of the study by Motamed and colleagues which was differentiated from each other by four obesity indices of WHtR, WC, WHR and BMI with four hypothesised single factor models (Motamed et al., 2016). However, in the current study, we used NC as an obesity index instead of WHR. The MetS variable was treated as a latent variable (the variable that that is inferred, not directly observed, from other variables that are observed) (Kenny, 2012).

Chi-square test with different fit indices, including CFI, GFI, AIC, TLI and RMSEA were used to assess the models. A model with RMSEA < 0.06, CFI > 0.95, and TLI > 0.95 was regarded as a good model-data fit (Hu and Bentler, 1999). The model with the lowest AIC value was considered the best model (Akaike, 1973). A maximum likelihood estimation was used to analyse the covariance of the variables.

3.7. REFERENCES

Akaike, H. (1973). Information theory and an extension of the maximum likelihood principle. In B. N. Petrov, & F. Csaki (Eds.), proceedings of the 2nd international symposium on information theory (267–281). Budapest: Akademiai Kiado.

Alberti, K.G.M.M., Eckel, R.H., Grundy, S.M., Zimmet, P.Z., Cleeman, J.I., Donato, K.A., Fruchart, J.C., James, W.P.T., Loria, C.M. and Smith Jr, S.C. (2009). Harmonizing the metabolic syndrome: a joint interim statement of the international diabetes federation task force on epidemiology and prevention; national heart, lung, and blood institute; American heart association; world heart federation; international atherosclerosis society; and international association for the study of obesity. *Circulation*, 120(16):1640–1645.

Anothaisintawee, T., Sansanayudh, N., Thamakaison, S., Lertrattananon, D. and Thakkinstian, A. (2019). Neck circumference as an anthropometric indicator of central obesity in patients with prediabetes: a cross-sectional study. *Biomed Research International*, 2019:1–8.

Ashwell, M., Gunn, P. and Gibson, S. (2012). Waist-to-height ratio is a better screening tool than waist circumference and BMI for adult cardiometabolic risk factors: systematic review and meta-analysis. *Obesity Reviews*, *13*(3):275 – 286.

Bradshaw, D. and Steyn, K. (2001). Poverty and chronic diseases in South Africa. *Tygerberg, South Africa: Burden of Diseases Research Unit*, 123:38–45.

Daniel, M.K., James, S.H., Han, K.C. and Elfas, R.N. (2019). Health Status and permanent loss to follow up of Ellisras Longitudinal Study subjects: Rural South African Context. In *Nutrition in Health and Disease-Our Challenges Now and Forthcoming Time*. Intech Open.

Hsieh, S.D. and Yoshinaga, H. (1995). Abdominal fat distribution and coronary heart disease risk factors in men-waist/height ratio as a simple and useful predictor. *International Journal of Obesity and Related Metabolic Disorders: Journal of the International Association for the Study of Obesity*, *19*(8):585 – 589.

http://thehda.co.za › Lephalale – Limpopo - The Housing Development Agency (HAD). 2015. (Accessed 12 July 2020).

Hu, L.T. and Bentler, P.M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling: *A Multidisciplinary Journal*, 6(1):1–55.

Jervas, E. (2018). Study of Neck Circumference as a Measure of Obesity in South-Eastern Nigerian Population. *Anthropology Open Journal*, 3(1):11–17.

Kenny, D.A. (2012). Multiple latent variable models: Confirmatory factor analysis.. Retrieved from: http://davidkenny.net>mfactor. (accessed 2 January 2021).

Kundu, R.N., Biswas, S. and Das, M. (2017). Mean arterial pressure classification: a better tool for statistical interpretation of blood pressure related risk covariates. *Cardiology and Angiology: An International Journal*, 6(1):1–7.

Langehoven ML, Kruger M, Gouws E, Faber M. (1991). MRC Food Composition Table, 3rd edition. Parow: Research Institute for Nutritional Diseases. Cape Town: South African Research Council, 75–108.

Monyeki, K.D., Van Lenthe, F.J. and Steyn, N.P. (1999). Obesity: does it occur in African children in a rural community in South Africa?. *International Journal of Epidemiology*, 28(2):287–292.

Monyeki, K.D., Cameron, N. and Getz, B. (2000). Growth and nutritional status of rural South African children 3–10 years old: The Ellisras growth study. *American Journal of Human Biology: The Official Journal of the Human Biology Association*, 12(1):42–49.

Monyeki, K.D., Toriola, A.L., Ridder, J.D., Kemper, H.C.G., Steyn, N.P., Nthangeni, M.E., Twisk, J.W.R. and Lenthe, F.V. (2002). Stability of somatotypes in 4- to 10-year-old rural South African girls. *Annals of Human Biology*, 29(1):37–49.

Monyeki, K.D., Kemper, H.C.G. and Makgae, P.J. (2006). The association of fat patterning with blood pressure in rural South African children: the Ellisras Longitudinal Growth and Health Study. *International Journal of Epidemiology*, 35(1):114–120.

Monyeki, K.D. and Kemper, H.C.G. (2008). The risk factors for elevated blood pressure and how to address cardiovascular risk factors: a review in paediatric populations. *Journal of Human Hypertension*, 22(7):450–459.

Monyeki, K.D., Kemper, H.C. and Makgae, P.J. (2009). Development and tracking of central patterns of subcutaneous fat of rural South African youth: Ellisras longitudinal study. *BMC Pediatrics*, 9(1):1–9.

Motamed, N., Zamani, F., Rabiee, B., Saeedian, F.S., Maadi, M., Akhavan-Niaki, H. and Asouri, M. (2016). The best obesity indices to use in a single factor model indicating metabolic syndrome: a population-based study. *Archives of Iranian Medicine,* 19(2):1101–15.

Must, A., Spadano, J., Coakley, E.H., Field, A.E., Colditz, G. and Dietz, W.H. (1999). The disease burden associated with overweight and obesity. *Jama*, 282(16):1523–1529.

Nedea, D. (2020). Waist to height ratio calculator. Retrieved from: https:www.mdapp.co/waist-to-height-ratio-whtr-calculator-433/. Accessed 21 November 2020.

Norton K, Olds T. Anthropometrica. Sydney: University of New South Wales Press; 1996:120-267.

Owolabi, E.O., Ter Goon, D., Adeniyi, O.V., Adedokun, A.O. and Seekoe, E. (2017). Prevalence and correlates of metabolic syndrome among adults attending healthcare facilities in Eastern Cape, South Africa. *The Open Public Health Journal*, 10(1):148–159.

Pladevall, M., Singal, B., Williams, L.K., Brotons, C., Guyer, H., Sadurni, J., Falces, C., Serrano-Rios, M., Gabriel, R., Shaw, J.E. and Zimmet, P.Z. (2006). A single factor underlies the metabolic syndrome: a confirmatory factor analysis. *Diabetes Care*, 29(1):113–122.

Seabra, G., Sauders, C, de Carvalh0 Padilha, P., Zajdenverg, Da Silver L.B.G. an e Souza Santos, M.M.A. (2015). Association between maternal glucose levels during pregnancy and gestational diabetes mellitus: an analytical cross-sectional study. *Diabetology and Metabolic Syndrome*, 7(17):1–7.

SDBIP. Available online: http://www.lephalale.gov.za/documents/sdbip.php (accessed on 17 September 2021).

Sesso, H.D., Stampfer, M.J., Rosner, B., Hennekens, C.H., Gaziano, J.M., Manson, J.E. and Glynn, R.J. (2000). Systolic and diastolic blood pressure, pulse pressure, and mean arterial pressure as predictors of cardiovascular disease risk in men. *Hypertension*, 36(5):801–807.

Shim, J.S., Oh, K. and Kim, H.C. (2014). Dietary assessment methods in epidemiologic studies. *Epidemiology and Health*, 36:e2014009.

Steyn, N.P., Myburgh, N.G. and Nel, J.H. (2003). Evidence to support a food-based dietary guideline on sugar consumption in South Africa. *Bulletin of the World Health Organization*, 81:599–608.

Steyn, N.P., Senekal, M., Norris, S.A., Whati, L., MacKeown, J.M. and Nel, J.H. (2006). How well do adolescents determine portion sizes of foods and beverages?. *Asia Pacific Journal of Clinical Nutrition*, 15(1):35.

Steyn, N.P., Nel, J.H., Malczyk, S., Drummond, L. and Senekal, M. (2020). Provincial Dietary Intake Study (PDIS): Energy and Macronutrient Intakes of Children in a Representative/Random Sample of 1–<10-Year-Old Children in Two Economically Active and Urbanized Provinces in South Africa. *International Journal of Environmental Research and Public Health*, 17(5):1717.

Waist circumference images, stock photos &vectors. From:https://www.shutterstock.com › search › waist + circumference. (accessed 25 July 2021).

World Health Organisation. 2008. waist circumference and waist–hip ratio: Report of a WHO expert consultation. From: https://www.who.int> Publications > i >item.(accessed 27 April 2021).

Yoo, E.G. (2016). Waist-to-height ratio as a screening tool for obesity and cardiometabolic risk. *Korean Journal of Pediatrics*, *59*(11):425.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Introduction

4.2. Characteristics of the study population

4.3. The prevalence of SSBs consumption among the study participants according to SSBs quartiles

4.4. The prevalence of metabolic syndrome components amongst gender stratified by SSBs quartiles

4.5. Logistic regression

4.6. Characteristics of the study population

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4.8. Goodness fit statistics for various factor models to predict metabolic syndrome by gender

4.9. Conclusion

4.10. References

4.1. INTRODUCTION

In this chapter, the findings of the study are outlined where the association between SSBs intake and MetS are explored. Furthermore, the best obesity indices such as NC, BMI, WC, and WHR to identify MetS among youth aged 22-30 years old were determined. This was carried out because of very limited studies regarding this topic in South African rural settings.

4.2. Characteristics of the study population

- Demographic characteristics

The current study comprised 593 participants with the number of females 51% (304) slightly above that of males 49% (289). The mean age of the study participants was 23 years for both females and males. However, the difference was not statistically significant (p=0.608).

4.2.1. Sugar-sweetened beverages variables

Male' participants who had higher SSBs consumption only showed a higher significant difference in mean log fructose (p=0.008). In females, all the SSBs quartiles showed no significant difference in mean values of log fructose (p=0.128), log sucrose (p=0.374), and log lactose (p=0.580). In the Tehranian study, different results were observed where both boys and girls who had higher SSBs consumption had higher intakes of glucose, fructose, sucrose. (Mirmiran et al., 2015). Furthermore, the Tehranian study considered glucose instead of lactose. The difference in the studies might be attributed to the fact that the current study considered older participants than the participants in the Tehranian study who were children and adolescents. This study compared its findings with the above study because of the lack of data around this topic in South Africa especially in rural settings.

- Metabolic syndrome components

In the current study both lower and higher SSBs quartiles in females showed a higher significant mean value of log WC (p=0.0053), DBP (p= 0.034) and TG (p=0.034). On the other hand, males reported no significant difference on any MetS components following both the lower and higher SSBs consumption. Different findings were found in a cross-sectional survey conducted by Shin et al. (2018) who

reported that for men, increased consumption of SSBs was linked to greater DBP (p=0.0107) but was not associated with BMI and other MetS components (Shin et al., 2018). However, among females, increased consumption of SSBs was positively associated with mean values of BMI, DBP, triglyceride, and fasting glucose (p = 0.0022, p=0.0320, p=0.0032, and p=0.0070), respectively. The difference in studies might have resulted from the difference in the sample size and population type whereas the later study included a smaller sample size and black participants.

The findings of the current study also confirm the previous report that indicated evidence of a non-linear effect between the SSBs intake and MetS dose-response relationship (Zhang et al., 2021). Because, in the study conducted by Chen et al. (2019) it was also reported that the consumption of low doses (< cup/week), middle doses (1-6 cups/week) and high doses (≥7 cups/week) of SSBs significantly increased relative risk of NAFLD by 14%, 26% and 53%, respectively (p=0.001, p<0.00001, p=0.03 respectively). Although the current study didn't focus on NAFLD per se, it shows that the consumption of SSBs have the potential of increasing the risk of attaining MetS or diseases even at lower doses.

Below are descriptive statistics of 593 participants (304 females and 289 males) according to sugar-sweetened beverages (SSBs) quartiles of the participants that enrolled in the current study. The data shows the demographics, SSBs variables, MetS components, and BP measurements of the Ellisras rural youth aged 22-30 years as recorded in Table 4.2.1.

Variables	Males					Females				
	SSBs Quartiles (M±SD) n=249				P-Value	SSBs Quartiles (M±SD) n=251				P-Value
	Q_{20}=19	Q_{50}=40	Q_{65}=56	Q_{90}=104		Q_{20}=19	Q_{50}=40	Q_{65}=56	Q_{90}=104	
	Q1 n=132	Q2 n=77	Q3 n=40	Q4 n=40		Q1 n=118	Q2 n=87	Q3 n=43	Q4 n=57	
Age (years)	23.65±2.03	23.66±1.91	23.40±1.92	23.57±1.99	0.831	23.89±2.00	23.81±2.08	23.97±2.13	23.37±2.05	0.608
Log Fructose (g)	-0.01±0.67	0.26±0.72	0.21±0.64	0.52±0.80	**0.008***	0.33±0.63	0.28±0.069	0.20±0.53	0.34±0.74	0.128
Log Sucrose (g)	0.33±0.83	0.23±0.82	0.03±0.76	0.41±0.74	0.564	0.48±0.81	0.16±0.82	0.40±0.83	0.34±0.85	0.374
Log Lactose (g)	-0.03±0.70	0.16±0.67	0.30±0.90	0.21±0.50	0.800	0.22±0.61	0.29±0.61	0.21±0.67	0.25±0.63	0.580
FBG (mmol/L)	5.15±0.77	5.40±0.67	5.18±0.79	5.42±0.85	0.177	5.50±0.88	5.51±0.82	5.71±0.72	5.42±0.96	0.439
Log WC (cm)	1.87±0.51	1.87±0.51	1.87±0.33	1.87±0.45	0.872	1.92±0.06	1.90±0.06	1.9±0.08	1.90±0.07	**0.053***
DBP (mm/Hg)	69.61±9.74	71.57±9.01	70.45±8.91	70.12±8.93	0.651	68.52±7.87	70.38±8.33	68.95±7.36	66.39±8.61	**0.034***
SBP (mm/Hg)	125.11±12.30	124.65±11.13	123.71±10.66	126.31±10.68	0.719	114.18±11.04	114.28±9.94	115.89±8.41	112.07±9.58	0.152
HDL-C(mmol/L)	1.24±0.26	1.18±0.29	1.20±0.32	1.20±0.30	0.497	1.06±0.25	1.09±0.28	1.01±0.25	1.15±0.31	0.067
TG (mmol/L)	1.00±0.48	0.96±0.42	0.88±0.33	0.87±0.35	0.336	1.00±0.43	0.94±0.46	0.88±0.35	0.80±0.32	**0.034***

Table 4.2.1: The participant's characteristics (N=596) of the Ellisras rural youth aged 22–30 years stratified by SSBs quartiles.

FBG=fasting blood glucose; TG=triglycerides; HDL-C= high density lipoprotein-cholesterol; WC=waist circumference; DBP= diastolic blood pressure; SBP=systolic blood pressure; M=mean; SD=standard deviation; SSBs=sugar-sweetened beverages,***p<0.05**

4.2.2. Obesity indices variables

In the general population of Ellisras, all the mean values of obesity indices (WC, WHtR, NC, BMI) were statistically significant ($p<0.001$). In females, the mean values of WC and BMI were significantly ($p<0.001$) higher than that of males, while mean values of NC and WHtR in males were significantly ($p<0.001$) higher compared to that of females. Similar findings were reported by Motamed and colleagues. (2016) where WC ($p<0.001$) and BMI ($p=0.035$) were significantly higher in females than in men. In contrast, the male result differed from that of Motamed et al. (2016) where mean values of WHtR were also higher in females compared to males. The probable explanation could be attributed to different geographical regions (Iran vs South Africa), population (Iranian vs African), sample size (5616 vs 593).

- Metabolic syndrome components

In the general population of Ellisras, there was no significant mean difference between DBP ($p=0.013$) and FBG ($p=0.371$). This nonsignificant mean difference of DBP ($p=0.013$) and FBG ($p=0371$) was also evident among gender. This was in contrast with the findings by Motamed et al. (2016) where there was a significant mean value of DBP ($p=0.010$) in the total population as well as between the genders. There was a significant mean difference of SBP, MAP, HDL-C and TG all ($p<0.001$) in the general population. Males had significantly ($p<0.001$) higher mean SBP, MAP and HDL-C values than females. Similar findings were reported in the study by Motamed et al. (2016) except for HDL-C which was higher in females in the study conducted by Motamed et al. (2016). Meanwhile, the mean values of WC were significantly ($p<0.001$) higher in females as compared to males. These results were consistent with the findings of Motamed et al. (2016).

The characteristics such as the demographic, MetS components and obesity indices variables among the Ellisras rural youth aged 22-30 years are depicted in Table 4.2.2.

Table 4.2.2: Descriptive characteristics for obesity indices and MetS components of the Ellisras rural youth aged 22-30 years.

Variable	Total (n=593) Mean±SD	Male (n=289) Mean±SD	Female (n=304) Mean±SD	P-value
Age (yrs)	25.0 ±1.95	25.0 ±1.92	25.0 ±1.97	0.142
DBP (mm/Hg)	1.84±0.06	1.85±0.06	1.84±0.06	**0.013***
SBP (mm/Hg)	2.08±0.05	2.10±0.04	2.06±0.04	**<0.001****
MAP (mm/Hg)	1.93±0.05	1.95±0.05	1.92±0.5	**<0.001****
FBG (mg/dL)	0.73±0.7	5.45±0.87	5.52±0.92	0.371
NC (cm)	33.45±3.00	35.24±2.44	31.75±2.44	**<0.001****
BMI (kg/m2)	1.36±0.93	1.32±0.64	1.40±0.10	**<0.001****
WC (cm)	1.89±0.07	1.87±0.05	1.91±0.08	**<0.001****
WHtR (cm)	0.46±0.08	1.04±0.60	0.95±0.51	**<0.001****
HDL-C (mg/dL)	0.43±0.12	0.64±0.12	0.02±0.19	**<0.001****
TG (mg/dL)	0.99±0.55	0.43±0.05	0.50±0.09	**<0.001****

Log transformed variables, Shapiro–Wilk test, independent t-test, BMI=body mass index, DBP=diastolic blood pressure, SBP=systolic blood pressure, FBG=fasting blood sugar, HDL-C=high density lipoprotein-cholesterol, MAP=mean arterial pressure, NC= neck circumference, TG=Triglycerides, WHtR= waist to height ratio, WC=waist circumference, ***p<0.05**, ****p<0.001**

4.3. Prevalence

4.3.1. The prevalence of SSBs consumption stratified by quartiles among Ellisras rural youth aged 22–30 years.

SSBs data was divided into four percentiles which were percentile 20, percentile 50, percentile 65 and percentile 90 where cut-off 19, 40, 56 and 104 were used for stratification of four quartiles (Q1, Q2, Q3, Q4: Q_{20}=19; Q_{50}=40; Q_{65}=56; Q_{90}=104). Based on the cut-offs used in this study together with the SSBs intake recommendation limit by the SA-FBG (Steryn et al., 2003) both Q1 and Q2 represent or falls under lower or recommended SSBs intakes and Q3 and Q4 represent higher SSBs intake. High SSBs is defined as ≥55g/day intake and the recommendation limit as ≤ 55g/day sugar by SA-FBDG (Steryn et al., 2003).

