Relationships between physical activity status, intima-media thickness and cardio-metabolic risk factors in a cohort of teachers: The SABPA-study

T Veldsman

orcid.org / 0000-0002-2605-4686

Thesis accepted in fulfilment of the requirements for the degree Doctor of Philosophy in Human Movement Science at the North-West University

Promoter: Dr M Swanepoel
Co-promoter: Prof MA Monyeki
Co-promoter: Prof JS Brits

Graduation: July 2020
Student number: 21684537

DECLARATION

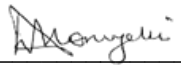
Dr M Swanepoel (promoter and co-author), Prof MA Monyeki (co-promoter and co-author) and Prof JS Brits (co-promoter and co-author) hereby give permission to the candidate, Ms T Veldsman, to include the articles as part of this doctoral thesis. The contribution of each co-author, both supervisory and supportive were kept within reasonable limits and included:

Ms T Veldsman:	Developing the proposal, writing the manuscripts, data analyses, interpretation of the results and compilation of the thesis.
Dr M Swanepoel:	Promoter of the study, assisted in data collection in the SABPA-study and coordination of the thesis, providing guidance in the writing of the manuscripts and the thesis.
Prof MA Monyeki:	Co-promoter of the thesis, assisted in the write up of the manuscripts, data analysis and interpretation of the results and comments on the thesis.
Prof SJ Brits:	Co-promoter, assisted in the article writing and comments on the thesis.
Prof L Malan:	Co-author, and the principal investigator of the SABPA-study, contribution to the article write-up.

This thesis serves in the fulfilment of the requirements for the PhD degree in Human Movement Sciences within the Physical Activity, Sport and Recreation research entity within the faculty of Health Sciences at the North-West University on the Potchefstroom campus.

Signature of student:  Date: 17/03/2020
(Ms T Veldsman)

Signature of promoter:  Date: 17/03/2020
(Dr M Swanepoel)

Signature of co-promoter:  Date: 17/03/2020
(Prof MA Monyeki)

Signature of co-promoter:  Date: 17/03/2020
(Prof SJ Brits)

ACKNOWLEDGEMENTS

The completion of this study was made possible through the help, support and guidance of family, friends and colleagues. I want to express my sincere appreciation to the following:

- My promoter, Dr Mariëtte Swanepoel, for your advice, assistance, positivity and motivation in writing this thesis. Your kind words of encouragement have motivated me to complete this thesis.
- My co-promoter, Prof Andries Monyeki, for your expert advice, endless patience, assistance with statistics, encouragement and invaluable input throughout the thesis. Thank you for always believing in me.
- Prof Sanette Brits, my co-promoter, thank you for all your guidance, feedback, and motivation in writing this thesis.
- My mentor, Prof Hanlie Moss, thank you for your guidance through not only the PhD journey but also your input and planning into my academic career.
- The North-West University (NWU) for providing the infrastructure in which I could complete this study.
- I am grateful to Prof Leoné Malan, the principal investigator in the SABPA-study for your willingness to teach me, and availability of the data collected in this large study.
- A special thank you to all the personnel and students who collected data in the SABPA-study. Also, my thanks to the participants of the SABPA-study.
- To Helen Robinson, my language editor, thank you for the professional, thorough work and input in this study.
- My NWU friends and colleagues, you have carried me through the last few years of my studies. Your constant reminders that it was all part of the journey motivated me to continue even when times were tough.
- My family for your continued encouragement. Especially my parents, Ivan and Jo-Anne, for your endless love, motivation and beliefs in my abilities.
- My friends, not from the NWU, thank you for supporting me over the past few years. You do not realise the impact it has had.
- My heavenly Father, for your constant guidance and motivation, and instilling a passion for research within me.

"Keep your dreams alive. Understand to achieve anything requires faith and belief in yourself, vision, hard work, determination, and dedication. Remember all things are possible for those who believe."

Gali Devers.

Tamrin Veldsman

The author

March 2020

SUMMARY

Physical inactivity is a significant health concern, contributing to the development of non-communicable diseases (NCDs) in the 21st century. Among NCDs, cardiovascular diseases (CVDs) are major contributors to the high mortality rate, therefore early detection of CVDs is needed. Carotid intima-media thickness (CIMT) is a non-invasive measure used to evaluate the progression of atherosclerosis, an underlying cause of CVD. However, limited research is available regarding the relationship between physical activity (PA), cardio-metabolic risk factors and CIMT in teachers. The main aim of this thesis was to determine the relationships between objectively measured PA status, cardio-metabolic risk factors and CIMT.

A cross-sectional study design using secondary data from the Sympathetic Activity and Ambulatory Blood Pressure in Africans (SABPA) prospective cohort study on a total of 216 teachers drawn from Dr Kenneth Kaunda District, North West Province, South Africa was employed. Only participants with 7-day ActiHeart PA data were included in the study. Cardio-metabolic risk factors were objectively measured; whereas, alcohol usage and smoking were subjectively assessed. Height (cm), mass/weight (kg) and biochemical values were determined following standard procedures. Also, sphygmomanometer and 24-hour ambulatory blood pressure recordings were used to measure resting blood pressure. SonoSite Micromaxx ultrasound was used to measure CIMT. Participants were classified as presenting with or without cardio-metabolic syndrome according to the Joint Interim Statement. Data were analysed using the Statistical Package for Social Sciences (SPSS) version 26. Descriptive statistics (mean±standard deviations) as well as frequencies were calculated. Partial correlations were determined to identify the relationship between the variables. The level of significance was set at $p \leq 0.05$.

The results of this study indicated that 67% of the participants were sedentary and 33% participated in light-intensity PA. Male teachers had significantly higher mean CIMT values than their female counterparts ($p < 0.05$). An inconclusive weak borderline negative association between CIMT and mean 7-day awake metabolic equivalent of task (METs) (r = -0.19; p = 0.08) was found, and CIMT was moderate inversely associated with total energy expenditure (r = -0.31; p = 0.05) in sedentary male teachers.

In the measures of body composition, waist circumference (WC) was positively and significantly (β = 0.151, p = 0.027) related to CIMT. A significant positive relationship was observed between WC and CIMT. The observed correlation was explained by 2.3% (R^2; 0.023) WC in the model, and it was an inconclusive borderline statistically significant ($F(2; 211) = 2.489$; p = 0.085) result. The addition of PA into the regression models did not change the magnitude of the regression coefficients for any of the body composition variables and CIMT.

Twenty-nine percent of the teachers were classified with cardio-metabolic syndrome. A weak significant positive relationship between WC and triglycerides in the entire group of teachers (r = 0.16; p = 0.02) was present. A weak significant negative relationship was found between mean 7-day awake METs and triglycerides (r = -0.29; p = 0.02), with an inconclusive borderline negative association between gamma-glutamyl transferase (GGT) and mean 7-day awake METs (r = -0.25; p = 0.06); activity energy expenditure (r = - 0.24; p = 0.06); and physical activity level (r = -0.23; p = 0.07). After adjustments for age group, self-reported smoking and alcohol use, a weak significant negative relationship between mean 7-day awake METs and triglycerides (r = -0.28; p < 0.01) remained with small changes.

The conclusion drawn from this study though not conclusive highlighted that participation in light PA was associated with lower CIMT, especially in female teachers. In addition, CIMT was positively associated with WC. The high cardiovascular risk profile (increased C-reactive protein, high overweight/obesity prevalence) diminished the protective role of PA in the relationship between obesity and CIMT. Physical activity is negatively associated with GGT and triglycerides in teachers with cardio-metabolic syndrome. Physical activity intervention studies are recommended to determine effective interventions to provide information on how to limit the development of atherosclerosis.

Keywords: *cardio-metabolic risk factors, cardio-metabolic syndrome, carotid intima-media thickness, metabolic syndrome, non-communicable disease, physical inactivity*

OPSOMMING

Fisieke onaktiwiteit is ’n belangrike gesondheidsorg probleem wat bydra tot die ontwikkeling van nie-oordraagbare siektes (NOSs) in die 21ste eeu. As deel van NOSs, lewer kardiovaskulêre siektes (KVSs) ’n belangrike bydrae tot die hoë sterftesyfer, daarom is dit belangrik om KVSs vroeg op te spoor. Karotis intima-media dikte (KIMD) is ’n nie-indringende maatstaf wat gebruik word om die vordering van aterosklerose, ’n onderliggende oorsaak van KVSs te evalueer. Daar is egter beperkte navorsing beskikbaar rakende die verband tussen fisieke aktiwiteit (FA), kardio-metaboliese risikofaktore en KIMD in onderwysers. Die hoofdoel van hierdie tesis was om die verwantskappe tussen objektiewe FA status, kardio-metaboliese risiko faktore en KIMD te bepaal.

'n Dwarsdeursnitstudie-ontwerp met behulp van sekondêre gegewens uit die Simpatiese Aktiwiteit en Ambulatoriese Bloeddruk in Afrika (SABPA) voornemende kohortstudie in 'n totaal van 216 onderwysers van Dr Kenneth Kaunda distrik in die Noordwes Provinsie, Suid-Afrika, is gedoen. Slegs deelnemers met 7-dae ActiHeart FA data was in die studie ingesluit. Kardio-metaboliese risiko faktore was objektief gemeet, alhoewel, alkohol gebruik en rook ook subjektiewe assesseer was. So ook, sfigmomanometer en 24-uur ambulatoriese bloeddruk metings om rustende bloeddruk te meet. SonoSite Micromaxx ultraklank was gebruik om KIMD te meet. Deelnemers was geklassifiseer as met of sonder kardio-metaboliese sindroom volgens die ‘Joint Interim Statement’. Data is ontleed deur gebruik te maak van die Statistical Package for Social Sciences (SPSS) weergawe 26. Beskrywende statistiek (gemiddelde±standaardafwykings) asook frekwensies was bereken. Gedeeltelike korrelasies was bepaal om die verbande tussen die veranderlikes aan te dui. Die vlak van betekenisvolheid was op $p \leq 0.05$ gestel.

Die studie resultate het daarop gedui dat 67% van die deelnemers sedentêr was en dat 33% aan lae-intensiteit FA deelgeneem het. Die manlike onderwysers het ’n betekenisvolle hoër gemiddelde KIMD gehad as die vroulike onderwysers ($p < 0.05$). ’n Swak nie-oortuigende grenslyn negatiewe verwantskap was gevind tussen KIMD en gemiddelde 7-dae metaboliese ekwivalent van taak (METs) ($r = -0.19$; $p = 0.08$), en KIMD was omgekeerd geassosieer met die totale energie-uitgawes ($r = -0.31$; $p = 0.05$) in manlike onderwysers.

In die metings van liggaamsamestelling, was middel omtrek (MO) ($\beta = 0.15$; $p = 0.027$) positief verwant aan KIMD. ’n Betekenisvolle verwantskap tussen MO en KIMD was gevind. Die bevonde korrelasie was verduidelik deur 2.3% (R-kwadraat; 0.023) MO in die model, en was nie-oortuigende grenslyn statisties betekenisvol ($F(2; 211) = 2.489$; $p = 0.085$). Deur FA in die regressie model in te voeg het nie die grootte van die regressie koëffisiënte van enige van die liggaamsamestelling veranderlikes en KIMD verander nie.

Nege-en-twintig persent van die onderwysers was met kardio-metaboliese sindroom geklassifiseer. ’n Lae betekenisvolle positiewe verwantskap tussen MO en trigliseriede was gevind in die totale groep onderwysers (r = 0.16; p = 0.02). ’n Lae betekenisvolle negatiewe verwantskap was gevind tussen die gemiddelde 7-dae wakker METs en trigliseriede (r = -0.29; p = 0.02), met ’n nie-oortuigende grenslyn negatiewe assosiasie tussen gamma-glutamieltransferase (GGT) en gemiddelde 7-dae wakker METs (r = 0.25; p = 0.06); aktiwiteitsverwante energieverbruik (r = -0.24; p = 0.06); en fisieke aktiwiteitsvlak (r = -0.23; p = 0.07). Na aanpassings gemaak is vir ouderdomsgroep, self-gerapporteerde rook en alkoholgebruik, het die lae betekenisvolle negatiewe verwantskap tussen 7-dae METs en gemiddelde trigliseriede (r = -0.28; p < 0.01) oorgebly met klein veranderinge.

Die gevolgtrekking vanuit die studie hoewel nie oortuigend nie beklemtoon dat deelname aan ligte FA assosieer word met laer KIMD, veral in vroulike onderwysers. Boonop, was KIMD positief assosieer met MO. Die hoë kardiovaskulêre risiko profiel (verhoogde C-reaktiewe proteïen, hoë voorkoms van oorgewig/obesiteit) het die beskermende rol van FA in die verhouding tussen obesiteit en KIMD verminder. Fisieke aktiwiteit het negatiewe assosiasies met GGT en trigliseriede in onderwysers met kardio-metaboliese sindroom getoon. Fisieke aktiwiteit intervensie studies word voorgestel om effektiewe intervensies te bepaal om inligting te verskaf oor hoe om die ontwikkeling van aterosklerose te beperk.