As shown in figure 4.3.1. Males had higher SSBs Q1, Q2 (24.8%, 32.9% respectively) which is according to the recommended added sugar intakes compared to females (23.6%, 29.6%) respectively whereas females had higher SSBs Q4 (31.3%) which is above the recommended intake than for males (26.6%). The current results suggest that females had a higher consumption of SSBs compared to their male counterparts. Corroborating the results of the previous study, in rural areas, the proportion of adults who consumed sucrose-sweetened beverages approximately doubled from 25% to 56% for men, whereas in women it was from 33% to 63% (Voster et al., 2014). The above results indicate a higher intake of SSBs levels than what is found in the current study (Voster et al., 2014). However, the results were in contradiction with the CRISBSA study which reported 52g/day sugar consumption in men and roughly 51 g/day in women (Jaffer et al., 2011). According to Hallam et al. (2016) the physiological explanation in the differences and increase in sugar/sweet food cravings results from the difference in hormonal concentration and mechanisms between males and females. Hormones such as testosterone, progesterone, and oestrogen play an important role in regulating food cravings and consumption (Hallam et al., 2016). Moreover, in females, craving for sugar or sweet food is increased when approaching the monthly period (Hallam et al., 2016). It was also explained that interaction in sociological, environmental, and biological factors also accounts for the differences in food craving (Hallam et al., 2016). In support of the above statement studies conducted by (Nederkoorn et al., 2000; Bernabe et al., 2013) reported that repeated exposure to taste, visual or olfactory cues are very significant in cue-induced craving while at the same time increasing the signal of salivation, heart and gastric activity. Moreover, internal factors such as feelings (boredom, loneliness, sadness etc) may as well trigger restless anticipation that often leads to individuals eating more than required (Bernabe et al., 2013). All these factors might affect the high SSBs intake seen in females. Figure 4.3.1. below shows the prevalence of SSBs consumption stratified by SSBs quartiles among Ellisras rural youth aged 22-30 years.

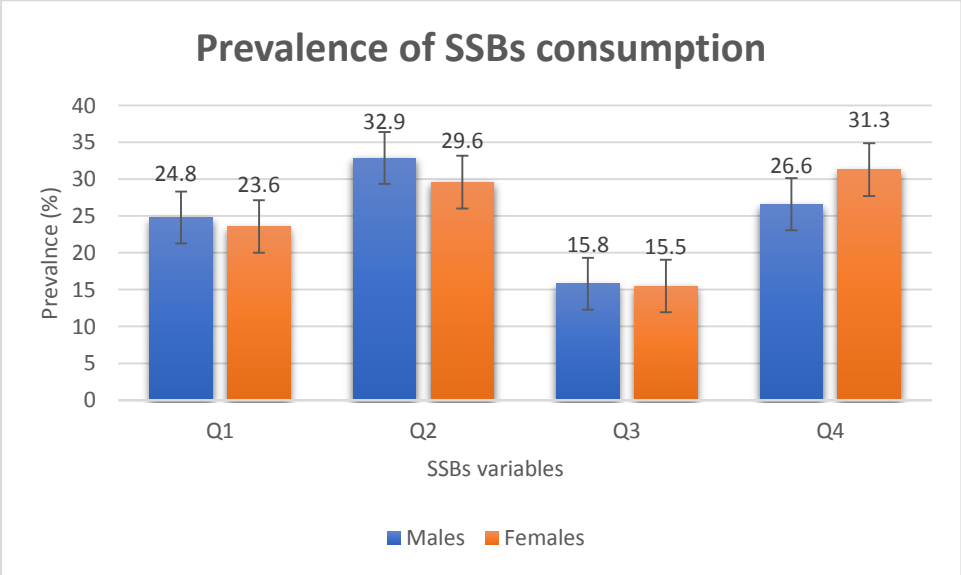

Figure 4.3.1. The prevalence of SSBs consumption was stratified by quartiles among Ellisras rural youth aged 22–30 years.

4.3.2: Prevalence of MetS components amongst Ellisras rural youth aged 22-30 years stratified by SSBs quartiles.

As shown in table 4.3.2: females depicted a high prevalence of most MetS components across SSBs quartiles compared to males. Among females, the third SSBs quartile demonstrated a higher prevalence of high FBG (64.5%) compared to (35.5%) in males. These findings are higher than those reported by (Muluvhu et al., 2018) where a higher prevalence of FBG was reported in females (28%) and (19%) in males.

In addition, the current study found a higher prevalence of low HDL-C and high WC among females compared to males and showed fluctuations across all the four SSBs quartiles. Moreover, elevated TG levels were higher among females than in males. A similar cross-sectional study conducted in the Boland district of the Western Cape Province, reported a higher prevalence of abdominal obesity measured by WC (63.3%) and low HDL-C (61.2%) in women compared to (31.7% and 39.0% respectively) of men (Kruger et al., 2017). However, contradicting results were found regarding elevated TG levels which were reported to be higher in men (53.7%) compared to 25.9% in women in the Boland district study. The differences in the studies might be due to the different working conditions where the participants from

the study by Kruger et al. (2017) consisted of only wine farm workers who involve mostly being outside and get exposed to hot, warm or cold weather conditions as previously reported by (Halonen et al., 2011) whereas in the latter study the participants were involved in various occupations such as in Matimba and Medupi electric power station, Iscor coal mine, and education (Lephalale Gov, 2018) which involves being mostly indoors. Furthermore, this study considered prevalent across the SSBs quartiles.

Moreover, the prevalence of high SBP was significantly higher among males compared to females and decreased with higher intakes of SSBs across all the four SSBs quartiles. Meanwhile, high DBP (100%) among males was significantly prevalent only in the first SSBs quartile and it was higher compared to that of females (0%). These results suggest a higher prevalence of blood pressure among males compared to females. Similar findings were previously reported in the Ellisras population by Sekgala et al. (2018) where the prevalence of both SBP and DBP were higher in males than in females. Furthermore, similar results were also found in a study conducted by Solomon and Mulugeta. (2019) among the Ethiopian population where elevated blood pressure was seen in men (65%) than in women (53%).

There are several possible explanations for the above findings. First, the physiological explanation of the current findings might be that female sex hormones such as oestrogen (Maris et al., 2005) expose them to increased levels of TG and HDL-C. Second, Rochlani et al. (2015) further indicated that gender difference in lipid profile is explained by a combination of the effect of hormones, hepatic lipase, and lipoprotein lipase activity, where women have higher lipoprotein lipase activity which favours more cholesterol metabolism and results in higher reduced HDL and TC compared to males. Third, the elevated WC or higher abdominal obesity seen among females could be attributed and influenced by factors related to social attitudes toward fatness and cultural norms, wherein African countries regarded being fat as a sign of happiness, wealth, and attractiveness (Peer et al 2016). Maris et al. (2015) further indicated that female sex hormones such as oestrogen are more protective against hypertension, and this clarifies why young females are at a lower risk of developing hypertension compared to their counterpart males. This suggests

that age plays a significant role in the development of hypertension or having elevated blood pressure (Rochlani et al., 2015).

Table 4.3.2. below, shows the gender-specific distribution of MetS components of the Ellisras rural youth aged 22-30 years according to SSBs quartiles.

Males Variables	**SSBs quartiles (%)**				**Females Variables**	**SSBs quartiles (%)**			
	Q1	Q2	Q3	Q4	Females	Q1	Q2	Q3	Q4
High FBG (mmol/L)	44.1	47.1	35.5*	44.7	High FBG (mmol/L)	55.9	52.9	64.5*	55.3
Low HDL-C (mmol/L)	25.3**	30.3**	30.0**	29.7**	Low HDL-C (mmol/L)	74.7**	69.7**	70.0**	70.3**
High TG (mmol/L)	46.7	46.7	49.3	44.7	High TG (mmol/L)	53.3	53.3	50.7	55.3
High WC (cm)	29.6**	34.0**	20.0**	31.8*	High WC (cm)	70.4**	66.0**	80.0**	68.2*
High SBP (mm/Hg)	82.1**	80.0**	80.0*	78.3**	High DBP (mm/Hg)	17.9**	20.0**	20.0*	21.7**
High DBP (mm/Hg)	100**	53.1	100	60.0	High SBP (mm/Hg)	0**	46.9	0	40.0

Table 4.3.2: Gender-specific distribution of MetS components of the Ellisras rural youth aged 22–30 years according to SSBs quartiles.

SSBs= sugar-sweetened beverages, FBG=fasting blood glucose; TG=triglycerides; HDL-C= high density lipoprote.in-cholesterol; WC=waist circumference; DBP= diastolic blood pressure; SBP=systolic blood pressure;*p<0.05; **p<0.001.

4.4. Correlation

4.4.1. The partial correlation coefficients between MetS components and obesity indices of the Ellisras rural youth aged 22-30 years.

In the current study all the obesity indices were found to be significantly correlated with one another however a strong correlation was found between BMI and WHtR ($r=0.895$, $p<0.001$); BMI and WC ($r=0.870$, $p<0.001$) and these correlations were better than that of BMI and NC ($r=0.182$, $p<0.05$). This was in contradiction with a study conducted by Patil and colleagues. (2017) where a weak correlation between BMI and NC ($r=0.405$) was observed.

In addition, a positive correlation between NC with MAP (SBP & DBP) ($r=0.317$, $p<0.001$); TG ($r=0.156$, $p<0.001$) and FBG ($r=0.018$) although it was nonsignificant ($p>0.05$). Similar results were reported by Zhou et al. (2013) and Laohabut et al. (2020) who also found a positive correlation of NC with BP, FBG, TG, LDL-C, and TC, although in the current study LDL-C and TC were not considered. Moreover, the current study found a positive correlation between NC and HDL-C ($r=0.317$, $p<0.001$) which was inconsistent with the findings by Zhou et al. (2013) and Laohabut et al. (2020) who found a negative correlation between NC and HDL-C.

With regard to other obesity indices BMI was correlated with (MAP: $r=0.086$, $p<0.05$; FBG: $r=0.046$; $p>0.05$, TG: $r=0.160$, $p<0.001$); WC was correlated with (MAP: $r=0.106$, $p<0.001$; FBG: $r=0.048$, $p>0.05$; TG: $r=0.191$, $p<0.001$); and WHtR was correlated with (MAP: $r=0.019$, $p<0.05$; FBG: $r=0.053$, $p>0.05$, $p<0.001$), these correlations are similar to those of NC however, the latter results found a negative correlation between the three obesity indices and HDL-C [BMI (HDL-C: $r=-0.146$, $p<0.001$); WC (HDL-C: $r=-0.107$, $p<0,001$); and WHtR (HDL-C: $r=-0.129$, $p<0.001$)]. This was in accordance with the results by Zhou et al. (2013) who also observed a positive correlation between anthropometric indices (NC, WC, BMI, WHpR) with cardiometabolic risk or MetS components and a negative correlation with HDL-C although WHtR was used in this study.

Moreover, the above results support what was reported in other studies that BMI can be used to classify obesity (Alziedan et al., 2019, Shrestha et al., 2018; Tal et al., 2019). Meanwhile, the WC and WHtR can be used as the simplest obesity indices to reflect visceral fat content, as well as better, predicting not only MetS but also other

cardiometabolic risk factors and mortality (Fan et al., 2016; Shrestha, 2018). Subsequently, the NC was also suggested as the best effective method to predict cardiometabolic factors and MetS (Alzeidan et al., 2019). Because it was reported that neck fat content is highly correlated with visceral fat content which is linked to adverse metabolic health effects (Luo et al., 2017; Patil et al., 2017).

The correlation of obesity indices and MetS components among the Ellisras rural youth aged 22-30 years is depicted in Table 4.4.1.

Table 4.4.1: Partial correlation coefficients of obesity indices and components of MetS of the Ellisras rural youth aged 22-30 years.

Variables	MAP mm/Hg	FBG (mg/L)	NC (cm)	BMI (kg/m^2)	WC (cm)	WHtR (cm)	HDL-C (mg/L)
MAP (mm/Hg)	1						
FBG mg/L	0.115**	1					
NC (cm)	0.317**	0.018	1				
BMI (kg/m^2)	0.086*	0.046	0.182*	1			
WC (cm)	0.106**	0.048	0.283**	0.870**	1		
WHtR (cm)	0.019*	0.053	0.101*	0.895**	0.954**	1	
HDL-C (mg/L)	0.125**	-0.096	0.013	-0.146**	-0.107**	-0.129**	1
TG (mg/L)	0.186**	-0.001	0.156*	0.160**	0.191**	0.157**	0.063

MAP=mean arterial blood pressure, FBG=fasting blood glucose, NC=neck circumference, BMI=body mass index. WC=waist circumference, WHtR=waist to height ratio, HDL-C=high density lipoprotein-cholesterol. *P < 0.05, **P < 0.001

4.4.1. The Spearman correlation coefficients for the correlation of MetS components and SSBs consumption of the Ellisras rural youth aged 22-30 years.

Among males, the correlation between SSBs consumption and all the MetS components was very weak and non-significant (p>0.05). Among females, the correlation of SSBs consumption and MetS components were also very weak, however, only TG (r=-0.163; p=0.013) and WC (r=-0.151; p=0.021) had a significant negative correlation. This was in contradiction with the findings by Shin et al. (2018) who found a positive correlation between SSBs consumption and high FBG and reduced HDL-C in addition to abdominal obesity. In the study by Shin et al. (2018) the sample size was larger (12112), they used FFQ to assess SSBs or diet, included age group of 35-65 years and last used NCEP/ATP III to define MetS which might

explain possible reasons for controversies in the studies. Table 4.4.2. below shows the correlation of MetS components and SSBs consumption of the Ellisras rural youth aged 22-30 years.

Table 4.4.2: Spearman correlation coefficients for the correlation of MetS components and SSBs consumption of the Ellisras rural youth aged 22-30 years.

MetS components	SSBs			
	Males		Females	
	R	P value	r	P value
FBG (mg/dl)	0.101	0.132	-0.024	0.710
HDL-C (mg/dl)	-0.080	0.327	0.074	0.260
TG (mg/dl)	-0.110	0.102	-0.163	0.013*
WC (cm)	0.058	0.387	-0.151	0.021*
SBP (mm/Hg)	0.026	0.699	-0.098	0.137
DBP (mm/Hg)	-0.026	0.705	-0.014	0.827

SSBs=sugar-sweetened beverages; HDL-C=high density lipoprotein cholesterol, WC= waist circumference, FBG=fasting blood glucose, SBP=systolic blood pressure, DBP=diastolic blood pressure, TG= triglycerides, r=correlation, *p<0.05.

4.5. Logistic regression

4.5.1. Logistic regression analysis for the association of SSBs consumption and risk of MetS components amongst Ellisras rural youth aged 22-30 years.

In the Ellisras population it was found that, for adjusted (OR=2.32; CI=1.15-4.70; p<0.05) and unadjusted (OR=2.34; CI=1.16-4.73; p<0.05) model, high FBG was only associated with SSBs in quartile 4 (CI =1.15-4.70; p<0.05) in males. Whereas the extended mantel-haenszel showed a significant linear trend (p for trend=0.049) in SSBs quartiles for the unadjusted models. High TG indicated fluctuating trend (p for trend =0.041) with increasing SSBs quartiles categories also for the unadjusted model. Moreover, low risk of reduced HDL-C was associated with both the second and fourth SSBs quartiles for both unadjusted (OR=0.40; CI=0.18-0.85; p<0.05; OR=0.37; CI=0.13-0.80; p<0.05) respectively and adjusted (OR=0.40; CI=0.18-0.85; p<0.05; OR=0.37; CI=0.17-0.80; p<0.05) in females. There was no significant association between high WC and any SSBs quartile (p>0.05) in both adjusted and unadjusted logistic regression models, however, there was a significant linear trend observed among the quartiles for the adjusted model (p trend =0.001). The high SSBs quartile 4 was likely to decrease the risk of high TG for both unadjusted

(OR=0.12; CI=0.01-0.87; p<0.05) and adjusted (OR=0.10; CI=0.01-0.83; p<0.05) models in females. Additionally, there was a significant linear trend observed in the SSBs quartile for high TG (p trend=0.006) for unadjusted models. The presents study's findings are partly in agreement with those reported in the previous studies. Previous studies reported that higher consumption or the highest SSBs quartile consumption was significantly associated with a higher incidence of obesity, MetS and its components that include hypertriacylglycerolaemia, central obesity/increased WC, impaired fasting glucose, high blood pressure/hypertension, and low HDL-C compared to lower SSBs intake or with the first (lower) SSBs quartile category (Dhinga et al., 2007; Barrio-Lopez et al., 2013; Ejtahed et al., 2015). Subsequently, in the study by Ejtahed et al. (2015), it was reported that the odds of MetS and its components indicated an increasing trend across the increasing SSBs quartiles. However, this contradicted with the findings of the current study where a non-linear trend in the SSBs quartile categories was observed suggesting association or possibility of causing risk of MetS and its components or related diseases following consumption of smaller quantities or doses of SSBs. The latter results confirm the previous report that indicated the evidence of a non-linear trend between the SSBs consumption and MetS that it does not always follow the dose-response relationship (Zhang et al., 2021).

In addition, in both the unadjusted and adjusted models, there was no significant association observed for high WC, high SBP, and high DBP with SSBs in the general population of Ellisras (males and females). This contrasted with the results obtained in the above studies by (Dhinga et al., 2007; Barrio-Lopez et al., 2013; Ejtahed et al., 2015). There are a few potential reasons that might explain different results that are found between the studies. First, different study populations, sample sizes, study designs, how SSBs were assessed, age group, characteristics of the participants and study location might partly provide reasons for contradicting findings. Second, it was reported that among the activities that are mainly practised in the rural areas include herding of livestock, doing agricultural activities, walking long distances to fetch firewood and water (Lephalale Gov, 2018) and this might have contributed as a form of physical activity. Physical activity was reported to contribute to increased energy expenditure, which is vital in maintaining a healthy, balanced body weight (DeBoeer, 2019) and the excess energy provided by the consumption of SSBs. On

the other hand, physical activity improves insulin sensitivity and lipids profile and thereby protects against diseases such as those that are linked with increased body weight, SBP and DBP (Myers et al., 2019; Zając-Gawlak et al., 2021).

The low risk induced by the consumption of SSBs on the development of some MetS components in the present study could be attributed to the types of SSBs that were mostly consumed by the Ellisras youth which included fruit juices, tea, coffee with full cream milk or powdered milk. However, the latter SSBs types were reported to be the second-largest consumed SSBs in both urban and rural areas of South Africa (Temple and Steyn, 2013; Ronquest-Ross et al., 2015). Moreover, those SSBs types were reported to contain ingredients such as antioxidants, fibres, proteins, vitamins (A, B12 and riboflavin) and minerals (calcium, phosphorus, magnesium, potassium, and zinc) amongst the others which were reported to be protective against adverse health effects (Ruxton et al., 2006). The probable mechanism that can partly explain the association between SSBs consumption and MetS components are indicated below.

The SSBs consumption disrupts the hormones that are involved in regulating energy balance and satiety centres, thus this might encourage over intake which increases positive energy in the body, overall body weight and WC (Malik et al., 2013; Deshpande et al., 2017). Moreover, over-consumption of fructose and sucrose from SSBs stimulates and initiates the production of lipid in the liver resulting in increased serum triglycerides and cholesterol (HDL-C) levels leading to accumulation, and the build-up of visceral fat (Lustig et al., 2012; Solomi et al., 2019). The glucose sugar contained in the SSBs has a higher glycaemic index that can result in high spikes of blood glucose and might lead to β-cell dysfunction, glucose intolerance, insulin resistance and inflammatory biomarker leading to increased incidence of T2DM (Malik and Hu, 2019). On the other hand, fructose inside the SSBs triggers the production of uric acid in the liver (Lustig et al., 2012) which leads to the activation of the renin-angiotensin system and consequently reduces nitric oxide production (Feig et al., 2008) leading to elevated blood pressure and high incidence of hypertension (Perez-Pozo et al., 2010). Table 4.5.1. below presents the odds ratios, 95% confidence interval and a linear trend for the association between MetS components and SSBs quartiles among the Ellisras rural youth aged 22-30 years.

Table 4.5.1: The odds ratios and 95% confidence interval for the association between MetS components and SSBs quartile

Males	**Unadjusted for Age**					**Adjusted for Age**				
Variables	**SSBs Quartiles**					**SSBs Quartiles**				
	Q1	Q2	Q3	Q4	*P* for Trend	Q1	Q2	Q3	Q4	*P* for Trend
		OR(CI)	OR(CI)	OR(CI)			OR(CI)	OR(CI)	OR(CI)	
High FBG (mmol/L)	1	1.29(0.678-2.49)	0.87(0.37-2.62	2.32(1.15-4.70) *****	**0.049**	1	1.31(0.68-2.53)	0.89(0.38-2.12)	2.34(1.16-4.73) *****	0.343
Low HDL-C (mmol/L)	1	0.98(0.48-2.03)	1.54(0.64-3.67)	1.40(0.66-2.98)	0.261	1	1.04(0.50-2.06)	1.62(0.67-3.90)	1.49(0.69-3.20)	0.226
High TG (mmol/L)	1	0.93(0.31-2.79)	0.29(0.03-2.42)	0.17(0.02-1.40)	**0.041**	1	1.09(0.35-3.42)	0.35(0.04-3.04)	0.19(0.02-1.65)	0.273
Excess WC (cm)	1	0.75(0.39-1.45)	1.02(0.45-2.23)	0.57(0.29-1.11)	0.957	1	1.15(0.52-2.54)	0.70(0.23-2.16)	1.21(0.52-2.83)	0.109
High SBP (mm/Hg)	1	0.97(0.49-1.92)	0.67(0.27-1.70)	0.99(0.47-2.08)	0.819	1	0.94(0.47-1.88)	0.67(0.26-1.71)	0.96(0.46-2.02)	0.111
High DBP (mm/Hg)	1	0.55 (0.12-2.55)	0.53(0.09-3.03)	0.97(0.25-3.78)	0.564	1	0.57(0.12-2.70)	0.58(0.010-3.33)	1.04(0.26-4.12)	0.177
Females Variables										
High FBG (mmol/L)	1	1.07(0.55-2.06)	1.36(0.61-3.06)	0.77(0.40-1.50)	0.525	1	1.07(0.55-2.06)	1.36(0.61-3.04)	0.77(0.40-1.50)	0.484
Low HDL-C (mmol/L)	1	0.40(0.18-0.85) *****	0.81(0.30-2.20)	0.37(0.13-0.80) *****	**0.050**	1	0.40(0.18-0.85) *****	0.81(0.30-2.19)	0.37(0.17-0.80) *****	0.860
High TG (mmol/L)	1	0.93(0.33-2.66)	0.22(0.03-1.82)	0.12(0.01-0.87) *****	**0.006**	1	0.92(0.32-2.61)	0.22(0.03-1.82)	0.10(0.01-0.83) *	0.407
Excess WC (cm)	1	1.07(0.50-2.29)	0.62(0.21-1.84)	1.15(0.51-2.59)	0.151	1	0.86(0.389-1.50)	1.01(0.44-2.31)	0.60(0.31-1.19)	**0.001**
High SBP (mm/Hg)	1	1.15(0.33-3.94)	0.75(0.14-4.09)	0.94(0.03-3.41)	0.819	1	1.15(0.33-3.94)	0.75(0.14-4.09)	0.94(0.24-3.41)	0.948
High DBP (mm/Hg)	1	0.70(0.04-1.46)	1.25(0.07-1.48)	1.32(0.36-1.62)	0.782	1	0.70(0.07-1.49)	1.24(0.07-1.49)	1.33(0.36-1.72)	0.995

among Ellisras rural youth aged 22-30 years.

SSBs=sugar-sweetened beverages; OR=odds ratio; CI= confidence interval; FBG= fasting blood glucose; HDL-C= high density lipoprotein-cholesterol; TG= triglyceride; SBP=systolic blood pressure; DBP= diastolic blood pressure; ***P< 0.05**

4.6. Goodness fit statistics model.

4.6.1. Goodness fit statistics for various factor models to predict metabolic syndrome amongst Ellisras rural youth aged 22-30 years.

A single model fit built on NC obtained a better fit index (CFI=0.90, TLI=0.71, RMSEA=0.05 and AIC= -429.21) for females than found in other indices, suggesting a better ability to predict MetS compared to other obesity indices. In males, all the single-factor models had RMSEA values closer to 0, CFI and TLI values greater than 0.95, indicating good fit indices, however, a single model fit built based on WC and WHtR had the smallest AIC values (−2680 and −2662 respectively), suggesting better fit indices than NC and BMI. This disagreed with the results of Gómez-Marcos and colleagues. (2013) where they found BMI as the best determinant of MetS in males and WC in females.

Concerning the above findings, it can be said that both males and females have different obesity indices to identify MetS. According to Zhang and colleagues. (2013) what causes gender differences among obesity indices is uncertain, but it was indicated that sex hormones, age, metabolism, anatomy, and physiology might play a partial role in the clarification of this. Hormones such as testosterone influences muscle mass to fat mass ratio in males where most develop android fat distribution mainly in the abdomen, chest and shoulder resulting in higher WC and WHtR (Bays et al., 2005). Nonetheless, oestrogen influences fat distribution in females where most develop gynoid fat distribution mainly around the hips, thighs and bottom when ageing (Bays et al., 2005).

Table 4.6.1. demonstrates standardised factor loading values for each of the four observed variables per model.

Table 4.6.1: Goodness-of-fit statistics for various factor models of metabolic syndrome among the Ellisras rural young adults.

Models for Males		**Measure of Fit**					**Models for Females**		**Measure of Fit**				
Factor Models	**Estimates**	**Chi-square (df)**	**CFI**	**TLI**	**RMSEA (CI) P-value**	**AIC**	**Factor Models**	**Estimates**	**Chi-square (df)**	**CFI**	**TLI**	**RMSEA (CI) P-value**	**AIC**
MAP	0.5273	Chi-square=0.12 Df=2 P-value=0.9418	1.000	1.112	0.000 (0.000;0.023) 0.971	-453.084	MAP	1.0000	Chi-square=3.84 Df=2 P-value=0.1463	0.90	0.71	0.050 (0.000;0.138) 0.352	-429.21
FBS	0.2227						FBS	0.1578					
TG	0.4786						TG	0.0952					
NC	0.4920						NC	0.1739					
MAP	0.4170	Chi-square=1.05 Df=2 P-value=0.5905	1.000	1.056	120.000 (0.000;0.097) 0.764	-2555.232	MAP	0.4787	Chi-square=10.87 Df=2 P-value=0.0044*	0.757	0.270	0.121 (0.058;0.195) 0.035	-2373.84
FBS	0.2033						FBS	0.0949					
TG	0.6015						TG	0.2507					
BMI	0.4760						BMI	0.5534					
MAP	0.4208	Chi-square= 1.14 Df=2 P-value=0.5652	1.000	1.051	0.000 (0.000;0.099) 0.747	-2680.055	MAP	0.3543	Chi-square= 11.36 Df=2 P-value=0.0034*	0.696	0.089	0.124 (0.061;0.198) 0.029	-2549.747
FBS	0.2254						FBS	0.0333					
TG	0.5824						TG	0.2938					
WC	0.4841						WC	0.6022					
MAP	0.4171	Chi-square= 1.32 Df=2 P-value=0.5178	1.000	1.046	0.000 (0.000;0.103) 0.712	-2661.463	MAP	0.3055	Chi-square=11.32 Df=2 P-value=0.0035*	0.657	0.028	0.124 (0.061;0.198) 0.030	-2533.703
FBS	0.2245						FBS	0.0188					
TG	0.5870						TG	0.3261					
WHtR	0.4312						WHtR	0.5746					

MAP=mean arterial pressure, FBG=fasting blood glucose, NC=neck circumference, BMI=body mass index. WC=waist circumference, WHtR=waist to height ratio, HDL=high density lipoprotein, TG=triglyceride, CFI= comparative fit index, TLI= tucker lewis index, RMSEA =root mean square error of approximation, AIC= akaike's information criterion, *p<0.001, chi-square test**.**

4.7. CONCLUSION

The findings of the current study showed an association between SSBs consumption and some MetS components (high TG, reduced HDL-C, and high FBG), suggesting no association between MetS and SSBs among young adults of the population studied. Moreover, it found the obesity indices such as WC, WHtR and NC as the better determinants of MetS. These obesity indices imply a likelihood to be used as the predictors of MetS, especially among young adults. Longitudinal studies are needed to investigate the association between SSBs consumption and MetS. and best obesity to use to identify MetS. Additionally, to further investigate the best obesity indices to determine MetS.

4.1.10. REFERENCES

Aeberli, I., Gerber, P.A., Hochuli, M., Kohler, S., Haile, S.R., Gouni-Berthold, I., Berthold, H.K., Spinas, G.A. and Berneis, K. (2011). Low to moderate sugar-sweetened beverage consumption impairs glucose and lipid metabolism and promotes inflammation in healthy young men: a randomized controlled trial*. The American Journal of Clinical Nutrition*, 94(2):479–485.

Akram, M. and Hamid, A. (2013). Mini review on fructose metabolism. *Obesity Research and Clinical Practice*, 7(2):e89–e94.

Alzeidan, R., Fayed, A., Hersi, A.S. and Elmorshedy, H. (2019). Performance of neck circumference to predict obesity and metabolic syndrome among adult Saudis: a cross-sectional study. *BMC Obesity*, 6(1):1–8.

Barrio-Lopez, M.T., Martinez-Gonzalez, M.A., Fernandez-Montero, A., Beunza, J.J., Zazpe, I. and Bes-Rastrollo, M. (2013). Prospective study of changes in sugar-sweetened beverage consumption and the incidence of the metabolic syndrome and its components: the SUN cohort. *British Journal of Nutrition*, 110(9):1722–1731.

Bays, H., Abate, N. and Chandalia, M. (2005). Adiposopathy: sick fat causes high blood sugar, high blood pressure and dyslipidemia. *Future Cardiology*, 1(1):39–59.

Bernabé, J.R.Y., Martínez, M.Á.G., Rodríguez, M.C. and Ruiz, A.S. (2013). Effects of exposure to food images on physiological reactivity and emotional responses in women with bulimia nervosa. *Psicothema,* 25(2):185–191.

Chen, H., Wang, J., Li, Z., Lam, C.W.K., Xiao, Y., Wu, Q. and Zhang, W. (2019). Consumption of sugar-sweetened beverages has a dose-dependent effect on the risk of non-alcoholic fatty liver disease: an updated systematic review and dose-response meta-analysis. *International Journal of Environmental Research and Public Health*, 16(12):2192.

DeBoer, M.D. (2019). Assessing and managing the metabolic syndrome in children and adolescents. *Nutrients*, 11(8):1788.

Deshpande, G., Mapanga, R.F. and Essop, M.F. (2017). Frequent sugar-sweetened beverage consumption and the onset of cardiometabolic diseases: cause for concern. *Journal of the Endocrine Society*, 1(11):1372–1385.

Dhingra, R., Sullivan, L., Jacques, P.F., Wang, T.J., Fox, C.S., Meigs, J.B., D'Agostino, R.B., Gaziano, J.M. and Vasan, R.S. (2007). Soft drink consumption and risk of developing cardiometabolic risk factors and the metabolic syndrome in middle-aged adults in the community. *Circulation*, 116(5):480–488.

Ejtahed, H.S., Bahadoran, Z., Mirmiran, P. and Azizi, F. (2015). Sugar-sweetened beverage consumption is associated with metabolic syndrome in Iranian adults: Tehran lipid and glucose study. *Endocrinology and Metabolism*, 30(3):334–342.

Fan, H., Li, X., Zheng, L., Chen, X., Wu, H., Ding, X., Qian, D., Shen, Y., Yu, Z., Fan, L. and Chen, M. (2016). Abdominal obesity is strongly associated with Cardiovascular Disease and its Risk Factors in Elderly and very Elderly Community-dwelling Chinese. *Scientific Reports*, 6(1):1–9.

Feig, D.I., Kang, D.H. and Johnson, R.J. (2008). Uric acid and cardiovascular risk. *New England Journal of Medicine*, 359(17):1811–1821.

Gómez-Marcos, M.A., Patino-Alonso, M.C., Recio-Rodríguez, J.I., Antón-Alvarez, J., Cabrejas-Sánchez, A., Fernandez-Alonso, C., Rubio-Galán, J., Arce, V. and García-Ortiz, L. (2013). Confirmatory factor analysis to assess the measure of adiposity that best fits the diagnosis of metabolic syndrome and relationship to physical activity in adults. *European Journal of Nutrition*, 52(5):1451–1459.

Hallam, J., Boswell, R.G., DeVito, E.E. and Kober, H. (2016). Focus: sex and gender health: gender-related differences in food craving and obesity. *The Yale Journal of Biology and Medicine*, 89(2):161.

Halonen, J.I., Zanobetti, A., Sparrow, D., Vokonas, P.S. and Schwartz, J. (2011). Outdoor temperature is associated with serum HDL and LDL. *Environmental Research*, 111(2):281–287.

Jaffer, N., Steyn, N.P. and Peer, N. (2011). Dietary data from the CRIBSA study. Unpublished Master's thesis. University of Cape Town. Cape Town.

Kruger, M.J. and Nell, T.A. (2017). The prevalence of the metabolic syndrome in a farmworker community in the Boland district, South Africa. *BMC Public Health*, 17(1):1–10.

Laohabut, I., Udol, K., Phisalprapa, P., Srivanichakorn, W., Chaisathaphol, T., Washirasaksiri, C., Sitasuwan, T., Chouriyagune, C. and Auesomwang, C. (2020). Neck circumference as a predictor of metabolic syndrome: A cross-sectional study. *Primary Care Diabetes*, 14(3):265–273.

Luo, Y., Ma, X., Shen, Y., Xu, Y., Xiong, Q., Zhang, X., Xiao, Y., Bao, Y. and Jia, W. (2017). Neck circumference as an effective measure for identifying cardio-metabolic syndrome: a comparison with waist circumference. *Endocrine*, 55(3):822–830.

Lustig, R.H., Schmidt, L.A. and Brindis, C.D. (2012). The toxic truth about sugar. *Nature*, 482(7383):27–29.

Malik, V.S., Hu, B., Walter, A.P., and Willet, W.C. (2013). Sugar-sweetened beverages and weight gain in children and adults: A systematic review and meta-analysis. *American Journal of Clinical Nutrition*. 98(4):1084–1102.

Malik, V.S. and Hu, F.B. (2019). Sugar-sweetened beverages and cardiometabolic health: an update of the evidence. *Nutrients*, 11(8):1840.

Maris, M.E., Melchert, R.B., Joseph, J. and Kennedy, R.H. (2005). Gender differences in blood pressure and heart rate in spontaneously hypertensive and Wistar-Kyoto rats. *Clinical and Experimental Pharmacology and Physiology*, 32(1-2):35–39.

Mirmiran, P., Yuzbashian, E., Asghari, G., Hosseinpour-Niazi, S. and Azizi, F. (2015). Consumption of sugar sweetened beverage is associated with the incidence of metabolic syndrome in Tehranian children and adolescents. *Nutrition and Metabolism*, 12(1):1–9.

Motamed, N., Zamani, F., Rabiee, B., Saeedian, F.S., Maadi, M., Akhavan-Niaki, H. and Asouri, M. (2016). The best obesity indices to use in a single factor model

indicating metabolic syndrome: a population-based study. *Archives of Iranian Medicine*, 19(2):110–115.

Muluvhu, T.C., Monyeki, M.A., Strydom, G.L. and Toriola, A.L. (2018). Relationship between selected metabolic risk factors and waist-to-height ratio among employees in Vhembe district municipality of Limpopo province, *South Africa. Asian Journal of Scientific Research*, 11(1):42–50.