Sleutelwoorde: kardio-metaboliese risiko faktore, kardio-metaboliese sindroom, karotis intima-media dikte, nie-oordraagbare siekte, fisieke onaktiwiteit

TABLE OF CONTENTS

Declaration i

Acknowledgements ii

Summary iv

Opsomming vi

Table of contents viii

List of tables xii

List of figures xiv

List of abbreviations xv

CHAPTER 1:

INTRODUCTION

1.1 INTRODUCTION 1

1.2 PROBLEM STATEMENT 1

1.3 OBJECTIVES 5

1.4 HYPOTHESES 5

1.5 MODEL FRAMEWORK FOR THIS THESIS 5

1.6 STRUCTURE OF THE THESIS 8

REFERENCES 9

CHAPTER 2:

PHYSICAL ACTIVITY, NON-COMMUNICABLE DISEASE AND CAROTID INTIMA-MEDIA THICKNESS: A LITERATURE REVIEW

2.1 INTRODUCTION 14

2.2 PHYSICAL ACTIVITY 15

2.2.1 Definition and recommendation 15

2.2.2 Measurements of physical activity 18

2.3 PHYSICAL INACTIVITY AS A MODIFIABLE RISK FACTOR 23

2.3.1 Oxidative stress and disease 24

2.4 NON-COMMUNICABLE DISEASE 25

2.4.1 Cardio-metabolic syndrome 26

2.5 CAROTID INTIMA-MEDIA THICKNESS 30

2.6 PHYSICAL ACTIVITY AND HEALTH 33

2.6.1 Physical activity and carotid intima-media thickness 38

2.7 SUMMARY 46

REFERENCES ……..……...…… 47

CHAPTER 3:

ARTICLE 1: Relationship between physical activity and carotid intima-media thickness among teachers in South Africa: the SABPA study

ABSTRACT ……...…… 69
INTRODUCTION ……... 70
METHODS …….. 71
Study design and participants ……... 71
Protocol …… 71
Subclinical atherosclerosis ……... 72
Biochemical analysis …… 73
Statistical analysis …… 73
RESULTS …… 74
DISCUSSION …….. 82
CONCLUSION …… 84
ACKNOWLEDGEMENTS AND SOURCES OF FUNDING …… 85
DISCLAIMER ……. 85
REFERENCES ……...……. 86

CHAPTER 4:

ARTICLE 2: The role of physical activity status in the relationship between obesity and carotid intima–media thickness in urban South African teachers: the SABPA study

ABSTRACT ……..……...……..…… 93
INTRODUCTION ……..……..... 94
PURPOSE OF THE STUDY ……...……...… 95
METHODOLOGY …….. 95
Study design ……...……... 95
Study population and sample …… 95
Anthropometric measurements ……..……...… 96
Objectively measured physical activity …… 96
Subclinical atherosclerosis ……...…… 97
Lifestyle factors …… 97
Data analysis …… 98
RESULTS …… 98
DISCUSSION …….. 105
CONCLUSION …… 106
FUNDING INFORMATION ……...…… 107

DISCLAIMER ……. 107
REFERENCES ……..…..… 108

CHAPTER 5:

ARTICLE 3: The relationship between physical status, body fatness and cardio-metabolic syndrome in a cohort of urban South African teachers

ABSTRACT ……..... 114
BACKGROUND ..……...……..... 115
METHODS …….. 116
Study design ……..……... 116
Study population and sampling ……..……...… 116
Data collection ……..……...……. 116
Data analysis …… 118
Ethical considerations …….. 118
RESULTS …… 118
DISCUSSION …….. 131
CONCLUSION …… 132
ACKNOWLEDGEMENTS ……..…… 133
COMPETING INTEREST ……...……..……. 133
AUTHORS CONTRIBUTIONS …….. 133
FUNDING INFORMATION ……... 133
REFERENCES …… 134

CHAPTER 6:

SUMMARY, CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

6.1 SUMMARY ……..……...……. 138
6.2 CONCLUSION ……...…….. 140
6.3 CONTRIBUTION OF THE STUDY …… 141
6.4 LIMITATIONS ……..…….. 142
6.5 RECOMMENDATIONS AND FUTURE RESEARCH …….. 143
REFERENCES ……..…..… 144

APPENDIX A:

ETHICS DOCUMENTATION

Approval of study ……....…. 146
Approval for amendment request ……....……..... 148
Ethics approval of the SABPA-study ……..…..... 149

APPENDIX B

INFORMED CONSENT …….……..……. 150

APPENDIX C

PROOF OF LANGUAGE EDITING ……...…..….. 160

APPENDIX D

GUIDELINES FOR AUTHORS

Cardiovascular Journal of Africa …….……..... 162

South African Journal for Research in Sport, Physical Education and Recreation ……..... 167

African Journal of Primary Health Care and Family Medicine ……....…… 174

APPENDIX E

PROOF OF ARTICLE SUBMISSION ……...…..... 184

LIST OF TABLES

TABLES IN CHAPTER 2:

Table 2.1 Physical activity guidelines for healthy adults aged 18 to 65 years (adapted from Haskell *et al*., 2007:1083–1084) ……... 17

Table 2.2 Definitions of the cardio-metabolic syndrome (compiled from Alberti *et al.*, 2009:1642; Eckel *et al*., 2005:1415; Ehrman *et al*., 2010:142) ……. 28

Table 2.3 Benefits of physical activity (adapted from Kadoglou *et al*., 2008:269; Lee *et al*., 2012:220; Physical Activity Guidelines Advisory Committee, 2018:D5; Seals *et al*., 2009:5547; Swain *et al*., 2014:336; Vogel *et al*., 2009:316; WHO, 2010:1) ……. 36

Table 2.4 A summary of the relationship between objectively measured physical activity and carotid intima–media thickness ……..……... 40

TABLES IN CHAPTER 3:

Table 1 Differences in carotid intima-media thickness between young and middle adulthood and male, and female teachers ……..……. 75

Table 2 Percentage scores and chi-square *p*-values for hypertension and CRP for the total group and according to PA and age group categories …… 76

Table 3 Descriptive statistics of the total group of participants according to physical activity categories and *p*-value for between groups ……..……. 77

Table 4 Differences in the characteristics of the participants according to physical activity categories …….. 78

Table 5 Correlations matrix *rho* (*r*) for anthropometric measurements, AEE and CIMT by activity groups …….. 80

Table 6 Partial correlation coefficient (*r*) for the relationship between CIMT and PA, controlled for age group, waist circumference, CRP, 24-h SBP and cholesterol ……... 81

TABLES IN CHAPTER 4:

Table 1 Differences in descriptive characteristics of the male and female teachers (mean±standard deviation except where indicated) ……..…... 98

Table 2 Differences in descriptive characteristics of the teachers according to body mass index classification ……... 99

Table 3 Independent t-test for participants according to waist-to-height ratio category ……. 100

Table 4 Spearman's *rho* correlation matrix for anthropometric measurements, activity energy expenditure and carotid intima–media thickness among overweight and obese participants in the sedentary and light-intensity physical activity groups …….. 102
Table 5 Controlled standardised regression coefficients (β) and *p*-values (95% confidence interval) for the relationship between carotid intima–media thickness and body composition, controlling for physical activity 103
Table 6 Multivariate linear regression for predicting carotid intima–media thickness ……... 103

TABLES IN CHAPTER 5:

Table 1 Descriptive characteristics of participants presenting with cardio-metabolic syndrome and participants without cardio-metabolic syndrome ……... 121
Table 2 The relationship between physical activity status, body fatness and cardio-metabolic risk factors in a cohort of urban South African teachers ……...…… 123
Table 3 Spearman correlation *rho* for anthropometric variables and cardio-metabolic syndrome variables according to teachers presenting with cardio-metabolic syndrome and without cardio-metabolic syndrome ……... 125
Table 4 Correlation coefficients adjusted for age group, sex, self-reported smoking and alcohol usage of the total group of teachers ……...…… 127
Table 5 Correlation coefficients adjusted for age group, sex, self-reported smoking and alcohol usage stratified by cardio-metabolic syndrome status …….. 129

LIST OF FIGURES

FIGURES IN CHAPTER 1:

Figure 1.1 Illustration of the SABPA study and data used in the thesis …….. 7

Figure 1.2 A schematic presentation of the structure of the thesis …….. 8

FIGURES IN CHAPTER 2:

Figure 2.1 Interaction between physical inactivity and atherosclerosis …….……...….. 32

Figure 2.2 The neuroendocrine response of physical stress (Compiled from Heijnen *et al*., 2016:2) …….. 35

FIGURES IN CHAPTER 3:

Figure 1 Percentage of total participants according to body mass index categories, age group and sex/age group combined ……..……..…..... 74

Figure 2 Activity classification for the entire group and male and female according to mean 7-day awake metabolic equivalents of task ……... 74

Figure 3 Percentage of participants in body mass index categories according to physical activity classification …… 75

FIGURES IN CHAPTER 5:

Figure 1 The prevalence of cardio-metabolic syndrome among teachers …… 118

Figure 2 The prevalence of sedentary and light physical activity among teachers with and without cardio-metabolic syndrome ……..…...…… 118

Figure 3 Distribution of prevalence of cardio-metabolic risk factors and lifestyle behaviours among teachers presenting with and without cardio-metabolic syndrome ……..…….. 120

LIST OF ABBREVIATIONS

ACSM	American College of Sports Medicine
AEE	Activity energy expenditure
AHA	American Heart Association
AIDS	Acquired immunodeficiency syndrome
AMBP	Ambulatory blood pressure
AMS	Artery measurement systems
ANOVA	Analysis of variance
BDNF	Brain-derived neurotrophic factor
BMI	Body mass index
BP	Blood pressure
CCA	Common carotid artery
CD	Carotid distensibility
CDC	Centers for Disease Control
CIMT	Carotid intima–media thickness
CRF	Cardiorespiratory fitness
CRP	C-reactive protein
CVD	Cardiovascular disease
DBP	Diastolic blood pressure
DEE	Diet-induced energy expenditure
DLW	Doubly labelled water
DNA	Deoxyribonucleic acid
ECG	Electrocardiogram
EYHS	European Youth Heart Study
FA	Fisieke aktiwiteit
FITT	Frequency, intensity, type and time
FITT-VP	Frequency, intensity, type, time, volume and progression
GGT	Gamma-glutamyl transferase
GPAQ	Global Physical Activity Questionnaire
HART	Hypertension in Africa Research Team

HbA1C	Haemoglobin A1c
HDL	High-density lipoprotein
HIV	Human immunodeficiency virus
HPA	Hypothalamic-pituitary-adrenal
HREC	Health research ethics committee
IDF	International Diabetes Federation
IMT	Intima–media thickness
IPAQ	International Physical Activity Questionnaire
ISAK	International Society for the Advancement of Kinanthropometry
JIS	Joint Interim Statement
KIMD	Karotis intima–media dikte
KVSs	Kardiovaskulêre siektes
LDL	Low-density lipoprotein
LPA	Light physical activity
METs	Metabolic equivalent of task
MRC	Medical Research Council
MS	Cardio-metabolic syndrome
MVPA	Moderate-to-vigorous physical activity
NCD	Non-communicable disease
NCEP ATP III	National Cholesterol Education Program Adult Treatment Panel III
NOSs	Nie-oordraagbare siektes
NRF	National Research Foundation
NWU	North-West University
PA	Physical activity
PaCT	Partnership for Cohort Research and Training
PAL	Physical activity level
PhASRec	Physical Activity, Sport and Recreation research focus area
REE	Resting energy expenditure
RMR	Resting metabolic rate
ROS	Reactive oxygen species
SABPA	Sympathetic Activity and Ambulatory Blood Pressure in Africans
SAJRSPER	South African Journal for Research in Sport, Physical Education and Recreation
SBP	Systolic blood pressure
SBRN	Sedentary Behaviour Research Network

SMAC	Sequential multiple analyser computer
SPSS	Statistical Package for Social Science
ST	Sedentary time
StatsSA	Statistics South Africa
TC	Total cholesterol
TEE	Total energy expenditure
TG	Triglycerides
VAT	Visceral adipose tissue
VPA	Vigorous physical activity
WC	Waist circumference
WHO	World Health Organization
WHR	Waist-to-hip ratio
WHtR	Waist-to-height ratio

CHAPTER 1:

INTRODUCTION

1.1 INTRODUCTION

Convincing evidence exists on the protective role of regular physical activity (PA) in the development of non-communicable diseases (NCDs) (Guthold *et al.*, 2018:1077; Lyden *et al.*, 2011:187; Vogel *et al.*, 2009:304). However, a large number of the global population remain physically inactive (WHO, 2016a). A physically inactive lifestyle is a major risk factor in the development of NCDs (WHO, 2018), in particular cardiovascular disease (CVD), which is the major cause of global mortality from NCDs (WHO, 2018). The strong link between physical inactivity, obesity and hypertension often predisposes individuals to develop a CVD (Andersson *et al.*, 2015:10; Kotsis *et al.*, 2006:1713). Carotid intima–media thickness (CIMT), a measure of end-organ damage, is used as a non-invasive marker to measure the risk of developing atherosclerosis in the carotid arteries to predict a future CVD event (Van Den Oord *et al.*, 2013:9).