Myers, J., Kokkinos, P. and Nyelin, E. (2019). Physical activity, cardiorespiratory fitness, and the metabolic syndrome. *Nutrients*, 11(7):1652.

Nederkoorn, C., Smulders, F.T.Y. and Jansen, A. (2000). Cephalic phase responses, craving and food intake in normal subjects. *Appetite*, 35(1):45–55.

Patil, C., Deshmukh, J., Yadav, S., Patil, S. and Sheikh, A. (2017). Neck circumference: A novel anthropometric tool for screening obesity in adults. *International Journal of Collaborative Research on Internal Medicine and Public Health*, 9(7):711–720.

Peer, N., Steyn, K. and Levitt, N. (2016). Differential obesity indices identify the metabolic syndrome in Black men and women in Cape Town: the CRIBSA study. *Journal of Public Health*, 38(1):175–182.

Perez-Pozo, S.E., Schold, J., Nakagawa, T., Sánchez-Lozada, L.G., Johnson, R.J. and Lillo, J.L. (2010). Excessive fructose intake induces the features of metabolic syndrome in healthy adult men: role of uric acid in the hypertensive response. *International Journal of Obesity*, 34(3):454–461.

Rochlani, Y., Pothineni, N.V. and Mehta, J.L. (2015). Metabolic syndrome: does it differ between women and men? *Cardiovascular Drugs and Therapy*, 29(4):329–338.

Ronquest-Ross, L.C., Vink, N. and Sigge, G.O. (2015). Food consumption changes in South Africa since 1994. *South African Journal of Science*, 111(9-10):01–12.

Ruxton, C.H., Gardner, E.J. and Walker, D. (2006). Can pure fruit and vegetable juices protect against cancer and cardiovascular disease too? A review of the evidence. *International Journal of Food Sciences and Nutrition*, 57(3-4):249–272.

SDBIP. Available online: http://www.lephalale.gov.za/documents/sdbip.php (accessed on 17 September 2021).

Sekgala, M.D., Monyeki, K.D., Mogale, A., Mchiza, Z.J., Parker, W., Choma, S.R. and Makgopa, H.M. (2018). The risk of metabolic syndrome as a result of lifestyle among Ellisras rural youth. *Journal of Human Hypertension*, 32(8):572–584.

Shin, S., Kim, S.A., Ha, J. and Lim, K. (2018). Sugar-sweetened beverage consumption in relation to obesity and metabolic syndrome among Korean adults: a cross-sectional study from the 2012–2016 Korean national health and nutrition examination survey (KNHANES). *Nutrients*, 10(10):1467.

Shrestha, N. (2018). Neck circumference as an indicator of overweight and obesity in youth. *American Journal of Applied Mathematics and Statistics*, 6(5):176–180.

Solomi, L., Rees, G.A. and Redfern, K.M. (2019). The acute effects of the non-nutritive sweeteners aspartame and acesulfame-K in UK diet cola on glycaemic response. *International Journal of Food Sciences and Nutrition*, 70(7):894–900.

Solomon, S. and Mulugeta, W. (2019). Disease burden and associated risk factors for metabolic syndrome among adults in Ethiopia. *BMC Cardiovascular Disorders*, 19(1):1–8.

Steyn, N.P., Myburgh, N.G. and Nel, J.H. (2003). Evidence to support a food-based dietary guideline on sugar consumption in South Africa. *Bulletin of the World Health Organization*, 81:599–608.

Tal, S., Litovchik, I., Klar, M.M., Maresky, H.S., Grysman, N., Wiser, I., Vitkon-Barkay, I., Marcus, G., Tzuman, O., Pereg, D. and Rum, V. (2019). The association between neck adiposity and long-term outcome. *PloS One*, 14(4):e0215538.

Temple, N.J. and Steyn, N.P. (2013). Sugar and health: a food-based dietary guideline for South Africa. *South African Journal of Clinical Nutrition*, 26:S100–S104.

Vorster, H.H., Kruger, A., Wentzel-Viljoen, E., Kruger, H.S. and Margetts, B.M. (2014). Added sugar intake in South Africa: findings from the Adult Prospective Urban and Rural Epidemiology cohort study. *The American Journal of Clinical Nutrition*, 99(6):1479–1486.

Zając-Gawlak, I., Pelclová, J., Groffik, D., Přidalová, M., Nawrat-Szołtysik, A., Kroemeke, A., Gába, A. and Sadowska-Krępa, E. (2021). Does physical activity lower the risk for metabolic syndrome: a longitudinal study of physically active older women. *BMC Geriatrics*, 21(1):1–9.

Zhang, Z.Q., Deng, J., He, L.P., Ling, W.H., Su, Y.X. and Chen, Y.M. (2013). Comparison of various anthropometric and body fat indices in identifying cardiometabolic disturbances in Chinese men and women. *Plos One*, 8(8):e70893.

Zhang, X., Li, X., Liu, L., Hong, F., Zhao, H., Chen, L., Zhang, J., Jiang, Y., Zhang, J. and Luo, P. (2021). Dose-response association between sugar-and artificially sweetened beverage consumption and the risk of metabolic syndrome: A meta-analysis of population-based epidemiological studies. *Public Health Nutrition*, 24(12):3892–3904.

Zhou, J.Y., Ge, H., Zhu, M.F., Wang, L.J., Chen, L., Tan, Y.Z., Chen, Y.M. and Zhu, H.L. (2013). Neck circumference as an independent predictive contributor to the cardio-metabolic syndrome. *Cardiovascular Diabetology*, 12(1):1–7.

CHAPTER 5

5.1. Introduction

5.2. Summary (Brief overview of Chapter 1, 2, 3, 4)

5.3. Perspective

5.4. Limitations

5.5. Recommendations

5.6. References

5.1. INTRODUCTION

This chapter summarises the results of the research study, it includes all the explanations and discussion of the main findings according to the hypothesis and the questions asked in chapter 1 and appropriate conclusions are made. This is followed by limitations and recommendations for future research concerning the association between SSBs intake and risk of MetS and the best obesity indices to use to identify MetS among Ellisras youth.

5.2. SUMMARY

Chapter 1 outlined the motivation for investigating the association between the consumption of SSBs and the risk of MetS in Ellisras rural areas in the Limpopo Province of South Africa. The need to further investigate the best obesity indices to identify MetS was also indicated. The subsequent objectives of the study which were stated in chapter one we're used to answering the above statements and are as follows:

I. Determine the prevalence of SSBs using a 24-hr recall questionnaire amongst Ellisras rural youth aged 22 to 30 years.

II. Determine the prevalence of MetS components (TG, HDL-C, FBG, WC, SBP, DBP) amongst Ellisras rural youth aged 22 to 30 years.

III. Determine which MetS components (TG, HDL-C, FBG, WC, SBP, DBP) are associated with the SSBs consumption amongst Ellisras rural youth aged 22 to 30 years.

IV. Determine if there was a risk of developing MetS following SSBs intake amongst Ellisras rural youth aged 22 to 30 years.

V. Determine the best obesity indices for identifying Mets amongst Ellisras rural youth aged 22 to 30 years.

VI. Determine if there is a correlation between obesity indices (BMI, WHtR, WC, NC) with MetS components (HDL-C, FBG, WC, MAP (SBP, DBP)) amongst Ellisras rural youth aged 22 to 30 years.

VII. Determine if there was a correlation between the SSBs consumption and MetS components amongst Ellisras rural youth aged 22 to 30 years.

Chapter 2, In the literature, the SUN prospective study of follow up of 6 years duration reported that “an increase in the consumption of SSBs is associated with high blood pressure, hypertriacylglycerolaemia, central obesity and impaired fasting blood glucose” (Barrio-Lopez et al., 2013). High consumption of SSBs also increases other risk factors associated with MetS such as gout, cancers, diabetes, increased uric acid levels, non-alcoholic fatty liver diseases, CVDs, and obesity to name a few (Knopp et al., 2005; Malik and Hu 2019). However, other studies indicated that not all types of SSBs are associated with the risk of developing MetS (Imamura et al., 2015; Imamura et al., 2019). It was reported in the literature that substitution of soft drinks/ carbonated drinks with water, plain tea, coffee, fresh fruit juice and milk amongst the others was associated with low risk of weight gain, obesity, T2DM and 29% reduction in risk of MetS (de Koning et al., 2011; Pan et al., 2013; Zheng et al., 2015; Pienovi et al., 2018; Imamura et al., 2019). Moreover, it was reported that obesity indices such as BMI, WC, WHtR and NC are used extensively to measure metabolic health effects (Fan et al., 2016; Shrestha et al., 2018; Tal et al., 2019).The BMI, WC and WHtR were reported as the simplest indices to precisely assess overall and central/abdominal obesity which are known to have a strong link with adverse metabolic health complications (Fan et al., 2016; Shrestha et al., 2018; Tal et al., 2019). The NC, on the other hand, was also reported as a relevant technique to identify measures of MetS and found to correlate positively with BMI, WC and WHtR in assessing metabolic risk factors (Luo et al., 2017; Patil et al., 2017; Alzeidan et al., 2019).

Chapter 3, the cross-sectional design of the study was explained. The methods that were followed to collect the data and how the data was analysed were also stated in this chapter. Logistic regression analysis was used to determine the association between SSBs consumption and risk of MetS. Goodness-of-fit statistics for various factor models were used to identify the best obesity index to determine MetS.

Chapter 4, the description of the results and the discussion were stated. In the Ellisras population the highest SSBs quartile was significantly associated with increased risk of high FBG ($p<0.05$) where there was a significant linear trend (p for trend=0.049) in SSBs quartiles in males. High TG indicated a fluctuating trend (p for trend =0.041) with increasing SSBs quartiles categories for males. Reduced HDL-C was associated with both the lower and higher SSBs quartiles ($p<0.05$) whereas the highest SSBs quartile likely decreased the risk of high TG ($p<0.05$) in females. Moreover, there was a significant linear trend observed among the quartiles (p trend =0.001). Additionally, there was no significant association between SSBs consumption and WC ($p>0.05$) but a significant linear trend across the SSBs quartile categories (p trend=0.001) in females. These findings are partly similar with those found in previous studies (Dhinga et al., 2007; Barrio-Lopez et al., 2013; Ejtahed et al., 2015). In males, a single model fit built based on WC and WHtR suggested a better fit index as compared to NC and BMI. Single model fit built on NC obtained a better fit index than other obesity indices in females.

In conclusion, the findings of the current study showed an association between SSBs consumption and some MetS components (high TG, reduced HDL-C, and high FBG). Moreover, the findings of the current study suggest that obesity indices such as WC, WHtR in males and NC in females can be used as important diagnostic tools in predicting MetS because of their stronger ability to precisely reflect visceral fats which are strongly linked to metabolic complications. Future work is needed to build on the current studies' results to investigate further on inflammatory variables such as C-reactive protein since it was proposed as a component of MetS, HOMA-IR can be added to the model as a measure of insulin resistance and last optimal cut-points of the obesity indices using Receiver Operating Characteristic (ROC) can be found. Longitudinal clinical studies with a longer duration are needed to further investigate the pathway/mechanism in which the consumption of SSBs results in MetS on a molecular level in rural South African settings.

Interpretation of the main findings and a comparison with the relevant literature together with the objectives and hypothesis stated in chapter 1.

Objective 1: Determine the prevalence of SSBs using a 24-hr recall questionnaire for Ellisras rural youth aged 22 to 30 years.

i. Hypothesis 1: The prevalence of SSBs consumption will be high amongst Ellisras participants compared to those studied in the world.

In our results, females showed a high SSBs consumption with the higher quartile Q4 having (31.3 %) than males (26.6%). The current result reported higher consumption or prevalence of SSBs among females compared to males which corroborate with the finding of the previous study conducted in rural areas that found the higher consumption of sucrose-sweetened beverages among women with 33% to 63% than 25% to 56% for men (Voster et al., 2014). However, the current study found a lower prevalence of SSBs consumption in both females and males compared to that reported by (Voster et al., 2014). In the literature, the physiological explanation in the differences and increase in sugar/sweet food cravings results from a difference in hormonal concentration and mechanisms between males and females, where hormones such as testosterone, progesterone and oestrogen play an important role in regulating food cravings and consumption (Hallam et al., 2016). Moreover, in females, craving for sugar or sweet food is increased when approaching the monthly period (Hallam et al., 2016). It was also explained that interaction in sociological, environmental, and biological factors also accounts for the differences in food craving (Hallam et al., 2016). In support of the above statement studies conducted by (Nederkoorn et al., 2000; Bernabe et al., 2013) reported that repeated exposure to taste, visual or olfactory cues are very significant in cue-induced craving while at the same time increasing the signal of salivation, heart, and gastric activity. Moreover, internal factors such as feelings (boredom, loneliness, sadness etc) may as well generate restless anticipations that often leads to individuals eating more than required (Bernabe et al., 2013).

With regard to the above results, the hypothesis is therefore accepted.

Objective 2: Determine the prevalence of MetS components (HDL-C, FBG, WC, SBP, DBP) among the Ellisras rural youth aged 22-30 years.

ii. Hypothesis 2: The prevalence of most of MetS components (FBG, HDL-C, WC, SBP and DBP) will be high among Ellisras rural youth aged 22-30 years compared to those studied in the world.

The current study found that the third SSBs quartile demonstrated a higher prevalence of high FBG in females (64.5%) compared to males (35.5%). These findings are higher than those reported by (Muluvhu et al., 2018). In the study conducted in the Vhembe district of the Limpopo Province (Muluvhu et al., 2018) it was found that the prevalence of FBG was higher in females (28%) than (19%) in males and this supports what was found in the current study.

The prevalence of low HDL-C and WC was significantly higher in females (74.7%, 69.7%, 70.0%, 70.3%; 70.4%, 66.0%, 80.0%, 68.2%) respectively compared to males (25.3%, 30.3%, 30.0, 29.7%; 29.6%, 34.0%, 20.0%, 31.8%) respectively and also showed fluctuations across all the four SSBs quartiles. These prevalence's are higher than those reported in the Western Cape by (Kruger et al., 2017). Kruger et al. (2017) reported that women demonstrated a higher prevalence of abdominal obesity as measured by WC (63.3%) and low HDL-C (61.2%) compared to (31.7% and 39.0% respectively) of men (Kruger et al., 2017). There are several possible explanations for the above findings. First, the physiological explanation of the current findings might be that female sex hormones such as oestrogen (Maris et al., 2005) exposes them to increased levels of TG and HDL-C. Second, Rochlani et al. (2015) further indicated that gender difference in lipid profile is explained by a combination of the effect of hormones, hepatic lipase, and lipoprotein lipase activity, where women have higher lipoprotein lipase activity which favours more cholesterol metabolism and results in higher reduced HDL and TC compared to males. Third, the elevated WC or higher abdominal obesity seen among females could be attributed and influenced by factors related to social attitudes toward fatness and cultural norms, wherein African countries being fat is regarded as a sign of happiness, wealth, and attractiveness, especially in females (Peer et al., 2016).

The prevalence of high SBP was significantly higher among males (82.1%, 80.0%, 80.0%, 78.3%) compared to females (17.9%, 20.0%, 20.0%, 21.7%) and decreased with higher intakes of SSBs across all the four SSBs quartiles. Meanwhile, high DBP (100%) among males was significantly prevalent only in the first SSBs quartile and it was higher as compared to that of females (0%). These results suggest a higher prevalence of blood pressure issues among males as compared to females. Similar

findings were previously reported in the Ellisras population by Sekgala et al. (2018) where the prevalence of both SBP and DBP were higher in males than in females. Furthermore, supporting results were also found in a study conducted by Solomon and Mulugeta. (2019) among the Ethiopian population where elevated blood pressure was seen in men (65%) more than in women (53%). The high prevalence of SBP and DBP or blood pressure was higher in the current study compared to that reported by (Sekgala et al., 2018 and Solomon and Mulugeta, 2019). Maris et al. (2015) indicated in an animal model that female sex hormones such as oestrogen are more protective against hypertension, and this partly explains why young females might be at a lower risk of developing hypertension compared to their counterparts' males. This suggests that age plays a significant role in the development of hypertension or having elevated blood pressure (Rochlani et al., 2015).

With regard to these findings, the original hypotheses are now addressed thus accepted.

Objective 3: Determine which MetS components (TG, HDL-C, FBG, WC, SBP, DBP) were associated with the SSBs consumption among the Ellisras rural youth aged 22 to 30 years.

iii. Hypothesis 3: All the components of MetS will be significantly associated with the consumption of SSBs amongst ELS rural youth aged 22 to 30 years.

The SSBs quartile 4 was associated with a high risk of high FBG for adjusted (OR=2.32; CI=1.15-4.70; p<0.05) and unadjusted (OR=2.34; CI=1.16-4.73; p<0.05) model were a significant linear trend (p for trend=0.049) was found in males. Low risk of reduced HDL-C was associated with the second and fourth SSBs quartiles for unadjusted ((OR=0.40; CI=0.18-0.85; p<0.05; OR=0.37; CI=0.13-0.80; p<0.05) respectively and adjusted (OR=0.40; CI=0.18-0.85; p<0.05; OR=0.37; CI=0.17-0.80; p<0.05) respectively in females. Moreover, the fourth SSBs quartile was likely to decrease the risk of high TG for unadjusted (OR=0.12; CI=0.01-0.87; p<0.05) and adjusted (OR=0.10; CI=0.01-0.83; p<0.05) models were the significant linear trend (p= trend 0.006) was observed. There was a significant linear trend association between SSBs quartiles consumption and high TG in males and high WC in females,

but logistic regression analysis didn't depict any association ($p>0.05$). These findings are partly similar to those reported in the literature which found a significant association of higher consumption of SSBs with a higher incidence of obesity, MetS and its components that include hypertriacylglycerolaemia, central obesity/increased WC, impaired fasting glucose, high blood pressure/hypertension, and low HDL-C compared to lower SSBs intake (Dhinga et al., 2007; Barrio-Lopez et al., 2013). Moreover, Ejtahed et al. (2015) reported that the participants in the higher SSBs quartile had a 35% increased risk of abdominal obesity, 27% risk of high BP, 24% risk of reduced HDL-C than those in the lowest quartile of SSBs consumption. Ejtahed et al. (2015) further explained that the risk of developing MetS and its components showed an increasing linear trend across the increasing SSBs quartiles which was in contradiction with what was reported in the current study which reported a fluctuating linear trend across the SSBs quartiles categories. However, this confirms the previous report that have shown a non-linear trend between the SSBs consumption and MetS and that it does not always follow the dose-response relationship (Zhang et al., 2021). The types of SSBs such as fruit juices, tea, coffee among others might partly explain the low risk found in the current study because their constituents or ingredients such as antioxidants, minerals, proteins fibre and vitamins lower the risk of developing diseases (Ruxton et al., 2006). In the literature physical activity was reported as one of the protective measures that reduce the risk of developing diseases because of its ability to increase energy expenditure, improve metabolic profile, insulin sensitivity and maintain a healthy body balance (DeBoeer, 2019; Myers et al., 2019; Zając-Gawlak et al., 2021). However, in the current study participants might have been involved in activities that increased their physical activity such as farming, walking long distances herding livestock, fetching water or firewood (Lephalale Gov, 2018), and would have decreased their risk of MetS.