This thesis investigates the relationship between PA status, CIMT and cardio-metabolic risk factors in a cohort of teachers. Current literature concerning PA status, cardio-metabolic disease and CIMT is lacking, both internationally and, especially, in South Africa. In this chapter, the high prevalence of physical inactivity and the risk in developing a NCD, in particular due to cardio-metabolic risk factors and the development of atherosclerosis as measured through CIMT, is explored. A research question is then derived from a problem statement and clear research objectives are provided, together with the research hypothesis. A model framework of this study within the larger Sympathetic Activity and Ambulatory Blood Pressure in Africans (SABPA) study is presented and, finally, the structure of this thesis is outlined.

1.2 PROBLEM STATEMENT

Physical inactivity remains a global public health concern (WHO, 2016a), even though substantial evidence on the benefits of regular PA exists (Physical Activity Guidelines Advisory Committee, 2018:A2). Physical inactivity is the fourth-leading cause of global mortality and leads to an annual estimate of 3.2 million deaths worldwide (WHO, 2016b). Global statistics indicate that 27.5% of adults (23.4% of men and 31.7% of women) are physically inactive and reflecting sedentary behaviour (WHO, 2018b). Sedentary behaviour refers to activities that do not increase energy expenditure above the level of 1.0–1.5 metabolic equivalents of task (MET) (Pate *et al*., 2008:174).

In South Africa, statistics indicate that 46.9% of adults (42.2% of men and 51.6% of women) do not participate in sufficient PA (WHO, 2015a). According to a survey conducted by the World Health Organization (WHO) in 51 low- and middle-income countries (212 021 total participants, 2 028 South

African participants), South Africa ranked as the country with the third-highest prevalence of physical inactivity (Guthold *et al*., 2008:491). Bauman and Sallis (2008:544) explained that in the 51-country survey, more women were physically inactive than men, making this a vulnerable population and a population at an increased risk of developing CVD. Dumith *et al*. (2011:25) compiled a report from three multicentre studies with similar protocols around the same period and found that predominantly urban and wealthy countries are more likely to have a high prevalence of physical inactivity. In Sub-Saharan Africa, the rapid urbanisation of lifestyle is characterised by lower participation in PA and an increased risk of developing cardio-metabolic diseases (Assah *et al*., 2011:495). Being physically inactive is associated with a lower quality of life, including loss of function and development of NCDs (Archer & Blair, 2011:395) and other chronic medical conditions or illnesses that are not infectious (Bradshaw *et al*., 2011:1).

Physical inactivity, is responsible for 6–10% of the major NCDs such as coronary heart disease, type 2 diabetes mellitus as well as breast and colon cancer (Lee *et al*., 2012:228). There are four main types of NCD – CVD, cancers, chronic respiratory diseases and diabetes mellitus (Bradshaw *et al*., 2011:1). Risk factors associated with NCDs are overweight, obesity, hypertension, hyperglycosaemia and raised low-density lipoprotein (LDL) cholesterol (Bradshaw *et al*., 2011:1). In 2014 the WHO described the prevalence of overweight in South African adults as 53.9% (43.2% men and 57.6% women) (WHO, 2015b) and the incidence of adult obesity in South Africa has been reported to have reached 26.8% of the population (15.7% men and 37.3% women) (WHO, 2015c). Obesity is a risk factor in the development of hyperglycosaemia, hypertension, high serum triglycerides, low high-density lipoprotein (HDL) cholesterol and insulin resistance, which lead to a higher risk in developing a CVD (Akbartabartoori *et al*., 2008:7; Alberti *et al*., 2006:474). The high prevalence of obesity also leads to a heightened incidence in type 2 diabetes mellitus (Hossian *et al*., 2007:213).

In the year 2015, NCDs contributed to 36.8% of deaths in South Africa (StatsSA, 2015:27). Cardio-metabolic syndrome is a disease comprising a constellation of maladaptive cardiovascular, renal, metabolic, prothrombotic and inflammatory abnormalities (Castro *et al*., 2003:393). Castro *et al*. (2003:393) explain that cardiovascular or metabolic disorders individually or combined lead to an increase in CVD morbidity and mortality, with cardio-metabolic disease risk factors contributing to CVD and stroke. Cardio-metabolic risk factors can be separated into two categories, modifiable risk factors (physical inactivity, smoking, hypertension, hyperglycosaemia, dyslipidaemia) and non-modifiable risk factors (age, sex, family history) (Micha & Mozaffarian, 2008:147). Wessel *et al.* (2004:1185) describe how lower self-reported physical fitness scores and physical activity were associated with a higher prevalence of CVD risk factors in women in the United States

In terms of modifiable risk factors for the development of coronary heart disease, black Africans showed low PA and higher rates of alcohol abuse and smoking (Hamer *et al*., 2011:240). In a large-scale study of 4506 people conducted in an urban community in Soweto, South Africa, heart failure was the most common primary diagnosis. The study indicated that black Africans were more likely to be diagnosed with heart

failure than coronary artery disease (Sliwa *et al*., 2008:919). Fifty-nine per cent of this urban African community had more than one risk factor for developing CVD (Sliwa *et al*., 2008:918).

Evidence exists that regular PA contributes to the prevention of several chronic diseases and risk factors in developing these diseases (Kohl *et al*., 2012:303; Warburton *et al*., 2006:80). PA is defined as any bodily movement produced by skeletal muscles and requiring energy expenditure (WHO, 2016b). When physically inactive individuals participate in regular PA, an increase of 0.68 years on average lifespan may occur (Lee *et al*., 2012:227). The indicated value may seem low, but it is a representation of the entire population's gain in life expectancy, not only that of the physically inactive individuals (Lee *et al*., 2012:227). Another study focusing on the increase in life expectancy carried out in the USA found that participating in moderate-to-high levels of PA increased participant's life expectancy by 1.3–3.5 years (Franco *et al*., 2005:2357). Recently, Li and colleagues (2018:348) revealed that adherence to five low-lifestyle factors (i.e. never smoking, a healthy weight, regular PA, a healthy diet and moderate alcohol consumption) could prolong life expectancy at the age of 50 by 14.0 and 12.2 years in men and women, respectively.

As mentioned previously, participating in regular moderate PA has significant health benefits. In a cross-sectional health survey performed in Scotland among 16- to 74-year-old adults (N=5460) by Akbartabartoori *et al*. (2008:7), regular PA reduced the risk associated with being overweight/obese and in turn reduced the risk of developing coronary heart disease and cardio-metabolic syndrome. A narrative review on the health benefits of PA stated that high levels of PA are associated with reduced risk of premature death due to CVD, development of type 2 diabetes mellitus, osteoporosis and specific cancers (colon and breast in particular), and with an increase in bone mineral density (Warburton *et al*., 2006:802). A meta-analysis of randomised controlled trials found that regular PA had a blood pressure-lowering effect of 3.84 mmHg for systolic blood pressure and 2.58 mmHg for diastolic blood pressure (Whelton *et al*., 2002:500). Regular PA also leads to a reduction in weight, abdominal obesity and cardio-metabolic risk in adult men and women (Kallings *et al*., 2009:83).

In a 6-month intervention of behavioural changes (PA and dietary intervention), weight loss of at least 5% significantly decreased CIMT in severely obese individuals (N=90) (Cooper *et al*., 2012:1595). CIMT is an intermediate phenotype for the detection of early atherosclerosis development (Van Den Oord *et al*., 2013:9). An increased risk of developing CVD in urban black African participants is apparent as opposed to their white counterparts (Hamer *et al*., 2011:240).

In a study by Testa *et al*. (2010:1435), cardiovascular diseases were reported as a leading cause of morbidity and mortality in the elderly, with atherosclerosis playing a crucial role as the primary causal event. Atherogenesis, therefore, is a complicated process that concerns mechanisms such as endothelial dysfunction and oxidative stress (Hansson, 2005:1690). Oxidative stress clearly, in some instances, manifested due to physical inactivity and was found to play a role in the risk of developing end-organ

damage (Bruwer, 2014:37). Carotid intimamedia thickness, as measured through sonography, is considered a simple non-invasive marker for atherosclerosis, to evaluate and measure atherosclerotic changes within the arterial walls (Ascenso *et al*., 2016:391; Inaba *et al*., 2011:128; Van Den Oord *et al*., 2013:2). Non-invasive vascular markers are valuable indicators of CVD risk and in the identification of the subclinical risk for developing a CVD before a CVD event has occurred (Parsons *et al*., 2016:194). In a systematic review and meta-analysis on CIMT and CVD risk, a positive association was found between increased CIMT and cardiovascular diseases such as myocardial infarction and stroke (Van Den Oord *et al*., 2013:9). The association between PA and CIMT has been sparsely investigated globally. Little is known about how often sedentary time should be interrupted to decrease the risk of developing CVD (Parsons *et al*., 2016:194).

Findings from the Partnership for Cohort Research and Training (PaCT) in teachers from various settings in four African countries (South Africa, Uganda, Tanzania and Nigeria) revealed a high prevalence of CVD risk factors (hypertension, 48.5%; hypercholesterolemia, 20.5%; smoking, 18.0%; diabetes 10.1%; chronic kidney disease, 10.4%; overweight and obesity, 84.7%) (Laurence *et al*., 2016:998). Furthermore, Bruwer (2014:71) reported that most teachers spend more awake time sedentary and less time doing light activities. At work, teachers spend most of their time either sitting, standing or slow-walking, and these activities are light energy-cost activities (Ainsworth *et al*., 2000:501). Teachers are considered to be in a high-stress profession, where facilities, lack of support, unsupportive parents, teaching evaluations, time management, organisational policies and parental expectations all contribute to the stress associated with the profession (Ravichandran & Rajendran, 2007:136). The classification of a teacher as a role model to learners is not a new concept; teachers need to model the importance of morally based decision-making, integrity, trust, honesty, fairness and respect, not only in classes but throughout their interaction with learners (Lumpkin, 2013:49). Due to the high stress levels of this profession, the large amount of sedentary time spent by teachers, and their status as role models, they were considered a suitable population for this study.

To the author's knowledge, there is paucity in the literature regarding the associations between PA status, cardio-metabolic risk factors and cardio-metabolic health (using CIMT) in a cohort of teachers in the North West Province of South Africa using an objective method of assessing PA. The research questions answered by this study are, firstly, what is the relationship between PA status and CIMT in a cohort of urban South African teachers? Secondly, what is the role of PA in the relationship between obesity and CIMT in a cohort of urban South African teachers? Lastly, what is the relationship between PA status, body fatness (i.e. BMI, waist circumference [WC], waist-to-height ratio [WHtR]) and cardio-metabolic syndrome in a cohort of urban South African teachers?

The study serves as the groundwork for developing focused lifestyle change education material and conducting focused PA interventions in urban communities in South Africa. The results of this study also serve as an objective measure of the participant's PA status, through the use of an ActiHeart, and provide

insight into the risk of developing CVD as measured by CIMT. Insight into the relationship between PA status, body fatness and cardio-metabolic syndrome in this cohort of teachers is also provided.

1.3 OBJECTIVES

The study aimed to investigate:

- The relationship between PA status and CIMT in a cohort of urban South African teachers.
- The role of PA in the relationship between obesity and CIMT in a cohort of urban South African teachers.
- The relationship between PA status, body fatness (i.e. BMI, WC and WHtR) and cardio-metabolic syndrome in a cohort of urban South African teachers.

1.4 HYPOTHESES

The study was based on the following hypotheses:

- There will be a significant negative relationship between the PA status and CIMT in a cohort of urban South African teachers.
- Physical activity will have a positive and significant role in the relationship between obesity and CIMT in a cohort of urban South Africa teachers.
- Positive and significant associations will be observed among PA, body fatness (i.e. BMI, WC and WHtR) and cardio-metabolic syndrome in a cohort of urban South African teachers.

1.5 MODEL FRAMEWORK FOR THIS THESIS

From the literature study, it became clear that more information about PA, cardio-metabolic risk factors and CIMT was needed. Data from this thesis formed part of the SABPA prospective cohort study, which commenced in 2008/2009 and was followed up in 2011/2012. The main aim of the SABPA-study was to assess the relationship between changes in lifestyle and increased sympathetic nervous system activity, as well as vascular dysfunction, in urbanised South African teachers, explicitly focusing on the link between coping strategies and the renin-angiotensin-aldosterone system; the teachers' stress profiles; catecholamine metabolites; obesity and inflammatory markers; and cardiovascular and cardio-metabolic syndrome indicators. When baseline measurements for the SABPA-study were taken in 2008/2009 (n=409), PA was measured using an ActiGraph; however, when follow-up measurements where taken in 2011/2012 (n=359), of this study, secondary data (i.e. anonymous demographics of the participants, anthropometric measurements, cardiovascular measures [CIMT and blood pressure], objectively measured PA, cardio-metabolic syndrome, biochemical measures [fasting serum cholesterol, HDL cholesterol, triglycerides, LDL cholesterol, glucose, gamma-glutamyl transferase (GGT)]), taken from the follow-up data of 2011/2012, were analysed. However, only the participants who wore the ActiHeart for seven full consecutive days (n=216) were included in the data analysis (Figure 1.1).

The literature review indicated that CIMT and PA have been sparsely investigated, as well as the role of PA in the relationship between CIMT and PA, and the relationship between PA, body fatness and cardio-metabolic syndrome. In answering the research questions, the aim was to contribute novel scientific information on the relationship between objectively measured PA and CIMT, the role of PA in the relationship between obesity and CIMT and the role of body fatness and cardio-metabolic syndrome, in a cohort of urban South African teachers. The information gained from this sub study will serve as a groundwork for educating the teachers with regards to lifestyle changes and designing effective physical activity intervention strategies in order to decrease the risk of NCDs and MS in the target population. The results of this study will also emphasise the level of NCD risk factors among the South African teachers and their PA status.

SABPA 1 (February/May, 2008/2009) study: The aim was to assess the relationship between lifestyle changes and sympathetic nervous system and vascular dysfunction in urbanised South African teachers; links to coping, renin–angiotensin–aldosterone system, stress profile, catecholamine metabolites, obesity and inflammatory markers, cardiovascular and cardio-metabolic syndrome indicators; demographic and general questionnaire.

SABPA 1, N=409

SABPA 2 (February/May 2011/2012) study: variables measured included: 24-hr blood pressure (using Cardiotens), manual blood pressure (using a sphygmomanometer), 12 lead resting electrocardiogram (ECG), physical activity (using ActiHeart); psychological distress (using Neethling Brain Instrument questionnaire), anthropometry, cortisol (using hair sample), 24h urine sample, demographic and general questionnaire, Baecke physical activity questionnaire, Teacher stress inventory, HIV/AIDS, urine sampling, anthropometry, Finometer; blood sampling, end-organ damage (CIMT as measured using SonoSite Micromaxx).

SABPA 2, N=359

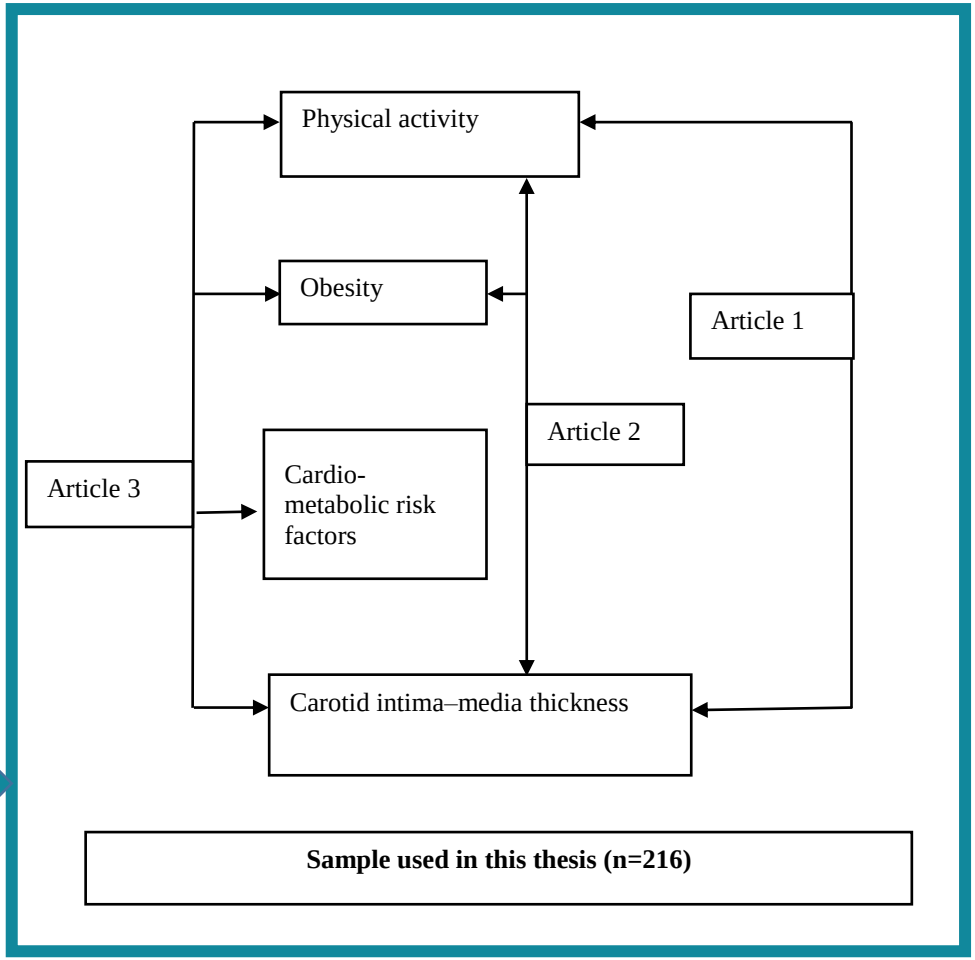


Figure 1.1: Illustration of the SABPA-study and data used in the thesis

1.6 STRUCTURE OF THE THESIS

This thesis is presented in article format; therefore the introduction (chapter 1), literature review (chapter 2) and the summary, conclusion, limitations and recommendations (chapter 6) are written in accordance with the North-West University referencing guidelines, and the three independent research articles (chapters 3–5) are written in accordance with the guidelines of the chosen journals for submission (including referencing styles). Exceptions were made in the three independent research articles (chapter 3–5) for the prescribed margins and line spacing, which adhere to the North-West University guidelines for uniformity of the thesis. The author guidelines for each journal are available in the appendices. Each chapter, therefore, has its own reference list. The literature review (chapter 2) is not a complete literature study, but a review of the most critical literature that forms the basis of the articles (chapters 3–5). The literature review is based on physical inactivity as a risk factor for cardio-metabolic disease and the role and relationship of PA in CIMT. The methodology of the study is explained in the research articles (chapters 3–5). A schematic presentation of the structure of the thesis is presented in Figure 1.2.

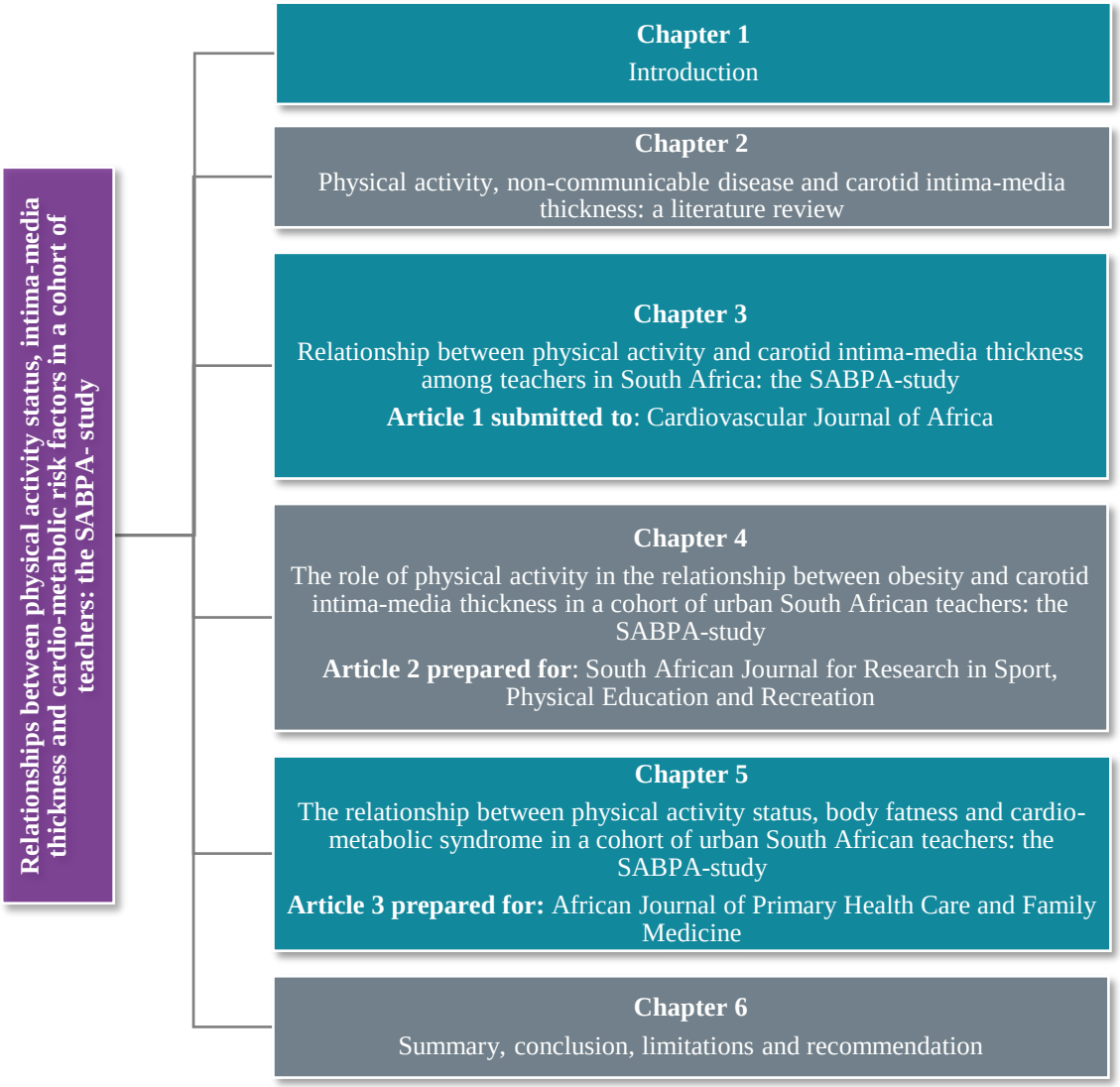


Figure 1.2: A schematic presentation of the structure of the thesis

REFERENCES

Ascenso, A., Palmeira, A., Mendes Pedro, L., Martins, S. & Fonseca, H. 2016. Physical activity and cardiorespiratory fitness, but not sedentary behaviour, are associated with carotid intima-media thickness in obese adolescents. *European Journal of Paediatrics*, 175:391–398. doi:10.1007/s00431-015-2654-x

Ainsworth, B.E., Haskell, W.L., Whitt, M.C., Irwin, M.L., Swartz, A.M., Strath, S.J., … & Leon, A.S. 2000. Compendium of physical activities: an update of activity codes and MET intensities. *Official Journal of the American College of Sports Medicine*, 32(9):498–516.

Akbartabartoori, M., Lean, M.E.J. & Hankey, C.R. 2008. The associations between the current recommendation for physical activity and cardiovascular risk associated with obesity. *European Journal of Clinical Nutrition*, 62(1):1–9. doi:10.1038/sj.ejcn.1602693

Alberti, K.G.M.M., Zimmet, P. & Shaw, J. 2006. Metabolic Syndrome – a new world-wide definition: a Consensus Statement from the International Diabetes Federation. *Diabetes Medicine*, 23:469–480. https://doi.org/10.1111/j.1464-5491.2006.01858.x

Andersson, C., Lyass, A., Larson, M.G., Spartano, N.L., Vita, J.A., Benjamin, E.J., Murabito, J.M., Esliger, D.W., Blease, S.J., Hamburg, N.M., Mitchell, G.F. & Vasan, R.S. 2015. Physical activity measured by accelerometry and its associations with cardiac structure and vascular function in young and middle-aged adults. *The Journal of the American Heart Association*, 4(3), e001528. doi:10.1161/JAHA.114.001528

Archer, E. & Blair, S.N. 2011. Physical activity and the prevention of cardiovascular disease: from evolution to epidemiology. *Progress in Cardiovascular Disease*, 53(6):387–396. doi:10.1016/j.pcad.2011.02.006

Assah, F.K., Ekelund, U., Brage, S., Mbanye, J.C. & Wareham, N.J. 2011. Urbanisation, physical activity, and metabolic health in Sub-Saharan Africa. *Diabetes Care*, 34(2):491–496. doi:10.2337/dc10-0990

Bauman, A.E. & Sallis, J.F. 2008. Global problems require global studies. *American Journal of Preventive Medicine*, 34(6):544–545. doi:10.1016/j.amepre.2008.03.001

Bradshaw, D., Steyn, K., Levitt, N. & Nojilana, B. 2011. *Non-communicable diseases – A race against time*. Medical Research Council of South Africa. http://www.health.uct.ac.za/usr/health/research/groupings/cdia/downloads/MRC_policy_brief.pdf Date of access: 19Feb. 2020.

Bruwer, E.J. 2014. *Physical activity status, chronic stress, cardiovascular risk factors and telomere length in an urban South African teachers' cohort: the SABPA study.* Potchefstroom: North-West University. (Doctoral thesis).