In line with the findings reported above, we thus reject the hypothesis.

Objective 4: Determine if the Ellisras rural youth was at risk of developing MetS following SSBs intake.

iv. Hypothesis 4: ELS rural youth aged 22 to 30 years will be at higher risk of developing MetS as compared to those studied in other parts of the world.

According to the joint interim statement by the IDF and various organisations (Alberti et al., 2009) an individual is diagnosed with MetS if having any three or more of the MetS components. In referring to the above-mentioned statement, females of the current study had reduced HDL-C, and high TG which was associated with the consumption of SSBs while males had high FBG which was associated with SSBs consumption. Therefore, the current study participants are at a lower risk of developing MetS as compared to those reported in the study by Ejtahed et al. (2015) who found increased odds of developing MetS as well as 35% higher odds of abdominal obesity, 24% odds of low HDL-C and 27% higher odds of elevated BP. The low risk of developing MetS found in the current study could have been from factors such as increased physical activity which might have resulted from activities such as walking long distances to fetch water and firewood, herding livestock in the field and doing farming (Lephalale Gov, 2018). This might have masked the effect of a high intake of SSBs and have resulted in a lower risk of MetS. Moreover, in the literature fruits juices, tea, coffee with cream milk were reported to be the second most consumed SSBs types after soft drinks by both the urban and rural dwellers (Temple and Steyn, 2013; Ronquest-Ross et al., 2015). However, the current study participants might also have consumed the above mentioned SSBs type which was reported to have the ability to protect against the diseases because of ingredients or constituents such as fibre, proteins, vitamins and minerals, protein, and antioxidants.

In line with the findings reported above, we thus reject the hypothesis.

Objective 5: Determine the best obesity indices for identifying Mets amongst ELS rural youth aged 22 to 30 years.

v. Hypothesis 5: All the obesity (BMI, WHtR, WC and NC) could identify MetS amongst ELS rural youth aged 22 to 30 years compared to those studied in the world.

In males, a single model fit built based on WC and WHtR suggested a better fit index than NC and BMI. Whereas in females single model fit built on NC obtained a better fit index compared to BMI, WC, WHtR. This disagreed with the results of Gómez-Marcos and colleagues. (2013) where they found that BMI was the best determinant of MetS in males and WC in females. The probable reason to account

for these differences could be that the participants were from a Spanish population and the study focused on a full adult age range (20–80 years) in the study by Gomez-Marcos et al. (2013) whereas in the current study only black youth aged 22-30 years were included. Neck circumference was reported to be the reliable, relevant, and best practical obesity index in females to determine MetS than other indices since it can be used to overcome or avoid limitations of WC, WHtR and BMI especially in health conditions that might affect the validity of measurements (Laasko et al., 2002; Hoebel et al., 2014). The health conditions include when the female participant is overweight or obese, pregnant, as well as in postmenopausal or menopausal status (Laasko et al., 2002; Hoebel et al., 2014). This is appropriate given that females in the current study are at childbearing age and ought to gain weight with each pregnancy. In addition, NC was also reported to have the ability to reflect the deposition of fat in the abdomen region which was reported to be associated with the release of basal and postprandial free fatty acids (FFAS) (Ferrannini et al., 2008; Koutsari, et al., 2008). In addition, the FFAS were reported to be commonly stored in subcutaneous tissue in females, however, this storage might partly explain the difference between the two genders (Ferrannini et al., 2008; Koutsari, et al., 2008). Additionally, it has been reported in literature that males tend to have an android body shape thus their fat distribution is mainly on the abdomen, chest, and shoulders which is indicative of the upper body fat distribution (Fan et al., 2016; Shrestha, 2018). Furthermore, the current study found WC and WHtR found as the simplest appropriate indices in males to assess central/abdominal obesity and a better predictor of metabolic health complications (Fan et al., 2016; Shrestha, 2018). However, BMI was found to be a poor reflection of body fat because of its inability to differentiate fat mass with fat-free mass and central obesity with abdominal obesity, even though it was reported to be used extensively in epidemiological studies (Peer et al., 2016; Anothaisintawee et al., 2019). However, this might form part of the reason why it was not the best obesity indices to determine MetS in both females and males of the current study.

With regard to the above-reported findings, we, therefore, reject the hypothesis.

Objective 6: Determine if there was a correlation between obesity indices (BMI, WHtR, WC, NC) with MetS components (TG, HDL-C, FBG, WC, MAP (SBP, DBP)).

vi. Hypothesis 6: All the obesity indices will be correlated with MetS components among ELS rural youth aged 22 to 30 years.

The current study found that all the four obesity indices (NC, WC, WHtR and BMI) were correlated with MetS components (MAP, FBG, TG and HDL-C). These findings corroborate with the findings reported in the literature by Zhou et al. (2013) and Laohabut et al. (2020) who also reported a correlation between NC, BMI, WC and MetS components (SBP&DBP, FBG, TG and HDL). This is appropriate because it was reported in the literature that BMI is the better commonly used method to classify obesity meanwhile, the WC and WHtR are the simplest obesity indices commonly method used to reflect visceral fat content (Ashwell et al., 2014; Ching et al., 2020). Therefore, the latter obesity indices were reported to be better predictors of not only MetS but also other cardiometabolic risk factors and mortality (Ashwell et al., 2014; Ching et al., 2020). Subsequently, the NC was also suggested as the best effective method to predict cardiometabolic factors and MetS because it was indicated that neck fat content is highly correlated with visceral fat content which is linked with an adverse metabolic health effect (Laasko et al., 2002; Ashwell et al., 2014; Hoebel et al., 2014; Ching et al., 2020).

With regard to the above finding, we, therefore, accept the hypothesis.

Objective 7: Determine if there was a correlation between the consumption of SSBs and MetS components (TG, HDL-C, FBG, WC, SBP, and DBP).

vi. Hypothesis 6: All the MetS components (TG, HDL-C, FBG, WC, SBP, and DBP) among ELS rural youth aged 22 to 30 years will correlate with the consumption of SSBs.

The correlation between the consumption of SSBs and all the MetS was non-significant ($p>0.05$) and very weak (ranging from $r=-0.026$ to $r=0.101$) in males meanwhile in females only TG ($r=-0.163$; $p=0.013$) and WC ($r=-0.151$; $p=0.021$) had a significant negative correlation. This contradicted with the finding reported by Shin

et al. (2018), where a positive association between SSBs consumption and BMI, TG, FBG and DBP in women while in men consumption of SSBs was associated with DBP and not associated with BMI and other MetS components. In the study conducted by Shin et al. (2018) a larger sample size was used (121120), FFQ was used to assess SSBs data, age group of 35-65 years were considered, and NCEP/ATP III was used to define MetS; while in the latter study a small sample size was used (593); a 24-hr questionnaire, included age group of 22-30 years old and used JIS to define MetS. The small sample size and the cross-sectional design and the 24hr questionnaire used in this study might partly explain why there was a weak and non-significant correlation between SSBs consumption and MetS components.

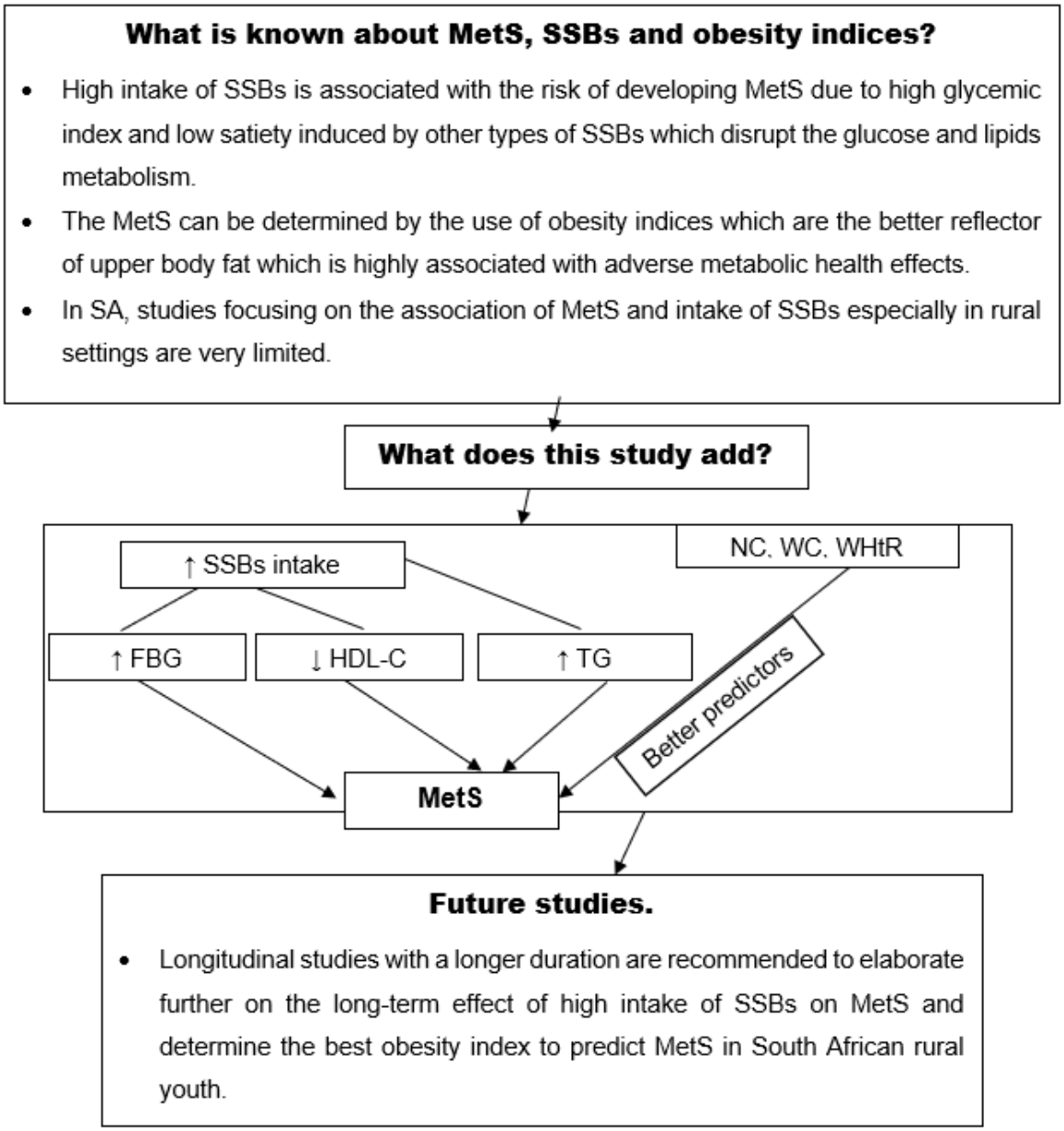

Figure 5.2.1. Shows the summary of the main results of the study.

5.3. PERSPECTIVES OF THE STUDY

This study highlights a low risk of MetS because of high SSBs consumption among the study participants. Another important aspect was that a non-linear association between SSBs intake and MetS components was found suggesting a non-dose-response relationship and this confirms the findings of previous reports (Zhang et al., 2020). These results also provide novel evidence that gender plays a significant role in the consumption of SSBs and in the development of MetS which supports the findings of previous studies (Kuk and Ardern, 2010). These findings are very

significant for South Africa which consists of a large number of youths with a high unemployment rate (Erzse et al., 2019; Okop et al., 2019) and who are the target of SSBs markets. Therefore, increased consumption of SSBs should be discouraged since lifestyle choices and habits established during this period (Winpeny et al., 2017) might progress and be practised later on in life. Moreover, MetS risk factors attained during this period (youth) might progress to adulthood or elderly hood. This could further exacerbate the burden of cardiovascular risk factors which was reported to prevail (Sebati et al., 2019) in the Ellisras area. Researching about this topic is very significant and could serve as a basis for intervention programs to consider gender when formulating programmes. Moreover, the programmes could focus on protective measures that support increased physical activity and healthier eating habits to better manage and prevent the alarming increase in non-communicable diseases in South Africa. Furthermore, the use of obesity indices in these populations can help screen and diagnose MetS as well as identify individuals at risk of health complications with the purpose of managing, preventing, and treating the metabolic risk factors while still at the early stages.

5.4. LIMITATIONS

It is of utmost importance to note factors that might have influenced the finding of the current study. This includes factors such as the study design, methodology and statistical analysis.

- Due to the cross-sectional design of the study, the SSBs consumption pattern (such as employment status, education, time of the month and etc.) of participants overtime was not shown, nor was the causal relationship with MetS.
- Although the study used a validated 24-hour dietary recall method for the collection of SSBs data, this method relies mostly on participant's memory to recall the beverages consumed the past 24-hours and it is not able to indicate the individual's day-to-day long term inter variability (Shim et al., 2014) and this might have an impact on the accuracy of the results.
- The study did not control for potential confounders such as socioeconomic and lifestyle factors such as physical activity, smoking, alcohol consumption, and energy intake because only a few significant associations were obtained.

Furthermore, the above statement provides the reason for minimal effect after controlling by age. However, according to Malik and colleague. (2019) the advantage of adjusting with fewer confounders is its generalisability for the real world because study participants are prone to change their lifestyle without the investigator's knowledge and intervention.

- The participants in this study resided in the rural areas of the Ellisras of the Limpopo Province as a result the current sample of the population cannot be generalised and be observed as a representative sample of other rural areas of South Africa. Moreover, only rural black youth were the focus of the study; therefore, this should be investigated further on other ethnic groups living in the urban area to allow comparison since SSBs consumption and risk of MetS might differ by region, gender, ethnic group, and the criterion used to define it (Rochlani et al., 2015).
- Additionally, the study only explored the association on youth thus a focus can also be put on different age groups.
- This current study is part of the current ongoing ELS which aimed to identify causes of non-communicable diseases and lifestyle modification, thus it was not designed particularly to address the hypotheses articulated in the current study. However, it is well known that SA has the highest prevalence rate of Mets and was ranked the seventh globally with the highest SSBs sales thus studies investigating the association between MetS and SSBs are very limited especially in rural areas of SA. Therefore, the current study will provide new data on the association of SSBs consumption and MetS. Moreover, on the best obesity indices to predict MetS.
- It must be noted that the associations found in the current study might probably be by chance even when bivariate logistic regression analysis was used in the adjusted model.

Strength of the study

- The study was well designed, done under controlled and adhered to all of the standard procedures.
- To the authors best knowledge, it was the first study to investigate the association between SSBs consumption with MetS and the best obesity indices to predict MetS among rural youth.

5.5. RECOMMENDATIONS

- Longitudinal studies are suggested to investigate the long-term association between the SSBs intake and risk of MetS.
- Extensive statistical analyses should be included in future longitudinal studies.
- Tax or levies should be imposed on SSBs to increase the prices and reduce the purchase and consumption.
- Low-calories beverages or water can be chosen over SSBs.
- Promotion and health intervention programmes can implement education and awareness campaigns or programmes to promote nutritional knowledge, the practice of healthy lifestyles such as decreasing in SSBs intake and change in attitude and behaviours towards SSBs especially in rural communities.
- It should be mandatory for food industries to reduce the sugar content of SSBs.
- Restriction of advertisement and promotion of SSBs through all kinds of media.
- Future longitudinal studies can implement WHtR, WC and NC as determinants of MetS to support the finding of the current study, especially in South African rural settings.
- Future large longitudinal studies are suggested to investigate the best obesity indices to determine MetS.

5.6. REFERENCES

Alberti, K.G.M.M., Eckel, R.H., Grundy, S.M., Zimmet, P.Z., Cleeman, J.I., Donato, K.A., Fruchart, J.C., James, W.P.T., Loria, C.M. and Smith Jr, S.C. (2009). Harmonizing the metabolic syndrome: a joint interim statement of the international diabetes federation task force on epidemiology and prevention; national heart, lung, and blood institute; American heart association; world heart federation; international atherosclerosis society; and international association for the study of obesity. *Circulation*, 120(16):1640–1645.

Alzeidan, R., Fayed, A., Hersi, A.S. and Elmorshedy, H. (2019). Performance of neck circumference to predict obesity and metabolic syndrome among adult Saudis: a cross-sectional study. *BMC Obesity*, 6(1):1–8.

Anothaisintawee, T., Sansanayudh, N., Thamakaison, S., Lertrattananon, D. and Thakkinstian, A. (2019). Neck circumference as an anthropometric indicator of central obesity in patients with prediabetes: a cross-sectional study. *BioMed Research International*, 2019:1–8.

Ashwell, M., Mayhew, L., Richardson, J. and Rickayzen, B. (2014). Waist-to-height ratio is more predictive of years of life lost than body mass index. *PloS One*, 9(9):e103483.

Barrio-Lopez, M.T., Martinez-Gonzalez, M.A., Fernandez-Montero, A., Beunza, J.J., Zazpe, I. and Bes-Rastrollo, M. (2013). Prospective study of changes in sugar-sweetened beverage consumption and the incidence of the metabolic syndrome and its components: the SUN cohort. *British Journal of Nutrition*, 110(9):1722–1731.

Bernabé, J.R.Y., Martínez, M.Á.G., Rodríguez, M.C. and Ruiz, A.S. (2013). Effects of exposure to food images on physiological reactivity and emotional responses in women with bulimia nervosa. *Psicothema*, 25(2):185–191.

Ching, Y.K., Chin, Y.S., Appukutty, M., Gan, W.Y. and Chan, Y.M. (2020). Comparisons of conventional and novel anthropometric obesity indices to predict metabolic syndrome among vegetarians in Malaysia. *Scientific Reports*, 10(1):1–13.