Castro, J.P., El-Atat, F.A., McFarlane, S.I., Aneja, A. & Sowers, J.R. 2003. Cardio-metabolic syndrome: pathophysiology and treatment. *Current Hypertension Reports,* 5:393–401. https://doi-org.nwulib.nwu.ac.za/10.1007/s11906-003-0085-y

Cooper, J.N., Columbus, M.L., Shields, K.J., Asudbonteng, J., Meyer, M.L., Sutton-Tyrrell, K., Goodpaster, B.H., DeLany, J.P., Jakicic, J.M. & Barinas-Mitchell, E. 2012. Effects of an intensive behavioural weight loss intervention consisting of caloric restriction with or without physical activity on common carotid artery remodelling in severely obese adults. *Metabolism Clinical and Experimental,* 61:1589–1597. http://dx.doi.org/10.1016/j.metabol.2012.04.012

Dumith, S.C., Hallal, P.C., Reis, R.S. & Kohl, H.W. 2011. Worldwide prevalence of physical inactivity and its association with human development index in 76 countries. *Preventive Medicine,* 53:24–28. http://dx.doi.org/10.1016/j.ypmed.2011.02.017

Franco, O.H., De Laet, C., Peeters, A., Jonker, J., Mackenbach, J. & Nusselder, W. 2005. Effects of physical activity on life expectancy with cardiovascular disease. *Archives of Internal Medicine,* 165(20):2355–2360. doi:10.1001/archinte.165.20.2355

Guthold, R., Ono, T., Strong, K.L., Chatterji, S. & Morabia, A. 2008. Worldwide variability in physical inactivity: a 51-country survey. *American Journal of Preventive Medicine,* 34(6): 486–494. doi:10.1016/j.amepre.2008.02.013

Guthold, R., Stevens, G.A., Riley, L.M. & Bull, F.C. 2018. Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1.9 million participants. *Lancet,* 6(10):1077–e1086. https://doi.org/10.1016/S2214-109X(18)30357-7

Hamer, M., Malan, L., Schutte, A.E., Huisman, H.W., van Rooyen, J.M., Schutte, R., Fourie, C.M.T., Malan, N.T. & Seedat, Y.K. 2011. Conventional and behavioural risk factors explain differences in sub-clinical vascular disease between black and Caucasian South Africans: The SABPA study. *Atherosclerosis,* 215(1):237–242. doi:10.1016/j.atherosclerosis.2010.12.015

Hansson, G.K. 2005. Inflammation, atherosclerosis, and coronary artery disease. *The New England Journal of Medicine,* 352:1685–1695. doi: 10.1056/NEJMra043430

Hossian, P., Kawar, B. & El Nahas, M. 2007. Obesity and diabetes in the developing world- a growing challenge. *The New England Journal of Medicine,* 356(3):213–215. doi:10.1056/NEJMp068177

Inaba, Y., Chen, J.A. & Bergmann, S.R. 2011. Carotid plaque, compared with carotid intima-media thickness, more accurately predicts coronary artery disease events: A meta-analysis. *Atherosclerosis,* 220:128–133. doi:10.1016/j.atherosclerosis.2011.06.044

Kallings, L.V., Johnson, J.S., Fisher, R.M., de Faire, U., Ståhle, A., Hemmingsson, E. & Hellénius, M. 2009. Beneficial effects of individualized physical activity on prescription on body composition and cardio-metabolic risk factors: results from a randomised controlled trial. *European Journal of Cardiovascular Prevention and Rehabilitation,* 16(1):80–84. doi:10.1097/HJR.0b013e32831e953a

Kohl, H.W., Craig, C.L., Lambert, E.V., Inoue, S., Alkandari, J.R., Leetongin, G. & Kahlmeier, S. 2012. The pandemic of physical inactivity: global action for the public. *Lancet,* 380(9838):294–305. https://doi.org/10.1016/S0140-6736(12)60898-8

Kotsis, V.T., Stabouli, S. V., Papamichael, C.M. & Zakopoulos, N.A. 2006. Impact of obesity in intima media thickness of carotid arteries. *Obesity*, 14(10):1708–1715. https://doi-org.nwulib.nwu.ac.za/10.1038/oby.2006.196

Laurence, E.C., Volmink, J., Esterhuizen, T.M., Dalal, S. & Holmes, M.D. 2016. Risk of cardiovascular disease among teachers in Cape Town: Findings of the South African PaCT pilot study. *South African Medical Journal*, 106(10):996–1001. doi:10.7196/SAMJ.2016.v106i10.10869

Lee, I, Shiroma, E.J., Lobelo, F., Puska, P., Blair, S.N. & Katzmarzyk, P.T. 2012. Effect of physical inactivity on major non-communicable diseases worldwide: An analysis of burden of disease and life expectancy. *Lancet,* 380(9838):219–229. http://dx.doi.org/10.1016/ S0140-6736(12)61031-9

Li, Y., Pan, A., Wang, D.D., Liu, X., Dhana, K., Franco, O.H., … Hu, F.B. 2018. Impact of healthy lifestyle factors on life expectancies in the US population. *Circulation,* 138(4):345–355. https://doi.org/10.1161/CIRCULATIONAHA.117.032047

Lumpkin, A. 2013. Teachers as role models teaching character and moral virtues. *Journal of Physical Education, Recreation and Dance,* 79(2):45–49. doi:10.1080/07303084.2008.10598134

Lyden, K., Kozey, S.L., Staudenmeyer, J.W. & Freedson, P.S. 2011. A comprehensive evaluation of commonly used accelerometer energy expenditure and MET prediction equations. *European Journal of Applied Physiology*, 111(2):187–201. doi: 10.1007/s00421-010-1639-8

Micha, R. & Mozaffarian, D. 2008. Trans fatty acids: effects on cardio metabolic health and implications for policy. *Prostaglandins, Leukotrienes and Essential Fatty Acids,* 79:147–152. doi:10.1016/j.plefa.2008.09.008

Parsons, T.J., Sartini, C., Ellins, E.A., Halcox, J.P.J., Smith, K.E., Ash, S., Lennon, L.T., Wannamethee, S.G., Lee, I.-M., Whincup, P.H. & Jefferis, B.J. 2016. Objectively measured physical activity, sedentary time and subclinical vascular disease: Cross-sectional study in older British men. *Preventive Medicine,* 89:194–199. http://dx.doi.org/10.1016/j.ypmed.2016.05.031

Pate, R.R., O'Neill, J.R. & Lobelo, F. 2008. The evolving definition of "sedentary". *Exercise Sport Science Reviews,* 36(4):173–178. doi: 0091-6331/3604/173Y178

Physical Activity Guidelines Advisory Committee. 2018. Physical Activity Guidelines Advisory Committee scientific report. https://health.gov/paguidelines/second-edition/report/pdf/PAG_Advisory_Committee_Report.pdf Date of access: 21 Oct. 2019.

Ravichandran, R., & Rajendran, R. 2007. Perceived sources of stress among teachers. *Journal of the Indian Academy of Applied Psychology,* 33(1):133–136.

StatsSA (Statistics South Africa). 2015. Mortality and causes of death in South Africa, 2014: Findings from death notification. http://www.statssa.gov.za/publications/P03093/P030932014.pdf Date of access: 29 Mar. 2016.

Sliwa, K., Wilkinson, D., Hansen, C., Ntyinthyane, L., Tibazarwa, K., Becker, A. & Stewart, S. 2008. Spectrum of heart disease and risk factors in a black urban population in South Africa (the heart of Soweto): a cohort study. *Lancet,* 371(9616), 915–922.

Testa, G., Cacciatore, F., Galizia, G., Della-Morte, D., Mazzella, F., Langellotto, A., … Abete, P. 2010. Waist circumference but not body mass index predicts long-term mortality in elderly subjects with chronic heart failure. *Journal of American Geriatrics Society,* 58(8):1433–1440. doi:10.1111/j.1532-5415.2010.02979.x

Van Den Oord, S.C.H., Sijbrands, E.J.G., Ten Kate, G.L., Van Klaveren, D., Van Domburg, R.T., Van Der Steen, A.F.W. & Schinkel, A.F.L. 2013. Carotid intima-media thickness for cardiovascular risk assessment: Systematic review and meta-analysis. *Atherosclerosis*, 228(1):1–11. http://dx.doi.org/10.1016/j.atherosclerosis.2013.01.025

Vogel, T., Brechat, P.H., Leprêtre, P.M., Kaltenbach, G., Berthel, M. & Lonsdorfer, J. 2009. Health benefits of physical activity in older patients: A review. *International Journal of Clinical Practice,* 63(2):303–320. doi: 10.1111/j.1742-1241.2008.01957.x

Warburton, D.E.R., Nicol, C.W. & Bredin, S.S.D. 2006. Health benefits of physical activity: the evidence. *Canadian Medical Association Journal,* 174(6):801–809. doi:10.1503/cmaj.051351

Wessel, T.R., Arant, C.B., Olson, M.B., Johnson, B.D., Reis, S.E., Sharaf, B.L., Shaw, L.J., Handberg, E., Sopko. G., Kelsey, S.F., Pepine, C.J. & Merz, C.N.B. 2004. Relationship of physical fitness vs body mass index with coronary artery disease and cardiovascular events in women. *The Journal of the American Medical Association*, 292(10):1179–1187. doi:10.1001/jama.292.10.1179

Whelton, S.P., Chin, A., Xin, X. & He, J. 2002. Effect of aerobic exercise on blood pressure: a meta-analysis of randomised, controlled trials. *Annals of Internal Medicine*, 136(7):493–503.

WHO (World Health Organization). 2015a. *Insufficient physical activity 2010.* http://gamapserver.who.int/gho/interactive_charts/ncd/risk_factors/physical_inactivity/atlas.html?indicator=i1&date=Male Date of access: 28 Mar. 2016.

WHO (World Health Organization). 2015b. *Prevalence of overweight, ages 18+ (2010–2014).* http://gamapserver.who.int/gho/interactive_charts/ncd/risk_factors/ overweight/atlas.html Date of access: 30 Mar. 2016.

WHO (World Health Organization). 2015c. *Prevalence of obesity, ages 18+, 2010–2014.* http://gamapserver.who.int/gho/interactive_charts/ncd/risk_factors/obesity/atlas.html Date of access: 28 Mar. 2016.

WHO (World Health Organisation). 2016a. Global strategy on diet, physical activity and health. http://www.who.int/dietphysicalactivity/factsheet_inactivity/en/ Date of access: 28 Mar. 2016.

WHO (World Health Organization). 2016b. *Physical activity.* http://www.who.int/topics/physical_activity/en/ Date of access: 30 Mar. 2016.

WHO (World Health Organization). 2018a. *Noncommunicable diseases.* https://www.who.int/en/news-room/fact-sheets/detail/noncommunicable-diseases Date of access: 17 Oct. 2019

WHO (World Health Organization). 2018b. *Global strategy on diet, physical activity and health.* http://www.who.int/dietphysicalactivity/factsheet_inactivity/en/ Date of access: 28 Mar. 2016.

CHAPTER 2:

PHYSICAL ACTIVITY, NON-COMMUNICABLE DISEASE AND CAROTID INTIMA–MEDIA THICKNESS: A LITERATURE REVIEW

2.1 INTRODUCTION

Physical inactivity is one of the major modifiable risk factors for non-communicable disease (NCD) and cardio-metabolic syndrome (MS), contributing to 6% of the annual global mortality (WHO, 2018a). Globally, one in four adults are regarded as being physically inactive (Guthold *et al*., 2018:1083). In a 51-country survey among low- and middle-income countries, South African men ranked as having the third-highest prevalence of physical inactivity and South African women ranked the fourth-highest prevalence (Guthold *et al*., 2008:489).

Physical activity (PA) includes all forms of bodily movement where skeletal muscles are contracted to increase energy expenditure (Bouchard *et al*., 2012:12; Caspersen *et al*., 1985:126; WHO, 2018a). The term physical inactivity is used to describe insufficient amounts of moderate-to-vigorous intensity PA (MVPA), i.e. not meeting specified PA guidelines (SBRN, 2017; Tremblay *et al*., 2017:9). The American Heart Association (AHA) advocates that individuals should participate in at least 150 minutes of moderate-intensity PA or 75 minutes of vigorous PA per week for health benefits (AHA, 2017). These health benefits are not only physiological but also psychological (Lee *et al*., 2012:220; Physical Activity Guidelines Advisory Committee, 2018:D5; Seals *et al*., 2009:5547; Swain *et al*., 2014:336; Vogel *et al*., 2009:316; WHO, 2010:1). Despite the numerous benefits of participating in regular PA, a large number of people remain inactive (Kohl *et al*., 2012:303), possibly due to crime and pollution, and a lack of parks, sidewalks or sport and recreation activities (WHO, 2018a).