DeBoer, M.D. (2019). Assessing and managing the metabolic syndrome in children and adolescents. *Nutrients*, 11(8):1788.

de Koning, L., Malik, V.S., Rimm, E.B., Willett, W.C. and Hu, F.B. (2011). Sugar-sweetened and artificially sweetened beverage consumption and risk of type 2 diabetes in men. *The American Journal of Clinical Nutrition*, 93(6):1321–1327.

Dhingra, R., Sullivan, L., Jacques, P.F., Wang, T.J., Fox, C.S., Meigs, J.B., D'Agostino, R.B., Gaziano, J.M. and Vasan, R.S. (2007). Soft drink consumption and risk of developing cardiometabolic risk factors and the metabolic syndrome in middle-aged adults in the community. *Circulation*, 116(5):480–488.

Ejtahed, H.S., Bahadoran, Z., Mirmiran, P. and Azizi, F. (2015). Sugar-sweetened beverage consumption is associated with metabolic syndrome in Iranian adults: Tehran lipid and glucose study. *Endocrinology and Metabolism*, 30(3):334–342.

Erzse, A., Marais, N.C., Hofman, K.J. and Christofides, N.J. (2019). Evidence for high sugar content of baby foods in South Africa. *South African Medical Journal*, 109(5):328–332.

Fan, H., Li, X., Zheng, L., Chen, X., Wu, H., Ding, X., Qian, D., Shen, Y., Yu, Z., Fan, L. and Chen, M. (2016). Abdominal obesity is strongly associated with Cardiovascular Disease and its Risk Factors in Elderly and very Elderly Community-dwelling Chinese. *Scientific Reports*, 6(1):1–9.

Ferrannini, E., Sironi, A.M., Iozzo, P. and Gastaldelli, A. (2008). Intra-abdominal adiposity, abdominal obesity, and cardiometabolic risk. *European Heart Journal Supplements*, 10(suppl B):B4–B10.

Gómez-Marcos, M.A., Patino-Alonso, M.C., Recio-Rodríguez, J.I., Antón-Alvarez, J., Cabrejas-Sánchez, A., Fernandez-Alonso, C., Rubio-Galán, J., Arce, V. and García-Ortiz, L. (2013). Confirmatory factor analysis to assess the measure of adiposity that best fits the diagnosis of metabolic syndrome and relationship to physical activity in adults. *European Journal of Nutrition*, 52(5):1451–1459.

Hallam, J., Boswell, R.G., DeVito, E.E. and Kober, H. (2016). Focus: sex and gender health: gender-related differences in food craving and obesity. *The Yale Journal of Biology and Medicine*, 89(2):161.

Hoebel, S., Malan, L., Botha, J. and Swanepoel, M. (2014). Optimizing waist circumference cut-points for the metabolic syndrome in a South African cohort at 3-year follow-up: the SABPA prospective cohort. *Endocrine*, 47(3):959–961.

Imamura, F., O'Connor, L., Ye, Z., Mursu, J., Hayashino, Y., Bhupathiraju, S.N. and Forouhi, N.G. (2015). Consumption of sugar-sweetened beverages, artificially sweetened beverages, and fruit juice and incidence of type 2 diabetes: systematic review, meta-analysis, and estimation of population attributable fraction. *BMJ*, 351:h357.

Imamura, F., Schulze, M.B., Sharp, S.J., Guevara, M., Romaguera, D., Bendinelli, B., Salamanca-Fernández, E., Ardanaz, E., Arriola, L., Aune, D. and Boeing, H. (2019). Estimated substitution of tea or coffee for sugar-sweetened beverages was associated with lower type 2 diabetes incidence in case-cohort analysis across 8 European Countries in the EPIC-InterAct Study. *The Journal of Nutrition*, 149(11):1985–1993.

Knopp, R.H., Paramsothy, P., Retzlaff, B.M., Fish, B., Walden, C., Dowdy, A., Tsunehara, C., Aikawa, K. and Cheung, M.C. (2005). Gender differences in lipoprotein metabolism and dietary response: basis in hormonal differences and implications for cardiovascular disease. *Current Atherosclerosis Reports*, 7(6):472–479.

Koutsari, C., Snozek, C.L. and Jensen, M.D. (2008). Plasma NEFA storage in adipose tissue in the postprandial state: sex-related and regional differences. *Diabetologia*, 51(11):2041–2048.

Kruger, M.J. and Nell, T.A. (2017). The prevalence of the metabolic syndrome in a farmworker community in the Boland district, South Africa. *BMC Public Health*, 17(1):1–10.

Kuk, J.L. and Ardern, C.I. (2010). Age and sex differences in the clustering of metabolic syndrome factors: association with mortality risk. *Diabetes Care*, 33(11):2457–2461.

Laakso, M., Matilainen, V. and Keinänen-Kiukaanniemi, S. (2002). Association of neck circumference with insulin resistance-related factors. *International Journal of Obesity*, 26(6):873–875.

Laohabut, I., Udol, K., Phisalprapa, P., Srivanichakorn, W., Chaisathaphol, T., Washirasaksiri, C., Sitasuwan, T., Chouriyagune, C. and Auesomwang, C. (2020). Neck circumference as a predictor of metabolic syndrome: A cross-sectional study. *Primary Care Diabetes*, 14(3):265–273.

Luo, Y., Ma, X., Shen, Y., Xu, Y., Xiong, Q., Zhang, X., Xiao, Y., Bao, Y. and Jia, W. (2017). Neck circumference as an effective measure for identifying cardio-metabolic syndrome: a comparison with waist circumference. *Endocrine*, 55(3):822–830.

Malik, V.S. and Hu, F.B. (2019). Sugar-sweetened beverages and cardiometabolic health: an update of the evidence. *Nutrients*, 11(8):1840.

Maris, M.E., Melchert, R.B., Joseph, J. and Kennedy, R.H. (2005). Gender differences in blood pressure and heart rate in spontaneously hypertensive and Wistar-Kyoto rats. *Clinical and Experimental Pharmacology and Physiology*, 32(1-2):35–39.

Muluvhu, T.C., Monyeki, M.A., Strydom, G.L. and Toriola, A.L. (2018). Relationship between selected metabolic risk factors and waist-to-height ratio among employees in Vhembe district municipality of Limpopo province, South Africa. *Asian Journal of Scientific Research*, 11(1):42–50.

Myers, J., Kokkinos, P. and Nyelin, E. (2019). Physical activity, cardiorespiratory fitness, and the metabolic syndrome. *Nutrients*, 11(7):1652.

Nederkoorn, C., Smulders, F.T.Y. and Jansen, A. (2000). Cephalic phase responses, craving and food intake in normal subjects. *Appetite*, 35(1):45–55.

Okop, K.J., Lambert, E.V., Alaba, O., Levitt, N.S., Luke, A., Dugas, L., Dover, R.V.H., Kroff, J., Micklesfield, L.K., Kolbe-Alexander, T.L. and Warren, S. (2019). Sugar-sweetened beverage intake and relative weight gain among South African adults living in resource-poor communities: longitudinal data from the STOP-SA study. *International Journal of Obesity*, 43(3):603–614.

Pan, A., Malik, V.S., Hao, T., Willett, W.C., Mozaffarian, D. and Hu, F.B. (2013). Changes in water and beverage intake and long-term weight changes: results

from three prospective cohort studies. *International Journal of Obesity*, 37(10):1378–1385.

Patil, C., Deshmukh, J., Yadav, S., Patil, S. and Sheikh, A. (2017). Neck circumference: A novel anthropometric tool for screening obesity in adults. *International Journal of Collaborative Research on Internal Medicine and Public Health*, 9(7):711–720.

Peer, N., Steyn, K. and Levitt, N. (2016). Differential obesity indices identify the metabolic syndrome in Black men and women in Cape Town: the CRIBSA study. *Journal of Public Health*, 38(1):175–182.

Pienovi, L., Bustos, P. and Amigo, H. (2018). Certain Selected Sugar-Sweetened Beverages and Metabolic Syndrome. *Nutrition Today*, 53(6):300–305.

Rochlani, Y., Pothineni, N.V. and Mehta, J.L. (2015). Metabolic syndrome: does it differ between women and men?. *Cardiovascular Drugs and Therapy*, 29(4):329–338.

Ronquest-Ross, L.C., Vink, N. and Sigge, G.O. (2015). Food consumption changes in South Africa since 1994. *South African Journal of Science*, 111(9-10):01–12.

Ruxton, C.H., Gardner, E.J. and Walker, D. (2006). Can pure fruit and vegetable juices protect against cancer and cardiovascular disease too? A review of the evidence. *International Journal of Food Sciences and Nutrition*, 57(3-4):249–272.

SDBIP. Available online: http://www.lephalale.gov.za/documents/sdbip.php (accessed on 17 September 2021).

Sebati, B., Monyeki, K., Kemper, H.C.G., Sekgala, M.D. and Mphekgwana, P. (2019). Anthropometric indices for predicting cardiovascular risk factors: Ellisras longitudinal study. *American Journal of Human Biology*, 31(6):e23293.

Sekgala, M.D., Monyeki, K.D., Mogale, A., Mchiza, Z.J., Parker, W., Choma, S.R. and Makgopa, H.M. (2018). The risk of metabolic syndrome as a result of lifestyle among Ellisras rural youth. *Journal of Human Hypertension*, 32(8):572–584.

Shim, J.S., Oh, K. and Kim, H.C. (2014). Dietary assessment methods in epidemiologic studies. *Epidemiology and Health*, 36:e2014009.

Shin, S., Kim, S.A., Ha, J. and Lim, K. (2018). Sugar-sweetened beverage consumption in relation to obesity and metabolic syndrome among Korean adults: a cross-sectional study from the 2012–2016 Korean national health and nutrition examination survey (KNHANES). *Nutrients*, 10(10):1467.

Shrestha, N. (2018). Neck circumference as an indicator of overweight and obesity in youth. *American Journal of Applied Mathematics and Statistics*, 6:176–180.

Solomon, S. and Mulugeta, W. (2019). Disease burden and associated risk factors for metabolic syndrome among adults in Ethiopia. *BMC Cardiovascular Disorders*, 19(1):1–8.

Tal, S., Litovchik, I., Klar, M.M., Maresky, H.S., Grysman, N., Wiser, I., Vitkon-Barkay, I., Marcus, G., Tzuman, O., Pereg, D. and Rum, V. (2019). The association between neck adiposity and long-term outcome. *PloS One*, 14(4):e0215538.

Temple, N.J. and Steyn, N.P. (2013). Sugar and health: a food-based dietary guideline for South Africa. *South African Journal of Clinical Nutrition*, 26:S100–S104.

Vorster, H.H., Kruger, A., Wentzel-Viljoen, E., Kruger, H.S. and Margetts, B.M. (2014). Added sugar intake in South Africa: findings from the Adult Prospective Urban and Rural Epidemiology cohort study. *The American Journal of Clinical Nutrition*, 99(6):1479–1486.

Winpenny, E.M., Penney, T.L., Corder, K., White, M. and van Sluijs, E.M.F. (2017). Changes in consumption of added sugars from age 13 to 30 years: a systematic review and meta-analysis of longitudinal studies. *Obesity Reviews*, 18(11):1336–1349.

Zając-Gawlak, I., Pelclová, J., Groffik, D., Přidalová, M., Nawrat-Szołtysik, A., Kroemeke, A., Gába, A. and Sadowska-Krępa, E. (2021). Does physical activity lower the risk for metabolic syndrome: a longitudinal study of physically active older women. *BMC Geriatrics*, 21(1):1–9.

Zhang, X., Li, X., Liu, L., Hong, F., Zhao, H., Chen, L., Zhang, J., Jiang, Y., Zhang, J. and Luo, P. (2021). Dose-response association between sugar-and artificially

sweetened beverage consumption and the risk of metabolic syndrome: A meta-analysis of population-based epidemiological studies. *Public Health Nutrition*, 24(12):3892–3904.

Zheng, M., Allman-Farinelli, M., Heitmann, B.L. and Rangan, A. (2015). Substitution of sugar-sweetened beverages with other beverage alternatives: a review of long-term health outcomes. *Journal of the Academy of Nutrition and Dietetics*, 115(5):767–779.

Zhou, J.Y., Ge, H., Zhu, M.F., Wang, L.J., Chen, L., Tan, Y.Z., Chen, Y.M. and Zhu, H.L. (2013). Neck circumference as an independent predictive contributor to cardio-metabolic syndrome. *Cardiovascular Diabetology*, 12(1):1–7.

ANNEXURES

ANNEXURE A

University of Limpopo
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TURFLOOP RESEARCH ETHICS COMMITTEE

ETHICS CLEARANCE CERTIFICATE

MEETING: **24 April 2020**

PROJECT NUMBER: **TREC/97/2020: PG**

PROJECT:

Title:	Investigating The Association Between Sugar-Sweetened Beverages Intake and Risk of Metabolic Syndrome Among Ellisras Rural Youth: Ellisras Longitudinal Study
Researcher:	MA Seloka
Supervisor:	Prof KD Monyeki
Co-Supervisor/s:	Ms M Matshipi
School:	Molecular and Life Science
Degree:	Master of Science in Physiology

PROF P MASOKO
CHAIRPERSON: TURFLOOP RESEARCH ETHICS COMMITTEE

The Turfloop Research Ethics Committee (TREC) is registered with the National Health Research Ethics Council, Registration Number: **REC-0310111-031**

Note:

i) **This Ethics Clearance Certificate will be valid for one (1) year, as from the abovementioned date. Application for annual renewal (or annual review) need to be received by TREC one month before lapse of this period.**

ii) **Should any departure be contemplated from the research procedure as approved, the researcher(s) must re-submit the protocol to the committee, together with the Application for Amendment form.**

iii) **PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES.**

Finding solutions for Africa

ANNEXURE B

CONSENT FORM

Project title:**Investigating the association between sugar-sweetened beverages intake and risk of metabolic syndrome among Ellisras rural youth:Ellisras Longitudinal Study**

Project leader: **Prof KD Monyeki**

Researcher: **Ms MA Seloka**

hereby voluntarily consent to participate in the following project: "Investigating the association between sugar-sweetened beverages intake and risk of metabolic syndrome among Ellisras rural youth: Ellisras Longitudinal Study

I understand that:

1. The study deals with anthropometric measurement (weight, weight circumference and skin folds), blood pressure and blood sample on the human body and dietary intake
2. The procedure may hold some risk for me that cannot be foreseen at this stage.
3. The Ethics Committee has approved that individuals may be approached to participate in the study.
4. The research project, aims and methods of the research, has been explained to me.
5. I will be informed of any new information that may become available during the research that may influence my willingness to continue my participation.
6. Access to the records that pertain to my participation in the study will be restricted to persons directly involved in the research.
7. Any questions that I may have regarding the research, or related matters, will be answered by the researcher/s.
8. Participation in this research is voluntary and I can withdraw my participation at any stage.
9. If any medical problem is identified at any stage during the research, or when I am vetted for participation, such condition will be discussed with me in confidence by a qualified person and/or I will be referred to my doctor.
10. I indemnify the University of Limpopo and all persons involved with the above project from any liability that may arise from my participation in the above project or that may be related to it, for whatever reasons, including negligence on the part of the mentioned persons.

Signature of interviewee **Signature of witness**

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Signature of interviewer----------

ANNEXURE C (ELLISRAS COMMUNITY LETTER)

UNIVERSITY OF LIMPOPO
DEPARTMENT OF PHYSIOLOGY AND
ENVIRONMENTAL HEALTH

Private bag x1106
Sovenga
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SOUTH AFRICA
Tel: (015) 268 2953
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The Headman (NDONA)

Dear Sir/Madam

ALL ELLISRAS LONGITUDINAL STUDY MEMBERS ARE KINDLY REQUESTED TO TAKE PART DURING THE PERIOD NOVEMBER 2019 TO December 2019

High blood pressure and obesity are problems that seem to be more common in the community than they were 21-30 years ago. This is most likely a result of both environmental and genetic factors. Genetic factors are those factors you “inherit” from your parents and grandparents. These conditions can lead to further health problems such as problems with eyesight, the heart and strokes, but the chance of having these problems can be lessened by treatment. It is my pleasure to report that the Department of Physiology and Environmental Health, University of Limpopo will commence with the Ellisras Longitudinal Study (ELS) shortly. The ELS will aim to track the role of lifestyle risk factors in determining adverse health outcomes. In particular, the development of non-communicable diseases, including obesity, hypertension, diabetes, and coronary heart disease in a cohort of rural adolescents of South Africa over time.

All Ellisras Longitudinal Study subjects will be requested to take part. This research is looking at the youth’ lifestyle risk factors and how they may affect the development of non-communicable

diseases, including obesity, hypertension, diabetes, coronary heart disease. If you agree to participate, you will be asked about what and how much you have eaten the previous day. Anthropometric measurements will include weight, height, waist circumference and your blood pressure will be measured.

These measurements and interviews will take place from November 2019 to December 2019.

Please allow me to refer to the PhD thesis of (Monyeki, 2000):

"…Bahlalerwa (cultural name of our population) I requested for your help and you responded positively. I am happy because together we could make a difference. I am appealing to all of us to support and avail ourselves to any form of research activities taking place in our area. Such activities are geared towards improving the health not only of the Bahlalerwa population but the whole of South Africa if not Africa. We should keep focus and if somehow, we could be blinded, with the help of the Almighty God the father of Jesus Christ, crystals like glass will fall from our eyes like what happen to Paul in the Holy Bible. Our vision will be broadening, and we will no longer think and perform our duties inside the box…."

Pass my regards to everybody at home.

Yours sincerely

Prof Kotsedi Daniel Monyeki
Principal Investigator: Ellisras Longitudinal

Dr Marlise van Staden
Study Head of Department

ANNEXURE D

Biochemical Measurements

Triglycerides (mmol/l)								
HDL cholesterol (mmol/l)								
LDL cholesterol (mmol/l)								
Insulin µIU/mL								

M 9. Have you been told by a doctor or other health worker in the past year (12 months) that you have elevated blood pressure or hypertension?

	yes= 1	no =2	Uncertain=3

M 10. Are you currently receiving any of the following treatments for high blood pressure?

	yes =1	no =2
Drug(s) prescribed by a doctor or other health worker[2]		
Special diet prescribed by a doctor or other health worker		
Advice or treatment to lose weight		
Advice or treatment to stop smoking		
Herbal or traditional remedy		

ANNEXURE E

ANTHROPOMETRY AND BLOOD PRESSURE

SUBJECT NUMBER: …… DATE OF BIRTH: ……. /……../……..

GENDER: SCHOOL/VILLAGE NAME .....SCHOOL NUMBER/VILLAGE

NUMBER: .....

No	Exam date	Height (cm)		Weight (kg)	
		1st trial	2nd trial	1st trial	2nd trial

NUMBER	EXAM DATE	Waist girth (cm)		Blood pressure 1st trial mmHg			Blood pressure 2nd trial (mmHg)			Blood pressure 3rd trial (mmHg)			COMMENTS	FIELD WORKERS CODE
		1st trial	2nd trial	SBP	DBP	PR	SBP	DBP	PR	SBP	DBP	PR		

SBP= Systolic Blood Pressure, DBP= Diastolic Blood Pressure, PR= Pulse R

ANNEXURE F: PERMISSION LETTER

University of Limpopo
Private Bag X1106, Sovenga, 0727, South Africa
Tel: (015) 268 2273, Fax: (015) 268 2272, Email:Solomon.Choma@ul.ac.za

To: Prof KD Monyeki
Principal Investigator: Ellisras Longitudinal Study

From: Choma SSR
Acting HOD: Pathology and Medical Sciences

Date: 11 June 2019

RE: ANALYSIS OF BLOOD SAMPLES

This memo serves to confirm that the Department of Pathology and Medical Sciences has the laboratory equipment to run the following tests as requested by Ms MA Seloka (201320335):-

- Triglycerides
- Cholesterol
- HDL-cholesterol
- Insulin
- glucose

Furthermore as per verbal communication, the department is willing to collaborate with your research group and will thus run these tests on your behalf at no cost except for inclusion of the responsible laboratory personell in co-authorship of research articles produced from the laboratory results of the above tests and provided that your department purchases reagents required for running these tests

Yours Sincerely,
Choma SSR

ANNEXURE: G - 24H RECALL QUESTIONNAIRE

ELLISRAS LONGITUDINAL STUDY

Subject number: | | | | | | Birth Date: DD MM YY | | | | | | Interwdate: DD MM YY | | | | | |

School name:_____ School number:_____Interviewer_____

DIETARY INTAKE QUESTIONNAIRES (24 HR RECALL)

Instructions:

Now I want you to tell me everything that you ate and drank yesterday. Lets start with when you woke up. Did you have anything to eat or drink?

- Enter each item eaten in grams under the correct interval of the day eaten.
- Make sure that the code is circled.
- Items not on the questionnaire should be looked up in the Quantity Manual or list of food codes.
- Specify fully when new items are entered and look up the code later.

ABBREVIATIONS:

Measures 1t = 1 rounded teaspoon 1T = 1 rounded tablespoon (15ml) 1SP = 1 rounded servingspoon (30ml) C = measuring cup (250ml) s/s = small size m/s = medium L/s = large E = enriched P = plain Milk: SM = skim milk WN = whole milk BL = blend CON = condensed milk ND = non-dairy	Bread Wh = white Br = Brown Ww = wholewheat Meat F = with fat FT = fat trimmed Oil/ Fat B = butter HM = hard margarine Med = medium fat/ light PM = polyunsaturated SO = sunflower oil WF = white fat PM = peanut butter	BR = breakfast (Up to 09h00) IS = in - between snack L = lunch (midday (12h00-14h00) D = dinner (evening (17h00-20h00) AD = after meal Comm = commercial Home = homemade Pot = poatato Cab = cabbage Carr = Carrot Fill = Filling Usually = at least 4x/week

	FOOD ITEMS	QUANTITY (g/ml)	BR	IS	L	IS	D	AD
TEA & COFFEE	Tea: 4038; Rooibos 4054	teacup = 180ml; mug = 250ml						
	Coffee 4037	cup = 180ml; mug = 250ml						
	+ Sugar White-3989; Brown-4005;Syrup-3988;Honey-3984	1 t sugar = 6g 1 t honey/syrup = 15g						
	+ Condensed Milk: WM -2714; Cond Milk: SM-2744; Condensed Milk, Non-Dairy-P0042	1t = 10g						
	+ Evaporated WM-2715; Evaporated SM-2827; Lite-P0043	1t = 3g						
	+ Non-Dairy Creamer-2751	1t = 4g						
	+ WM Powder-2831	1t = 4g						
	+ Milk: SM-2719; WM-2718	MEDIUM PORTIONS:						
	BL-2771; 2%-2772	20ml - tea in cup						
	Soy-2737; Breast-2741; Goat-2738	35ml - tea in mug						
	Formula* (Specify):_____ No of Scoops/Bottle:_____	40ml - coffee in cup 75ml - coffee in mug						
	Other (Specify) _____							
MILK & MILK DRINKS	Buttermilk - 2713	s/s = 175ml l/s = 500ml ½c = 125g						
	Maas/Amazi/Sourmilk - 2787							
	Custard: SM-2717; WM-2716	s/s = 350 ml						
	Milk: SM-2719; WM-2718	to drink ½c = 125ml baby bottle = 250ml						
	BL-2771; 2%-2772							
	Soy-2737; Breast-2741; Goat-2738							
	* Formula (Specify):_____ No of Scoops/Bottle:_____							
	+ Sugar White-3989;Brown-4005; Syrup-3988;Honey-3984	1 t sugar = 6g 1 t honey/syrup = 15g						
	+ Ice Cream-3519; Sorbet-3491	1 scoop = 40g						
	+ Sustagen-4079; Complan-4082	2 scoops = 25g; 1T = 15g						
	+ Milo/Cocoa/Horlicks/Ovaltine-2736; Drinking Chocolate-4287	1t = 5g						
	Yoghurt: Plain SM-2734; WM-2757	s/s = 175ml Yogisip = 350ml ½c = 125g						
	Flav-2756; Fruit-2732							
	Flavoured milk - 2774	carton = 250ml s/s plastic = 350ml						
	Other (Specify) _____							
COLD DRINKS	Apple Juice – No Sugar – 3606	Liquifruit s/s = 250ml						
	Apricot: + Sugar-3539; No Sugar-3610	L/s = 500ml						
	Mango-3683; Granadilla-3680; Grape-3690	Ceres s/s = 200ml						
	Orange: +Sugar-3562; No sugar-3638	cartons/bottles						
	Guava: +Sugar-3554; No Sugar-3629	s/s = 350ml						
	Peach-3642; Pear-3645; Naartjie-3682	L/s = 500ml						
	Cold drinks: Squash-3982							
	Mageu-4056	s/s bottle = 350ml						
	Carbonated-3981	L/s bottle = 500ml						
	Diet Cold. & Low-Cal - 3990	s/s can = 340ml						

* Infasoy-2808; Isomil-2796; Lactogen 1-2821; Lactogen 2-2822; Nan-2819; Pelargon-2820; Portagen-2799; Pregestimil-2800; Prosobee-2795; S26-2806; S26 Infagro-2810; SMA-2814; Similac-2797; Similac PM-2817

2

	Dairy Fruit Mix - 2791							
	FOOD ITEMS	QUANTITY (g/ml)	BR	IS	L	IS	D	AD
	+ Sugar White-3989;Brown-4005;Syrup-3988; Honey-3984	1t = 6g						
	Syrup (undiluted)-2865; Guava Syrup-2864	1t = 5g						
	Other (Specify) _____							
BREAKFAST CEREALS	Maltabella: Soft-3241; Mabella: Soft-3437	½c = 125g						
	M/Meal: Soft: Plain-3399; Enrich-4277	1c soft = 250g						
	Stiff: Plain-3400; Enrich-4278	1c stiff = 250g						
	Crumbly: Plain-3401; Enrich-4279	1c crumbly = 140g						
	Sour Porridge: Maize with Vinegar-P0001, Maize Fermented- P0002 Mabella with Vinegar-P0003; Mabella Fermented-P0004	½c = 125g 1c = 250g						
	Oats-3239; Tastee Wheat-3240	½c = 125g						
	Corn Flakes-3243; Sugar Frosted-3374	1c = 40g						
	Honey Crunch and Muesli - 3303	½c = 65g						
	Pronutro: Great Start-3438; High Energy-3245; Wholewheat-3436	½c = 50g						
	Puffed Wheat-3325; Sweetened-3376 (Honey Smacks)	½c = 12g						
	Raisin Bran-3373; Fruit Loops-3425	Raisin Bran ½c = 45g Fruit Loops ½c = 18g						
	Special K-3322; All Bran-3242	½c = 25g						
	Rice Crispies-3252; Cocopops-3372	½c = 20g						
	Weetbix – 3244	1 = 25g						
	+ Fat: B -3479; HM-3484; Med-3531; PM-3496; WF-3516	1 t PB = 12g; 1 t marg/oil = 5g						
	Ghee-3525; PB-3485; Butro-3523; SO-3507							
	+ Sugar White-3989;Brown-4005; Syrup-3988;Honey-3984	1 t sugar = 6g 1 t honey/syrup = 15g						
	+ Cond Milk:SM-2744; Cond WM-2714;Cond ND- P0042	1t = 10g						
	+ Evap WM-2715; Evap SM-2827; Evap Light-P0043	1t = 3g						
	+ Non-Dairy Creamer-2751	1t = 4g						
	+ WM Powder-2831	1t = 4g						
	+ Milk: SM-2719; WM-2718	125g – Instant cereal						
	BL-2771; 2%-2772	60g – porridge						
	Soy-2737; Breast-2741; Goat-2738	180g – Pro Nutro						
	Formula (Specify):_____ No of Scoops/Bottle:_____							
	Other (Specify) _____							
BREAD	Bread: Comm & Home: Wh-3210	Wh + Br 10mm = 30g Ww 10mm = 35g Wh + Br 20mm = 60g Ww 20mm = 70g						
	Br-3211							
	Ww-3212							
	Cream Crackers-3230; Provita-3235; Tuc 3331; Crackers Ww-3391	Cr Cracker = 8g; Tuc = 4g; Provita = 6g						
	Maize Meal Bread - 3278	m/s = 30g; L/s = 50g						
	Muffins: Plain-3408; Bran-3407	6cm diam = 35g 8cm diam = 60g						

	Rolls: Wh-3210; Br-3211; Ww-3212	Wh round (10cm) = 30g Wh long (18cm) = 40g						
	Roti: SO-3358; HM-3357	s/s = 50g (Roti)						
	FOOD ITEMS	QUANTITY (g/ml)	BR	IS	L	IS	D	AD
	Rusks: Comm Wh-3364; Bran-3330	Outspan = 15g; All Bran = 30g						
	Comm Buttermilk: Wh-3329;	Wh = 35g; Ww = 30g						
	Home Buttermilk: Wh-3215; Ww-3255; Bran & Raisins-3380	Wh = 30g; Ww = 30g						
	Scones: (Wh) SM-3411; WM-3237 (Ww) SM-3412; WM-3320	6cm diam = 35g 8cm diam = 60g						
	Vetkoek: Wh-3257; Ww –3324; Dumpling-3210 (no yeast)	8cm diam = 60g						
	Other (Specify) _____							
SPREADS ON BREAD	Beef Fat-3494; Mutton Fat-3497; Lard-3495	Thin Med Thick						
	Butter-3479; Butro-3523	5 10 15						
	Ghee-3525; WF-3516;							
	Fishpaste-3109; Liver Spread-2922; Meat Paste-2917	5 7 10						
	Jam-3985; Honey-3984; Syrup-3988	10 20 35						
	Marg: H-3484	5 7 10						
	Med-3531							
	PM-3496							
	Marmite-4030; Meat Spread (Bovril)-4029	2 4 7						
	Peanut Butter-3485; Sandwich Spread-3522; ChocSpread-P0005	5 10 20						
	Other (Specify) _____							
EGGS	Eggs: Boiled/Poached - 2867	1 egg = 50g						
	Curried - 2902	1 egg + sauce (IT) = 75g						
	Fried: B-2868; HM-2877; PM-2878	1 egg = 52g						
	SO-2869; Bacon Fat-2870							
	Scrambled/Omelette: SM + B-2886; SM + HM-2887	IT = 35g; 1SP = 80g ¼c = 115g (± 2 eggs) omelette = 60g egg (med) 120g (L/s)						
	SM+PM-2888; SM+SO-2889; WM+B-2874							
	WM+HM-2890; WM+PM-2891; WM+SO-2873							
	Other (Specify) _____							
CHEESE	Cheddar-2722;	grated: med = 10g Thick = 15g 1 cheezi = 20g; cubes = 30g 1 slice = 8g						
	Gouda/Sweetmilk-2723							
	Cheese Spread-2730	med = 12g; thick = 25g						
	Cottage Cheese; Creamed-2759; Cream Cheese-2725	thin = 10g med = 20						
	Cottage Cheese: Fat Free-2729; Low Fat-2760	med = 20g; thick = 30g						
	Macaroni Cheese: SM-3343; WM-3301	1T = 45g; 1 SP = 90g; ½c = 115g						
	Pizza (Cheese + Tomato)-3353	S/s = 90g; L/s = 340g						
	Savoury Tart+Asparagus-3367;+Vienna-3326;+Tuna-3366	wedge: small = 65g; med = 75g; large = 110g						
	Other (Specify) _____							
MEAT	Bacon: Fried: Lean-2915 F-2906	1 rasher = 10g						

	Beef:Corned/Silverside/Cold cuts:F-2924;Bully Beef-2940	138 x 85 x 3 = 20g ½c = 100g						
	Lean-2962; Curry Beef-P0006							
	Fillet: F-2933; FT-2929	100 x 70 x 10 = 90g						
	FOOD ITEMS	QUANTITY (g/ml)	BR	IS	L	IS	D	AD
M E	Mince: Pan Fried F-2910; Lean-2961; Curry-3015	T = 40; SP = 85g ½c = 100g						
	- Savoury (Tomato + Onion)-2987							
	- Cottage Pie: WM + HM-3009							
	Roast: F-2944; FT-2960	120 x 60 x 5 = 35g 120 x 60 x 10 = 70g						
	Rump: Fried: F-2908; FT-2959	S/s 130 x 70 x 15 = 125g L/s 165 x 70 x 30 = 270g						
	Sirlion/T-Bone: Grilled: F-2946; FT-2907							
	Stew: Vegetables (Fat Meat)-3006	1 SP = 105g; ½c = 125g						
	: Pot + Carrots + Peas + Onions (Lean Meat)-2909							
	Biltong: Beef-2911; Game-2912	grated 1SP = 10g beefeater = 18g sliced 1SP = 35g						
	Bobotie: Lean, SM, SO-3013; F, WM, S0-2986	1SP = 85g; ½c = 115g						
	Chicken: Boiled + Skin-2926; No Skin-2963; Curry-P0007	breast + skin = 125g thigh = 90g drumstick = 42g foot = 30g wing = 30g pie(comm)=150g home = 90g liver = 30g; stomach = 20g						
	Feet-2997; Giblets-2998; Heads-2999							
	Pie (Comm)-2954							
	Roast + Skin-2925; No Skin-2950; Fried-2925							
	Stew: Vegetables-3005	1SP = 90g; ½c = 125g						
	Tomato + Onion – 2985							
	Batter Dipped-Fried eg. Kentucky-3018	1SP = 105g; ½c = 125g						
	Burger Pattie –2950	1 pattie = 80g						
	+ Bun (4 cm diam)-3210	1 bun = 60g						
	Cornish Pie: (Comm) - 2953	med = 150g						
	Frankfurter-2937	155 x 20 = 45g 168 x 21 = 60g						
	+ Roll (16 cm long)-3210	1 roll = 40g						
	Goat meat: Stewed (plain)-4281; (+ Veg)-4282	120 x 60 x 5 = 35g 120 x 60 x 10 = 70g						
	Fried F-P0008; Fried FT-P0009							
	Grilled F-P0010; Grilled FT-P0011							
	Ham-2967; Ham & Tongue loaf-2990	med slice = 25g						
	Heart: Beef-2968; Sheep-2969	sheep heart = 60g sheep kidney = 30g beef kidney = 85g						
	Kidney: Beef-2923; Sheep-2956							
	Lung: Beef-3019							
	Lasagne: SM-3440; WM-3261	T = 40g; SP = 75g; ½c = 120g						
	Liver: Fried : Beef-2920; Sheep-2955; Patty (Fried) -2971	sheep = 55g chicken = 30g beef = 80g						
	Cooked: Chicken-2970							
	Meat Ball: F + Egg-2965; F-No Egg-2966	50mm = 60; 75mm = 120g						
	Lean + Egg-3033; Lean, No Egg-3034							
	Meat Loaf: F-3035; Lean-3002	80 x 85 x 15mm slice = 80g						

	Meat Patty: (Hamburger)-2984	s/s = 50g; m/s = 100g						
	+ Bun (4 cm diam)-3210	1 bun = 60g						
	Mutton: Chop (grilled) F-2927; FT-2934	loin chop = 60g rib chop = 40g						
	Roast: F-2947; FT-2973	s/s slice = 30g med = 70g						
	FOOD ITEMS	QUANTITY (g/ml)	BR	IS	L	IS	D	AD
MEAT	Stew: Plain-2974; Irish-2916 (Vegetables) Curry-3039; Greenbean-3040	1SP = 105g; ½c = 125g						
	Offal: Cooked-Tripe(Pens&Pootjies)-2951;Vetderm-P0023 (Specify): _____	1SP = 105g; ½c = 125g						
	Oxtail: Stewed-2976							
	Polony-2919	slice 5mm thick = 8g comm slice = 16g						
	Pork: Chop (Grilled) F-2930; FT-2977	chop: 115 x 80 x 20 = 100g schnitzel: 115 x 80 x 20 =110g roast: 110 x 65 x 5 = 30g 1SP = 105g; ½c = 125g 3 ribs = 130g						
	Crumbed-2992; Spareribs-3010							
	Rib, Braised: F-3046; FT-3045							
	Roast: F-2958; FT-2978							
	Salami and Russians-2948	slice 5mm thick = 12g 1 Russian = 50g						
	+ Roll-3210	1 roll = 40g						
	Samoosa: with Veg-3414; Meat-3355	s/s = 42g						
	Sausage: Beef: Dry-2949; Cooked-2931 (Boerewors)	thin x 200mm = 45g thick x 185mm = 90g						
	+ Roll-3210	1 roll = 40g						
	Pork: Cooked-2932	med = 55g						
	+ Roll-3210	1 roll = 40g						
	Roll/Meat Pie (Comm)-2939	25mm pie = 120g roll x 135mm = 165g						
	Spaghetti Bolognaise: Lean-3388; F-3260	T=40g; SP = 75g; ½c = 100g						
	Steak & Kidney: Pie-2957; Stew-2979	comm pie = 120g (30mm) 1SP = 100g; ½c = 135g						
	Tongue: Ox-2935; Sheep:2980	slice 75 x 45 x 10 = 40g						
	Toppers/Imana: Cooked-3196	SP = 85g; ½c = 120g						
	Veal: Cutlet (Fried): Plain-3049; Crumbed-2983	1 chop = 90g						
	Vienna Sausage/Canned Sausage-2936	100mm = 30g; 150mm = 40g						
	+ Roll-3210	1 roll = 40g						
	Worms/Insects:Mopani,Dried-4250;Mopani,Canned-4284; Specify: _____							
	Wild Birds, Animals; Specify: _____							
	Other (Specify) _____							
FISH	Bokkems (Dry Fish)-3097	1 s/s = 25g (120mm) L/s = 40g (135mm)						
	Fatty Fish: Kipper; Galjoen; Snoek; Shad: Fried (SO)-3084; Batter-3094; Grill-3082	small 50 x 55 x 30 = 60g med 100 x 55 x 30 = 120g stew 1 SP = 95; ½c = 140g						
	Salted-3097; Steam-3103; Smoked-3112							
	Stew-3076 (Tomato and Onion) / Pickled / Curried							