Physical inactivity, a significant risk factor in the development of NCDs, contributes to the development of oxidative stress, which leads to end-organ damage and premature mortality (Camarillo-Romero *et al*., 2012:3). Non-communicable disease include cardiovascular disease (CVD), cancer, chronic respiratory disease and diabetes (WHO, 2018b) and are responsible for 71% of global mortality (Bradshaw *et al*., 2011:1; WHO, 2018b). In South Africa, 51% of all deaths are attributed to NCDs and 19% of these deaths are due to CVD (Den Ruijter *et al*., 2012:796; WHO, 2018c). Certain CVD risk factors tend to cluster and are known as MS (Huang, 2009:231; Kirk & Klein, 2009:761).

Several diagnostic criteria for MS exist; however, in 2009 the Joint Interim Statement (JIS) was established to harmonise the diagnosing of MS and to propose one method of diagnosing it that included ethnic-specific waist circumference (WC) cut-points (Alberti *et al*., 2009:1642). Having MS, doubles an individual's risk

of developing a CVD in the next decade, and increases their risk fivefold of developing type 2 diabetes mellitus (Alberti *et al.*, 2009:1641; Eckel *et al*., 2005:1417). An underlying cause of CVD is atherosclerosis and can be detected through a non-invasive measure of carotid intima–media thickness (CIMT) (Ascenso *et al.*, 2016:391; Dawson *et al*., 2009:2273; Inaba *et al*., 2011:128*;* Nezu *et al*., 2015:1; Touboul *et al.*, 2007:75; Van den Oord *et al*., 2013:2).

The background to identifying atherosclerotic risk in adults and investigating the relationship between PA, MS and CIMT needs to be well understood. Therefore this chapter reviews the literature on PA, NCDs including MS, and CIMT. In the write-up of this chapter, the following research engines were used: Science Direct, EbschoHost, SA ePublications (Sabinet) and Google Scholar. Databases used were Academic Search Premier, ERIC, MEDLINE, SPORTDiscus, and Health Source-Nursing/Academic edition. Theses and dissertations were included in the search, as well as cross-referencing. The following keywords were used to search for relevant information: *carotid intima–media thickness*; *cardio-metabolic risk factors*; *cardio-metabolic syndrome; non-communicable disease*; and *physical activity*.

The literature in this chapter is presented as follows:

- Physical activity definitions and recommendations
- Methods used in measuring PA
- Physical inactivity is a modifiable risk factor
- Oxidative stress
- Non-communicable diseases and MS
- Carotid intimamedia thickness
- Physical activity and disease
- Physical activity and CIMT.

The chapter closes with a summary of the literature review.

2.2. PHYSICAL ACTIVITY

2.2.1 Definition and recommendations

The terms ‘physical activity’, ‘exercise’ and ‘physical fitness’ are often used interchangeably; this, however, is not correct, as each term refers to a different concept (Caspersen *et al*., 1985:126). The definition of PA, recommendations for PA participation and the influence of PA on an individual’s physical and psychological health have been studied since the early 1900s (Caspersen *et al.*, 1985:126; Fox, 1999:411; Pate *et al*., 1995:402). In 1985 **PA** was defined as “any bodily movement produced by skeletal muscles that result in energy expenditure” (Caspersen *et al*., 1985:126). The definition was further elaborated by Bouchard *et al*. (2012:12) as “any bodily movement produced by skeletal muscles resulting

in an increase in metabolic rate over resting energy expenditure". To date, the same definition for PA is used (WHO, 2018a).

Physical fitness has been defined as a set of attributes individuals have or achieve that relate to their ability to perform PA (Caspersen *et al.*, 1985:129). Physical fitness consists of two categories – health-related components and performance-related components (Bouchard *et al.*, 2012:14). Health-related physical fitness includes cardiorespiratory endurance, muscular endurance, body composition and flexibility (Caspersen *et al.*, 1985:128), whereas performance-related components of physical fitness include agility, balance, coordination, muscle strength, power, reaction time and speed (Bouchard *et al*., 2012:14).

Physical exercise is defined as "any bodily movement that results in energy expenditure and is a planned, structured and repetitive bodily movement to improve or maintain one's physical fitness" (Caspersen *et al*., 1985:126). PA is a complex behaviour that is not limited to physical exercise (Caspersen *et al.*, 1985:130).

In describing PA behaviours, one refers to the frequency, intensity, type, and duration (FITT principle) of the prescribed activity (Bauman *et al*., 2006:93; Bouchard & Katzmarzyk, 2010:9; Warren *et al*., 2010:128). The American College of Sports Medicine (ACSM) explains that not only should the frequency, intensity, type and duration of activity be reported, but also the volume and progression (FITT-VP) of an exercise (Riebe *et al*., 2018:143).

One of the essential descriptors of PA participation is an explanation of the different intensities of PA. Physical activity intensity can be measured objectively using a participant's heart rate or subjectively through the rate of perceived exertion (Bouchard & Katzmarzyk, 2010:9). A compendium of PA was developed for different code activities (for example, bicycling, conditioning exercises, dancing, fishing and hunting, gardening, walking, running and other activities) to ensure that global comparison of PA intensities can be achieved. It is important to note that PA includes a variety of specific activities performed in various settings, each with its metabolic equivalent of task (MET) (Ainsworth *et al*., 2000:498). The use of different MET values can be used to explain different intensities at which activities are performed (Hills *et al*., 2014:4).

The definition of a MET is: "a simple and easily understandable method for expressing the energy expenditure of PA as multiples of the resting metabolic rate (RMR), where one MET is the amount of oxygen consumed while sitting at rest and is equal to 3.5 ml O_2 per kg body weight multiplied by time (in minutes)" (Hills *et al*., 2014:4; Jetté *et al*., 1990:555). The Compendium of PA is an extensive document that has been used since 1993 to describe various activities and their different intensities (Ainsworth *et al*., 2011:1579). In 2011 it was updated to explain 821 different activity codes, of which 561 codes were measured by published information, and the intensities of these various activities were expressed as multiples of resting MET levels ranging from 0.9 METs (sleeping) to 23 METs (fast running on a treadmill at 22.5 km/h) (Ainsworth *et al*., 2011:1576).

Different occupational demands, sport, leisure-time PA, exercise, physical work and household chores are included in the broad term 'physical activity', not merely exercise (Bouchard *et al*., 2012:12). Different activities are executed at different intensities. When describing these intensities, terms such as light-intensity (1.6–2.9 METs), moderate-intensity (3.0–5.9 METs) and vigorous-intensity (≥6 METs) are used (Ainsworth *et al.*, 2011:1576; Physical Activity Guidelines Advisory Committee, 2018:C7). In contrast to PA, sedentary behaviour and physical inactivity refer to activities that do not increase energy expenditure above the level of 1.0–1.5 METs (Pate *et al*., 2008:174). Desk jobs, reading, time spent on electronic devices (screen time), and sitting time are examples of sedentary behaviours (Ainsworth, 2008:8).

The global recommended levels of PA for health benefits in adults, as explained by the World Health Organization (WHO) (2010:9), advocate that individuals engage in 150 minutes of accumulated moderate-intensity aerobic PA or 75 minutes accumulated vigorous-intensity aerobic PA per week or an equivalent combination of moderate and vigorous PA. The WHO (2010:9) further elaborates on these recommendations by stating that aerobic activity should comprise of a minimum of 10 minutes per bout of activity and resistance training for all major muscle groups at least 2 days per week. In 2003, a panel comprising of physicians, epidemiologists, exercise scientists and public health experts assembled to amend the original guidelines from the Centers of Disease Control (CDC) and ACSM for PA and public health (Haskell *et al*., 2007:1083). Haskell *et al*. (2007:1083), indicated the recommended daily level of PA as a minimum of 30 minutes moderate-intensity aerobic PA 5 days per week and 20 minutes of vigorous-intensity aerobic PA 3 days per week. Muscle-strengthening and flexibility exercises should be performed at least on two or more non-consecutive days per week, where eight to ten exercises can be done using major muscle groups (Haskell *et al*., 2007:1084; WHO, 2010:9). The guidelines for recommended PA, according to Haskell *et al*. (2007:1083), are summarised in Table 2.1.

Table 2.1: Physical activity guidelines for healthy adults aged 18 to 65 years (adapted from Haskell *et al*., 2007:1083–1084)

Mode	Intensity	Duration	Frequency
Aerobic activity	Moderate Vigorous	Minimum 30 minutes Minimum 20 minutes	5 days per week 3 days per week
Muscle strength and flexibility	Amount: 8–10 exercises Major muscle groups	Repetitions: 8–12	2 days per week

The recommendations for PA from the ACSM indicate that healthy adults should participate in moderate PA, at least 3–5 days weekly for 15–60 minutes (Bouchard *et al*., 2012:29). Moderate-intensity activities include brisk walking that noticeably elevates the heart rate and should be done in bouts lasting a minimum of 10 minutes and accumulate to 30 minutes per day (Haskell *et al*., 2007:1083; WHO, 2018a). Vigorous-

intensity activities include jogging that causes rapid breathing and substantial elevations in heart rate (Haskell *et al*., 2007:1084; WHO, 2018a). These recommendations for PA are in addition to routine activities of daily living of light intensity as well as moderate-intensity activities of less than 10 minutes in duration (Haskell *et al*., 2007:1084). The AHA indicates that 30 minutes of moderate-intensity activities should be carried out for a total of 150 minutes for 5 days a week to achieve overall cardiovascular health, or at least 25 minutes vigorous aerobic activity at least 3 days per week for a total of 75 minutes (AHA, 2017).

Physical activity refers to a behaviour that results in energy expenditure above resting values (Bouchard e*t al*., 2012:12); and consists of total energy expenditure (TEE), which is the total amount of energy expended in 24 hours. Total energy expenditure comprises of four components: resting energy expenditure (REE), diet-induced energy expenditure (DEE), activity energy expenditure (AEE) and spontaneous PA such as fidgeting (DeLany, 2012:129; Westerterp, 2017:340).

In adulthood, the most significant component of TEE for a moderate PA individual is body maintenance (REE), and DEE results from about 10% of the total energy ingested for an average diet (Westerterp, 2017:340). For a moderately active individual AEE amounts to 30–40% of the TEE (Westerterp, 2017:340). In highly physically active people, PA energy expenditure may contribute 60–70% to their TEE (Warren *et al*., 2010:129). TEE and REE are similarly affected by body size (Westerterp, 2017:340). Overweight or obese persons (with a high BMI) generally participate in minimal movement due to the higher cost of weight-bearing activities (Westerterp, 2017:340). Objective measurement of PA can be used to predict energy expenditure (Hills *et al*., 2014:1).

2.2.2 Measurements of physical activity

In a comparative international study, Bauman *et al*. (2009:6) stated that international comparisons of NCD risk factors, including obesity and tobacco use, are possible, but comparisons of PA among countries is challenging due to a lack of standardised and validated instruments for measuring PA patterns. When considering methods of measuring PA and TEE, it is essential to understand the reliability, validity and responsiveness of the measurement techniques (Warren *et al*., 2010:128). Reliability refers to the trustworthiness of the measurement technique, whereas validity refers to the ability of a measurement method to measure what it is supposed to (Warren *et al*., 2010:128). Responsiveness refers to the ability of a measuring instrument to monitor change over time (Warren *et al*., 2010:129). Physical activity can be measured through objective and subjective measures.

The doubly labelled water (DLW) technique is the criterion or "gold standard" method of assessing TEE in free-living humans (Hills *et al*., 2014:1) and was introduced in the measurement of TEE in humans almost 40 years ago (Schoeller & van Santen, 1982:955). This method provides the most precise measurement of TEE (Ainsworth, 2008:8) over 4–20 days (Park *et al*., 2014:242). The DLW technique is a method where individuals receive a loading dose of water labelled with stable isotopes of hydrogen (^{2}H) and oxygen (^{18}O)

(Park *et al*., 2014:242). After participants ingest the labelled water and the isotopes mix with the hydrogen and oxygen in body water, energy is expended as carbon dioxide through breathing and water is expended through urine, sweat and other means such as evaporation, each at different rates (Park *et al*., 2014:242).

The DLW technique is known for its accuracy, and precision is used in a wide variety of populations, including the most vulnerable such as infants and pregnant or lactating women, as it is a non-invasive procedure and bears minimal risk to participants (Hills *et al*., 2014:3). However, DLW is an expensive technique for evaluating PA and a specialised laboratory is needed to perform the sample analysis (DeLany, 2012:131; Johansson & Westerterp, 2008:1031). Thus, due to the cost implications, this method is usually performed on small populations (Plasqui & Westerterp, 2007:2372) and its use is not always possible in developing countries or large study populations (Plasqui & Westerterp, 2007:2376; Park *et al*., 2014:246). Although DLW is considered the gold standard for the validity of PA measurement, it does not provide information on the frequency, intensity or duration of PA; however, it is a precise measure of TEE under free-living conditions (Kelly *et al*., 2016:3; Plasqui & Westerterp, 2007:2372; Warren *et al*., 2010:130).

The direct calorimetry method for measuring metabolic rate measures heat loss using a calorimeter (Kenny *et al*., 2017:1765; Ndahimana & Kim, 2017:72). Heat loss occurs in four ways in human beings – conduction, convection, radiation and evaporation (Kaiyala & Ramsay, 2011:253). Use of the direct calorimeter has enabled the use of indirect calorimetry (gaseous exchange between living organisms and the atmosphere) as well as direct calorimetry (Kenny *et al*., 2017:1765). Its use is thus an indication that energy expenditure in humans can be measured or estimated by measuring the consumption of oxygen (Kenny *et al*., 2017:1766). When TEE is measured using DLW or direct or indirect calorimetry, the actual amount of energy expenditure due to PA can be measured by subtracting the RMR from the TEE. A calorimeter is a closed system to ensure that all heat produced from metabolism can be measured and that no energy is transferred to the individual's surroundings; to meet these specifications requires an exceptional system, which is very expensive and technologically challenging to achieve (Kenny *et al*., 2017:1769). Kenny *et al*. (2017:1781) state there is only one known useful calorimeter used today, because of the expense and technical challenges. Direct calorimetry does not provide estimates for free-living energy expenditure as it can only be used in a confined environment and in laboratory conditions (DeLany, 2012:130). Fortunately, there are other methods to estimate energy expenditure, such as use of PA questionnaires, accelerometers, pedometers, heart rate monitors and activity diaries (Johansson & Westerterp, 2008:1031).

Various self-report measures for PA that have been validated, such as the International Physical Activity Questionnaire (IPAQ) (Graig *et al*., 2003:1389; Hagströmer *et al*., 2006:761; Helmerhorst *et al*., 2012:4; Van Poppel *et al*., 2010:593) and the Global Physical Activity Questionnaire (GPAQ) (Bull *et al*., 2009:799; Herrmann *et al*., 2013:222). Questionnaires are an inexpensive and easy way to gain information about PA and energy expenditure in different populations (Demeyer & Watz, 2018:109; Kelly *et al*., 2016:4). Self-report questionnaires are usually self-administered; however, for people with low literacy,

clinicians (biokineticists) can easily administer them through interviews (Ainsworth, 2008:7). Although there are several benefits to administering questionnaires, the risk of participants inaccurate reporting their PA participation arises, as they may not understand how to rate the intensities at which they participate and may have difficulty in recalling past events (Ainsworth *et al*., 2012:81).

The GPAQ was developed to report on PA patterns during a typical week in a variety of countries, especially in countries where the PA patterns and energy expenditure of persons are different from those in developed countries (Armstrong & Bull, 2006:66; Herrmann *et al*., 2013:222). For analysis of the GPAQ, all PA intensities are converted to MET values, with 4 METs allocated to moderate-intensity activities and 8 METs assigned to time spent participating in vigorous PA (WHO, 2018a). The GPAQ has proven fair to moderate validity in a European population (N=354 participating in PA; N=366 during sitting time predictions), using objective ActiGraph GT3X+ measurements (Wanner *et al*., 2017:7). Adding to the validity of the GPAQ, Cleland *et al*. (2014:1263) indicated that it could appropriately be used to indicate moderate-to-vigorous PA in high-income countries.

The IPAQ short and long-form instruments assess PA and energy expenditure (Guthold *et al*., 2008:487) across broad settings, and include questions about leisure-time PA, domestic and gardening activities and transport-related PA (IPAQ, 2005:2). Participants recall their PA patterns over the past 7 days, the accuracy of which relies on the participant's cognitive abilities (Kim *et al*., 2012:449). Shortcomings of global and international questionnaires include that they do not take into account different cultures, educational levels and interpretation of the questionnaires, participants' understanding of PA intensities or climate differences across countries (Guthold *et al*., 2008:492).

In a 51-country survey using the IPAQ, consistency in reporting of PA values and PA status among men and women was found (Guthold *et al*., 2008:492). In another study, the IPAQ was tested for reliability and validity in 12 developing and developed countries, demonstrating reliability especially in urban areas, suggesting that it an efficient measurement of PA (Graig *et al*., 2003:1388). Limitations of the GPAQ and IPAQ include over-reporting of the amount of moderate- and vigorous-intensity PA compared with that measured by an accelerometer (Herrmann *et al*., 2013:232; Lee *et al*., 2011:124; Tucker *et al*., 2011:460). A review on the use of the IPAQ indicated that the mode of delivery, lack of understanding of the questions in the way the researcher intended and low levels of education are all challenges when using this questionnaire (Hallal *et al*., 2010:260).

To accurately quantify levels of PA and to eliminate the bias of subjective measures (self-reported questionnaires, PA diaries and interviews), a shift to objective measurement has occurred, which includes the use of pedometers, accelerometers, heart rate monitors, or combined accelerometers and heart rate monitors. Pedometers are small, lightweight, portable and affordable devices that measure the steps taken by individuals, and are not invasive or intrusive (Ainsworth, 2008:6; Butte *et al.*, 2012:7; Warren *et al*., 2010:134). Most are accurate at measuring the number of steps taken during walking only, but do not

measure non-locomotor activities or the intensities to which activities are performed (Warren *et al*., 2010:136). Challenges in the use of pedometers include that they do not record horizontal or upper extremity movement and do not account for differences in stride length. This means that their use is very limited for estimating TEE (Butte *et al.*, 2012:8; DeLany, 2012:131). Another challenge in the use of pedometers is that the measurement of rate and intensity of PA is not possible (Warren *et al*., 2010:136).

Accelerometers, battery-operated electronic sensors that detect motion and acceleration in the body (Ainsworth, 2008:6; Hills *et al*., 2014:5; Plasqui & Westerterp, 2007:2372; Warren *et al*., 2010:132), are cost-efficient, versatile and have minimal participant discomfort; therefore these have been a device of choice in PA research (Lyden *et al*., 2011:187). Accelerometers provide data on the frequency, time and duration of acts of daily living (Plasqui & Westerterp, 2007:2373) and are commonly worn at the waist (Ainsworth, 2008:6). Several studies have concluded that accelerometers are objective, practical, non-invasive, accurate and reliable tools for measuring PA (Colbert *et al.*, 2011:867; Rothney *et al*., 2010:1790; Sirard *et al*., 2011:671; Vanhelst *et al*., 2012:694). Accelerometers provide information about an individual's movement over time and can capture continuous data over an extended period (Hills *et al*., 2014:5). The most robust relationships in measuring energy expenditure result from walking and jogging activities, but slightly decline for vigorous-intensity activities (Warren *et al*., 2010:132).

Limitations of accelerometers include difficulty in measuring upper body movement or cycling due to the placement position (hip or wrist), underestimating the energy cost due to walking uphill or when carrying heavy loads, and a lack of waterproofing, meaning they cannot measure activity during swimming and other water-based sport or PA (Warren *et al*., 2010:132). Contradictory research results exist on the use of these devices to predict TEE and MET values. Lyden and colleagues (2011:193) conducted intensive research testing three accelerometers (ActiGraph, Actical and RT3) in a variety of activities and concluded that they did not produce accurate TEE or MET values over a broad range of activities. The ActiGraph underestimates energy expenditure for active daily living and vigorous treadmill activities; however, it has increased accuracy when measuring moderate-intensity activities (Lyden *et al*., 2011:193).

Another instrument for measuring PA is a combined heart rate monitor and accelerometer (Warren *et al*., 2010:134). Usually, energy expenditure due to participation in PA is estimated using the linear relationship between an elevated heart rate and an increase in energy expenditure above a certain threshold (Warren *et al*., 2010:134). However, heart rate monitoring should only be used to measure the duration of moderate- and high-intensity activities (Warren *et al*., 2010:134). Due to the overlap in heart rate variables in sedentary behaviour and low-intensity PA, a threshold value is used to discriminate PA energy expenditure and sedentary time (Butte *et al.*, 2012:8). β-blocker medication taken to control hypertension and β2 stimulants taken for asthma will influence the heart rate of participants during PA (Butte *et al.*, 2012:8).

In using the combined accelerometer and heart rate monitor, the pros of each device are merged, thereby counteracting some of the disadvantages of using either method alone (Bruwer, 2014:29; Warren *et al*.,

2010:134). For example, heart rate monitors are less efficient at estimating energy expenditure at low intensities, but accelerometers are highly capable at these intensities (Bruwer, 2014:29; Warren *et al*., 2010:134). Determining when the accelerator devices are not worn is difficult, but this can be indicated by a combined device by monitoring the heart rate of participants (Warren *et al*., 2010:134). The ActiHeart (GBO/67703, CamNtech Ltd., Cambridgeshire, UK) a combined accelerometer and heart rate device has been established as a valid and reliable measure of PA, estimating TEE in adults in free-living conditions at rest and in a wide range of activities (light, moderate and vigorous intensity) (Brage *et al*., 2005:568), and has been validated by the DLW technique (Barreira *et al*., 2009:69; Campbell *et al*., 2012:599; Crouter *et al*., 2008:710; Spierer *et al*., 2011:666). The ActiHeart has shown the ability to provide precise relative estimates of PA intensity during walking and running (Brage *et al*., 2005:567).

The ActiHeart device is waterproof and does not need to be removed, except when replacing the electrodes; therefore, TEE can be measured and not only PA (Warren *et al*., 2010:134). However, the use of the ActiHeart device can also be used in the South African population, since the combined accelerometer and heart rate device is ideal since these devices can be used in any population and their burden on the participant is low. However, they are rather costly (Bruwer, 2014:32; Warren *et al*., 2010:136). Another benefit of the ActiHeart combined accelerometer and heart rate device is that it does not only supply measurements of energy expenditure, but also a ratio of TEE and RMR, such as physical activity level (PAL) (Di Pietro *et al*., 2004:1542). PAL is considered to correct for differences in body size (Westerterp, 1999:60). People with larger body types require more energy to perform activities that require the body mass to move than those with smaller body sizes (Westerterp, 1999:60; Westerterp, 2017:340).

Persons with a physically active occupation are likely to have a PAL of ≥1.75; those engaging in light occupational and leisure-time activity are expected to have a PAL of 1.55–1.60 and sedentary participants will have a PAL of 1.4 (WHO, 2000:114). To avoid being obese, populations should strive for a PAL of ≥1.75 (WHO, 2000:114). The likelihood of men becoming overweight is reduced when they have a PAL of ≥1.8 (WHO, 2000:118). PAL is influenced by the proportion of time spent in low- and moderate-intensity activities and not merely in a single bout of vigorous PA (Westerterp, 2001:539; Westererp, 2009:825). The focus of PAL is on body size, body composition and energy expenditure in people that have reached adult weight (Westerterp, 2017:340). Energy expenditure can be predicted from height, weight, age and sex, whereas PA among participants differs (Johansson & Westerterp, 2008:1031). The ability to objectively measure PA and energy expenditure is essential against a background of an alarming global increase in physical inactivity, a modifiable risk factor for NCDs and cardio-metabolic risk factors (Hills *et al*., 2014:1).

2.3 PHYSICAL INACTIVITY AS A MODIFIABLE RISK FACTOR

Physical inactivity is a risk factor for developing NCDs and is a significant health concern in the 21st century (Blair, 2009:1). This statement is supported by the WHO (2018a), stating that physical inactivity remains a global public health concern (WHO, 2018a), even though substantial evidence exists of the benefits associated with participating in regular PA (Akbartabartoori *et al*., 2008:8). Physical inactivity is listed as the fourth-highest cause of global mortality and leads to an estimated 3.2 million deaths annually (WHO, 2018a). In the report of a 168-country survey conducted by the WHO, the urgency of physical inactivity is contextually positioned by explaining that a quarter of adults globally are physically inactive (28% or 1.4 billion people) and are at risk of developing physical inactivity-related diseases (Guthold *et al*., 2018:1083). Globally 27.5% of adults (23.4% men and 31.7% women) aged 18 years and above are physically inactive (WHO, 2018a). The highest prevalence of inactivity was found in the United States (US) and Eastern Mediterranean regions, with almost 50% of women and 40% of men physically inactive (WHO, 2018a). Although the AHA has guidelines on PA, worldwide, 31.9% of individuals do not adhere to the recommendations (Hallal *et al*., 2012:248). In a 51-country survey conducted by the WHO in low- and middle-income countries (total participants, N=212 021; South African participants, n=2028), 17.7% of the total population were classified as physically inactive. South African men were ranked with the third-highest incidence of physical inactivity (43.0%) and South African women rated with the fourth-highest incidence of being physically inactive (46.6%) (Guthold *et al*., 2008:489). Guthold *et al*. (2018:1079) indicated that a third (33%) of the South African population are physically inactive.

Rates of physical inactivity are generally higher in women and the elderly population (Dumith *et al*., 2011:25; Guthold *et al*., 2018:1082). The higher rates of physical inactivity can be explained by different sex roles in various activities, for example, housework and transport, and the variation in intensity of these activities between sexes (Guthold *et al*., 2018:1084). The 51-country survey report also explained that rapid urbanisation might contribute to high levels of physical inactivity in these developing countries (Guthold *et al*., 2008:492). An increase in technological advancements limits the amount of physical labour needed to accomplish many daily tasks and predominantly urban countries have a higher prevalence of physical inactivity (Dumith *et al*., 2011:25; Hallal *et al*., 2012:247). The high rates of physical inactivity in South Africa could be explained by the rapid rate of urbanisation that is considered a key characteristic in the development of cardio-metabolic diseases (Assah *et al.*, 2011:495). Being physically inactive is associated with a lower quality of life, including loss of function and the development of NCDs (Archer & Blair, 2011:395; Kohl *et al*., 2012:303).