	Fish Cakes: (Fried): Home-3098; Comm-3080	65 x 15mm = 50g						
	Fish Fingers: (Fried)-3081	85mm = 35g						
	Haddock: Smoked (Boiled)-3061	70 x 70 x 15 = 65g						
	Mackerel Canned-3113	1 = 80g (15 mm)						
	Pilchards: Tomato Sauce-3102; Brine-3055	1 = 75g						
	FOOD ITEMS	QUANTITY (g/ml)	BR	IS	L	IS	D	AD
	Sardines: + Sauce-3087; + Oil-3104	s/s = 7g; L/s = 25g						
	Smoorsnoek-3074	1SP = 55g; ½c = 80g						
	Sole: Fried-3090; Grilled-3073	baby sole: 180mm = 70g						
	Tuna: Oil Pack-3093; Tuna: Water-3054; Salmon-3058	¼c = 50g						
	White Fish: Hake, Haddock, Kingklip; Cod : Stew-3076 (Tom + On); Baked+Fat-3092; No Fat-3089 : Grilled-3079; Batter-3072; Fried-3060	s/s piece 50 x 55 x 30 = 60g med 100 x 55 x 30 = 120g stew 1 SP = 95g; ½c = 140g						
	Other: eg Fresh Water Fish; Specify:_____ P0012							
	Other (Specify) _____							
STARCH	M/Meal: Soft: Plain-3399; Enrich-4277 Stiff: Plain-3400; Enrich-4278 Crumbly: Plain-3401; Enrich-4279 Mabella Cornrice/Sorghum cooked (soft or stiff)-3437 Sour Porridge: Maize & Vinegar-P0001, Fermented-P0002 Mabella with Vinegar-P0003; Fermented-P0004	T SP ½c stiff 75 120 125 crum 30 75 70 soft 75 120 125						
STARCH	Maize Rice (Mealie Rice)-3250	25 45 85						
STARCH	Samp: (Cooked) –3250; Fresh Mealies-3725	55 125 125						
STARCH	Rice: Wh-3247; Br-3315	25 60 85						
STARCH	Spaghetti/Macaroni: (Cooked)-3262	35 70 90						
STARCH	Spaghetti + Tomato Sauce -3258	45 80 125						
STARCH	Stamped Wheat/Wheat Rice-3249	30 80 80						
STARCH	+ Fat: B -3479; HM-3484; Med-3531; PM-3496; WF-3516 Ghee-3525; PB-3485; Butro-3523; SO-3507	1 t PB = 12g; 1 t marg/oil = 5g						
STARCH	Other (Specify) _____							
LEGUMES	Baked Beans-3176	T SP ½ c 50 105 135						
LEGUMES	Beans: (Cooked) Haricot-3185; Sugar-3205; Kidney-3183	50 85 135						
LEGUMES	Breyani: Rice + Lentils + Ghee-3194; +SO-3193	40 80 85						
LEGUMES	Lentils: Cooked/curried-3179	40 80 90						
LEGUMES	Samp and Beans (1:1)-3402; Comm-P0045 (No fat added) Samp & Peanuts (80:20) P0013	50 125 125						
LEGUMES	Soup: Comm (Packets)-3165	125						
LEGUMES	Split Pea-3157; Lentil-3153; Beef + Veg-3159; Bean-3145	35 80 130						
LEGUMES	Sousboontjies (Dried Bean Salad)-3174	40 105 135						

	Stew: Bean + Potato + Onion-3178						60	120	125								
	Other (Specify) _____																
COOKED VEGETABLES		Boil	Fat Added (or Fried)														
		NF	B	HM	PM	SO	T	SP	½C								
	Gr Beans	3696		3788	3789		25	60	60								
	Gr Bean Curry	3791					40	75	120								
	GrBean+Pot+Onion			3792		3794											
	FOOD ITEMS						QUANTITY (g/ml)			BR	IS	L	IS	D	AD		
COOK	Beetroot + Sugar	3699					40	70	80								
	- No Sugar	3698															
	Brinjal	3700		3800		3802	1 slice = 20g (70mm) + batter = 30g										
	- Fried + Egg					3803											
	- + Tomato + Onion			3796		3798	50	100	130								
	Brocolli	3701		3805			25	60	75								
	Brussels Sprouts	3703		3808			50										
		Boil	Fat Added (or Fried)														
		NF	B	HM	PM	SO	T	SP	½C								
	Cabbage	3756		3810		3812	30	55	80								
	Cab + Pot + Onion			3813		3815	35	75	80								
	Carrots	3757		3816	3817		20	50	80								
	Car + Pot + Onion			3822		3824	35	70	105								
	Carrot + Sugar	3818		3819	3820		25	50	85								
	Cauliflower	3716		3825	3826		40	65	80								
	Caul + Cheese Sauce	3715					43	70	90								
	Marogo/imifino* Amaranth leaves	3980					40	105	90								
	Marog + Peanuts Ratio: 80:20	P0014					55	120	105								
	Mealies (corn)	3725					30	60	95								
	Sweetcorn	3726					55	125	135								
	Canned Whole Kernel	3942					55	125	135								
	Mix Veg (Froz)	3727		3835	3836	4269	35	75	75								
	Mushroom (Sliced)	3729		3839		3841	30	65	80								
	Mushroom, Raw					3842	30	65	80								
	Onions (Sliced)	3773		3844		3730	50										
	Onion + Batter					3846	rings: med = 40g										
	Peas	3719		3856			30	65	85								
	Peas, Frozen	4146					30	65	85								
	Peas + Sugar	3720		3859			30	65	85								
	Potato: + Skin	4155					s/s = 60; m/s = 90g										
	: Baked + Skin	3736					s/s = 60g; m/s = 90g										
	: Chips					3740	½c = 50g; med = 80g										

	: Peeled	3737		3867	3868		s/s = 60g; m/s = 90g; (90 x 60 x 40)							
	: Sauté			3871		3873	3	50	90					
	Potato Cake					3915	1 med = 40g (75 x 30)							
	Potato Mash (SM)				3875		50	115	125					
	Potato Mash (WM)			3876										
	Potato (Roast): Beef Fat-3878; Chicken-3923; Lamb-3736; Pork-3956						1 med = 90g							
	* If indigenous, specify local name: _____													

	FOOD ITEMS						QUANTITY (g/ml)			BR	IS	L	IS	D	AD
		Boil	Fat Added (or Fried)												
		NF	B	HM	PM	SO	T	SP	½c						
COOKED VEGETABLES	Pumpkin (Yellow)	4164					45	85	105						
	Butternut	3759													
	Pump + Sugar	3728		3893											
	Pump Fritter					3784	75 x 50 x 9 = 25g								
	Spinach	3913		3898	3899		40	105	90						
	Spinach + Peanuts Ratio: 80:20	P0015					55	120	105						
	Spin + Pot + Onion			3901	..	3786	50	105	110						
	Squash –Gem	3760					½ gem = 45g 1 SP marrow = 85g								
	Gem Squash + Sugar	3754													
	Squash –Marrow	4179													
	Marrow + Sugar			3885											
	Sw Potato:without skin	3903					50	110	145						
	Sw Potato with Skin	3748													
	Sw Pot + Sugar			3749											
	Tomato + Onion	3925					35	75	140						
	Tom + Onion +Sugar	3910													
	Tomato			3908		3767	1 slice 5mm = 15g (thin); med = 25g								
	Turnips	3911					25	45	90						
	Other (Specify)														
SAL	Asparagus-3695						med asparagus = 15g								
	Avocado-3656						¼ avo (80 x 50mm) = 40g								
	Beetroot (Grated) + Sugar-3699						1T = 25g; SP = 65g								
	Carrot: (Grated)+ Sugar-3721						1T = 25g;								
	+ Pine + Orange - 3710; + Orange Juice = 3711						1T = 35g; 1SP = 60g								
	Coleslaw + Mayonnaise-3705						T = 20g; SP = 40g; ½c = 50g								

Cucumber Raw/Pickled-3718	med slice = 10g; thick = 15g							
Lettuce-3723	1 med leaf = 30g							
Mixed (Tom + Cucum + Lett) - No Dressing-3921	1T = 40g; 1SP = 85g							
Mixed Green - No Dressing-3927								
Potato Salad + Mayonnaise (Comm), Egg-3928	T = 45g; 1SP = 105g; ½c = 120g							
Tomato (Raw)-3750	med = 120g; slice = 15g							
Other (Specify) _____								

	FOOD ITEMS					QUANTITY (g/ml)	BR	IS	L	IS	D	AD
DRESSINGS	French Dressing-3487					1t = 5g; 1T = 15g						
	Mayonnaise: Home-3506; Comm-3488; Low Fat- 3489					1t = 10g 1T = 40g						
	Oil: Olive-3509; Sunflower-3507; Canola-4280					1t = 5g; 1T = 15g						
	Salad Dressing: Cooked-3503; Low-Oil-3505											
FRUIT		Canned + Sugar	Raw	Dry	Stewed							
	Apple	3599	3532	3600	3603	1T = 60g; ½c = 120g; 1 med = 160g (52 x 66)						
	Apricot	3535	3534	3536	3537	1 med = 35g						
	Banana		3540			1 med = 75g						
	Dates		3543			1 med = 10g						
	Figs		3544	3557		1 med = 40g (45 x 44) 1 dry = 20g						
	Fruit Salad	3580	3605	3593	3590	½c = 110g (med)						
	Granadilla		3545			1 med = 22g						
	Grape Fruit	3547	3546			½ med = 125g						
	Grapes	3623	3550			med bunch = 230g; ½c =90g						
	Guava	3553	3551			med (6cm) = 95g						
	Litchi	3631	3632			med (3cm) = 8g						
	Mango	3633	3556			135mm = 350g						
	Naartjie	3635	3558			med = (5cm) = 75g						
	Orange		3560			med (7cm) = 180g						
	Pawpaw		3563			wedge 165 x 26 x 27 = 90g						
	Peach	3567	3565	3568	3569	1 med = 160g (60 x 65)						
	Pear	3583	3582	3585	3586	1 med (80 x 65mm) = 165g						
	Pineapple	3648	3581			1 slice (85 x 10mm) = 40g						
	Plum		3570			1 med = 50g (45 x 40)						
	Prunes	3676	4230	3596	3564	1T = 50g; ½c = 110g; 1 = 12g						
	Raisins		3552			handfull = 27g						
	Strawberries	3653	3573			1 med = 12g; ½c = 80g						

	Sweetmelon, Green		3575			1 wedge (145 x 31 x 20mm) = 60g; ¼ = 110g						
	Sweetmelon, Yellow		3541									
	Watermelon		3576			slice (330 x 70mm) = 220g						
	Wild Fruit, Berries: Specify: _____											
	Other Fruit:											

	FOOD ITEMS			QUANTITY (g/ml)	BR	IS	L	IS	D	AD
		SM	WM							
PUDDINGS	Apple + Batter	3345	3327	med serving = 70g						
	Apple Crumble		3334	med serving = 70g						
	Baked Pudd + Syrup	3348	3312	med serving = 30g 30 x 65 x 65 = 50g						
	- No Syrup	3347	3221							
	Blancmange	3282	3281	SP = 75, ½c = 95g						
	Egg Type eg. Bread, Sago	3346	3263	1T = 50g; ½c = 140g; SP = 100g						
	Ice Cream: Commercial Regular-3483			scoop = 40g; 1SP = 65g; ½c = 75g						
	Commercial Rich-3519									
	Ice Lollies-3982									
	Soft Serve-3518			plain = 135g; + flake = 155g						
	Sorbet-3491			1SP = 65g; ½c = 75g						
	Instant Pudding	3314	3266	T = 45g; SP = 95g; ½c = 145g						
	Jelly-3983			1T = 35g; 1SP = 75g; ½c = 110g						
	Jelly + Fruit-4006			1T = 40g; 1SP = 90g; ½c = 125g						
	Jelly Whip	2749	2750	1T = 55g; SP = 95g; ½c = 120g						
	Pancake/Crumpets	3344	3238	1 crumpet = 25g pancake = 70g						
	Trifle-3311; Vermicelli Pudding-3385			½c = 130g (med)						
	Other Puddings (Specify) _____									
SA UC	Cream: Plant-3492; Canned-3499			1T = 13g (not whipped)						
	- Fresh (12%) -3481; Heavy (dessert, 20%)-3480			1T = 30g (whipped)						
	Chocolate Sauce-3129			T = 15g						
	Custard: SM-2717; WM-2718			T = 13g; SP = 40g						

	Sugar-3989	1t = 6g						
	Other (Specify) _____							
CAKE	Banana Loaf: WM + HM-3333; SM + PM-3370	slice = 45g; 90 x 80 x 10mm						
	Cake –Carrot-3392	80 x 40 x 40 = 50g						
	- Plain: SM + HM-3286; PM-3287	single slice = 50g (75 x 75 x 20mm) double slice = 100g (plain) icing = 10g per slice						
	WM + B-3218; HM-3288; SO-3290							
	Cake Icing: HM-4014; PM-4015							
	- Chocolate (No Icing) WM-3289; SM-3339							
	FOOD ITEMS	QUANTITY (g/ml)	BR	IS	L	IS	D	AD
CAKE	- Fruit: Comm-3291; Home-3427	home: 70 x 85 x 15mm = 70g comm: 90 x 70 x 15mm = 35g						
	- Sponge (Plain)-3219	100 x 50 x 50 = 40g						
	- Swiss Roll-3292	slice = 60g; 15cm thick						
	Cheese Cake: Baked-3293; Unbaked-3294	slice 95 x 50 x 30mm = 70g						
	Other (Specify) _____							
COOKIES & SPECIAL BREADS	Comm + Fill-3217; Plain-3216; Shortbread-3296	plain = 10g + fill = 15g						
	Home: Plain HM-3233; PM-3341	plain = 15g + fill = 20g hertzog = 50g; cupcake = 35g shortbread = 12g						
	Jam-3295; Oats-3265							
	Custard Slice-3338	110 x 45 x 35mm = 250g						
	Date Loaf; HM-3256; PM-3340	slice 90 x 75 x 10mm = 40g						
	Doughnuts: Jam-3423; Plain-3232	med round = 45g med long = 90g						
	Eclairs + Cream + Chocolate-3268	1 = 120g (160mm)						
	Gingerbread: HM-3253; PM-3371	90 x 75 x 15 = 70g						
	Koeksister-3231	100 x 35 = 60g						
	Pumpernickel Bread-3283	slice 85 x 100 x 10mm = 30g						
	Raisin Bread-3214	slice 85 x 100 x 10mm = 30g						
	Rye Bread-3213	slice 85 x 100 x 10mm = 30g						
	Sweetcorn Bread-3379	slice 85 x 100 x 10mm = 30g						
	Other (Specify) _____							
	Apple: HM-3224; PM-3352	50 x 50 x 50mm = 70g (med)						
	Coconut-3228	wedge 50 x 100 x 30mm= 55g						
	Condensed: HM-3294; PM-3439	95 x 70 x 30mm = 90g						
	Fridge (Fruit): HM-3394; PM-3434							
	Lemon Meringue: HM-3226; PM-3349	100 x 70 x 35mm = 75g						
	Milk (Short) WM + HM-3360; SM + PM-3351	120 x 70 x25mm = 75g						
	Milk (Flaky) WM + B-3443; WM + HM-3229							

	Savoury: Aspar-3367; Tuna-3366; Vienna-3326	120 x 50 x 25 = 75g						
	Tipsy: HM-3323; Jam-3225	87 x 70 x 50mm = 90g						
	Other (Specify) _____							

	FOOD ITEMS	QUANTITY (g/ml)	BR	IS	L	IS	D	AD
SWEETS	Bubble/Chewing gum-3993	See Manual						
	Chocolates: Assorted-3992							
	Coated Bars eg. Tex, Lunch, Chomp-3997							
	Milk (White Chocolate)-3987							
	Nuts/Raisins-3994							
	Plain eg Smarties, Flake, Aero-4003							
	Dry Fruit Sweets-3995							
	Fruit Gums-4000							
	Hard/Jelly Sweets eg. Sugus, Jelly Tots, Fruit Drops-3986							
	Ice Lollies-3982							
	Marshmallows-4001							
	Meringues-4008							
	Peanuts: Raw-4285; Peanut Brittle-4002;							
	Roasted, Salted-3458; Roasted Unsalted-3452							
	Peppermints-4004							
	Popcorn: Plain-3332; Sugar Coated-3359							
	Potato Crisps eg. Simba, O=Gradys-3417							
	Raisins, Seedless-4232							
	Snacks – Fritos, Niknaks, Cheese Curls-3267							
	Soft Sweets - Fudge, Toffees, Caramel-3991							
	Other (Specify) _____							
OTHER	Cheese Sauce: WM + HM-3125; SM + PM-3128	SP = 65g; 1T = 25g						
	Curry Sauce-3130	1T = 25g						
	Chutney-3168; Atjar-3117; Tomato Chutney-3114	1T = 14g; 1T = 60g						
	Gravy: Comm-3119; Meat-3122; NF-3121	1T = 15g; SP = 35g						
	Mustard-4034	1t = 6g						

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Seloka, M.A., Matshipi, M., Mphekgwana, P.M. and Monyeki, K.D., 2022. The Association between the Consumption of Sugar-Sweetened Beverages and Metabolic Syndrome Components in Young Rural Adults in South Africa. *Applied Sciences*, *12*(6), p.3015. https://doi.org/10.3390/ app12063015.