Physical inactivity is a significant risk factor in the development of NCDs (WHO, 2018b). Lee *et al*. (2012:227) estimated that a physically inactive lifestyle causes 6–10% of the main NCDs (CVD, type 2 diabetes, and breast and colon cancers). Furthermore, 1.6 million global deaths were attributed to physical inactivity in 2015 (Murray *et al*., 2016:1691) creating a significant global economic burden (Ding *et al*., 2016:1323). Unfortunately, due to variation in PA measurement methods, prevalence and health systems,

comparisons between countries to estimate the financial burden of physical inactivity are difficult (Ding *et al*., 2017:15). In 2013, 0.6 billion US dollars were spent on healthcare costs resulting from physical inactivity in Africa (Ding *et al*., 2016:1317). Physical inactivity caused an alarming 9% of global premature deaths in 2008 (Lee *et al*., 2012:227). In a 31-year follow-up, individuals who were physically inactive during their youth showed a high prevalence of disturbances in normal glucose metabolism later in life (Kallio *et al*., 2018:1196). Another follow-up study (15 years) assessing participants' objectively measured PA indicated that people who participated in more than 10 hours of sedentary behaviour daily had two and a half times higher risk of all-cause mortality compared to persons with 6.5 hours of sedentary behaviour per day (Dohrn *et al*., 2018:704).

The historical development of PA research indicates a strong need for policyholders to develop a global action plan to lower the global rates of physical inactivity (Friedenreich & McNeil, 2018:474). The WHO has developed a new global action plan to help countries increase policy actions to improve PA rates. The goal of this 2018–2030 action plan is to decrease the incidence of physical inactivity by 10% by 2025 and 15% by 2030 (WHO, 2018d). Physical inactivity rates are still rising in higher-income countries and this suggests that actions taken to reduce inactivity by 10% by 2025 are too slow (Guthold *et al*., 2018:1085).

2.3.1 Oxidative stress and disease

The contribution of physical inactivity to the development of cardio-metabolic diseases may be explained by the development of oxidative stress (James *et al*., 2012:429). The biological mechanisms linking physical inactivity to cardio-metabolic disease risk are not fully understood, but oxidative stress due to physical inactivity may be a mediator in the development of cardio-metabolic disease (James *et al*., 2012:429). Oxidative stress may be caused by consumption of industrial vegetable oils, insufficient antioxidants, cigarette smoking, chronic psychological stress, environmental toxins, dysregulated circadian rhythms, infections, iron overload and physical inactivity (Kresser, 2018). Oxidative stress is considered to be an imbalance between free radicals and antioxidative mechanisms, or the excess production of reactive oxygen species (ROS) (Bloomer *et al*., 2009:1; Sies & Jones, 2007:45). During cell metabolism, oxygen is used to produce energy, and in the formation of adenosine triphosphate, ROS are generated (Pham-Huy *et al*., 2008:89) and react with surrounding molecules at the site of ROS formation (Roberts & Sindhu, 2009:706). Reactive oxygen species include superoxide radical, hydroxyl radical, hydrogen peroxide, nitric oxide and peroxynitrite radical (Roberts & Sindhu, 2009:706).

Reactive oxygen species may play both harmful and beneficial roles in the body (Pham-Huy *et al*., 2008:89; Steinbacher & Eckl, 2015:367). Low and moderate levels of ROS are useful to normal cellular signalling pathways, gene expression, immune function such as eliminating pathogenic microorganisms, and skeletal muscle force production (Li *et al*., 2016:18; Pham-Huy *et al*., 2008:90; Powers *et al*., 2011:947; Powers & Jackson, 2008:1265). High levels of ROS and low levels of antioxidants lead to the development of

oxidative stress (Pham-Huy *et al*., 2008:91; Powers & Jackson, 2008:1244) causing damage to proteins, lipids and nucleic acids that contribute to cell and tissue injury (Li *et al*., 2016:11).

Oxidative stress contributes to the development of deoxyribonucleic acid (DNA) damage, CVD, MS, hypertension, diabetes, chronic kidney disease, stroke, alcoholic liver disease, atherosclerosis, ageing, inflammatory responses, initiation of cancerous forming cells, Alzheimer's disease, Parkinson's disease, autoimmune disorders, asthma and chronic obstructive pulmonary disease, and it influences drug actions and toxicity (Alessio & Hagerman, 2006:19; Biswas, 2016:1; Biswas & Lopes de Faria, 2007:223; Pham-Huy *et al*., 2008:89,91; Roberts & Sindhu, 2009:706; Sies, 1985:6; Sies & Jones, 2007:45). Hyperlipidaemia and hyperglycaemia may contribute to the risk of developing atherosclerosis, obesity and diabetes (Chambless *et al*., 1997:483; Sies & Jones, 2007:45), and increase vasodilation, which contributes to the risk of developing cardio-metabolic diseases (Sies & Jones, 2007:45). Antioxidants, however, play a protective role against ROS by either scavenging the ROS, inhibiting the formation of ROS, or removing and repairing the damage caused by ROS (Li *et al*., 2016:12).

In any situation where an increase in oxygen consumption takes place, an acute state of oxidative stress may occur (Fisher-Wellman & Bloomer, 2009:16). Therefore, during acute PA the contraction of skeletal muscles may contribute to the formation of free radicals leading to increased ROS production (Fisher-Wellman & Bloomer, 2009:2; Powers & Jackson, 2008:1244; Steinbacher & Eckl, 2015:357; Yavari *et al*., 2015:1). Oxidative stress may develop from several mechanisms, such as mitochondrial use of oxygen or release in catecholamine during either aerobic or anaerobic physical exercise (Fisher-Wellman & Bloomer, 2009:15; Steinbacher & Eckl, 2015:357). The production of specific ROS depends on the mode, intensity and duration of activity (Fisher-Wellman & Bloomer, 2009:17).

A physically inactive lifestyle increases oxidative stress (Kresser, 2018). Bruwer *et al*. (2014:37) indicated that chronic overnutrition and physical inactivity could lead to increased amounts of glucose and free fatty acids, causing oxidative stress that in turn leads to endothelial cell dysfunction, β-cell dysfunction and muscle adipocytes, which could lead to vasoconstriction, decreased insulin secretion and impaired glucose tolerance, respectively. These contribute to the development of atherosclerosis and diabetes. Oxidative stress contributes to the development of atherosclerosis by increasing endothelial dysfunction (Heitzer *et al*., 2001:2673; Keaney, 2000:217).

2.4 NON-COMMUNICABLE DISEASE

Non-communicable diseases are chronic diseases and are responsible for 70% of global mortality, with almost three-quarters of the deaths being premature and over 85% of these deaths occurring in low- and middle-income countries (Bradshaw *et al*., 2011:1; WHO, 2018b). Non-communicable diseases are non-infectious diseases that cannot be transferred from one individual to another (Bradshaw *et al*., 2011:1). The main NCDs include CVD, cancer, chronic respiratory diseases and diabetes (WHO, 2018b; WHO, 2019). Unhealthy lifestyle behaviours (modifiable behaviours), such as physical inactivity, tobacco use and

unhealthy diets, contribute to the development of cardio-metabolic risk factors and diseases such as hypertension, overweight/obesity, hyperglycaemia and raised low-density lipoprotein (LDL) cholesterol (Bradshaw *et al*., 2011:1; Chambless *et al*., 1997:483; Mayosi *et al*., 2009:936; Riebe *et al*., 2018:48; Seals *et al*., 2009:5547; WHO, 2018b; WHO, 2019).

In Sub-Saharan Africa, there is an ever-growing concern over the double burden of disease the population faces – the residual burden of communicable (infectious) conditions and the emerging epidemic of NCDs (Joubert, 2015:3; Okafor, 2012:58). The increase in NCD rates could also be influenced by the rapid transition from rural living to urbanisation, which leads to changes in diet and, often, an increase in the psychological stress experienced by the Sub-Saharan African population (Joubert, 2015:3; Okafor, 2012:58). According to statistics for South Africa in 2016, an alarming 51% of all deaths were ascribed to NCDs (WHO, 2018c). In South Africa, 19% of the mortality rate is due to CVD, 10% due to certain cancers, 4% due to respiratory diseases and 7% due to diabetes (Den Ruijter *et al*., 2012:796; WHO, 2018c). In terms of the risk factors 37% of the total South African population is inactive, 20% smoke, 27% are obese, 24% have elevated blood pressure, and 10% have increased glucose levels (WHO, 2018c). Within NCDs, CVD is among the leading causes of global mortality (Den Ruijter *et al*., 2012:796; Seals *et al*., 2009:5541).

Another factor contributing to the development of CVD is ageing, which is associated with endothelial dysfunction and stiffening in the arteries (Seals *et al*., 2009:5547). Endothelial dysfunction is defined as an impairment in the normal functioning of the endothelial cells, leading to vasoconstriction, thrombosis, upregulation of cell adhesion molecules, increased cytokine and chemokine secretion, and leukocyte adherence (Camarillo-Romero *et al*., 2012:3). Certain CVD risk factors tend to occur in clusters and the cluster of risk factors for the development of CVDs is known as MS (Huang, 2009:231; Kirk & Klein, 2009:761). The CVD morbidity risk associated with MS has been found to be higher than the risk of morbidity due to a single risk factor (Isomaa *et al*., 2001:688).

2.4.1 Cardio-metabolic syndrome

Cardio-metabolic syndrome is also known as metabolic syndrome and previously as syndrome X or insulin resistance syndrome (Ehrman *et al*., 2010:141; Kirk & Klein, 2009:762). Cardio-metabolic syndrome refers to a cluster of metabolic abnormalities that pose increased risk for the development of CVD and diabetes, and increased risk of coronary heart disease and other forms of atherosclerotic disease (Alberti *et al*., 2009:1640; Kassi *et al*., 2011:48; Kirk & Klein, 2009:764; Motala *et al*., 2009:8; Okafor, 2012:56; Saklayen, 2018:1; Strasser, 2013:147). Lifestyle risk factors for the development of MS include physical inactivity, smoking and poor dietary habits (Camarillo-Romero *et al*., 2012:3; Huang, 2009:231; Roberts & Sindhu, 2009:709; Strasser, 2013:147). Metabolic risk factors include abdominal obesity, insulin-resistant metabolism, dyslipidaemia (increased triglycerides and reduced high-density lipoprotein [HDL]), overweight and obesity and increased blood pressure (Alberti *et al*., 2009:1640; Bankoski *et al*., 2011:497; Han & Lean, 2015:81; Kirk & Klein, 2009:764). Insulin resistance syndrome promote atherogenesis, the

formation of atherosclerotic plaque, dyslipidaemia, hypertension and a proinflammatory state affecting the progression of atherosclerosis (Bornfeldt & Tabas, 2011:575).

Cardio-metabolic syndrome is both a clinical and public health concern (Alberti *et al*., 2009:1641; He *et al*., 2014:231). In the public health sector; there should be a focus on managing lifestyle risk factors by increasing PA and decreasing the prevalence of overweight and obesity in the clinical setting (Alberti *et al*., 2009:1641). The association between inflammation, overweight and obesity may influence the development of MS (Monteiro & Azevedo, 2010:5). Identifying individuals with MS and managing their risk factors should be a focus of the health care system (Alberti *et al*., 2009:1641), as people diagnosed with MS are at twice the risk of developing a CVD in the following 5–10 years compared with those without the syndrome, and a fivefold increased risk of developing type 2 diabetes mellitus (Alberti *et al*., 2009:1641; Eckel *et al*., 2005:1417). In a meta-analysis of MS and CVD, MS was associated with a doubled risk of mortality from CVD, myocardial infarction and stroke and one and a half times increased risk of all-cause mortality (Mottillo *et al*., 2010:1119). Those with MS had significantly higher risk of developing coronary artery disease and higher rates of all-cause mortality even with no diagnosed CVD present (Lakka *et al*., 2002:2715).

Several criteria have been proposed for diagnosing MS (Camarillo-Romero *et al*., 2012:1). The most commonly used are those of the WHO, International Diabetes Federation (IDF) and the National Cholesterol Education Program Adult Treatment Panel iii (NCEP ATP III). In Table 2.2, the definitions for MS classified by the NCEP ATP III, WHO (Eckel *et al*., 2005:1415) and IDF (Alberti *et al*., 2009:1642) are shown.

In the JIS, to harmonise the definition of MS from the IDF, National Heart, Lung and Blood Institute, AHA, World Health Federation, International Atherosclerosis Society and the International Association for the Study of Obesity, it is proposed that central obesity should not be a prerequisite for the diagnosis of the MS, but instead three out of the five IDF criteria for diagnosis are used (Alberti *et al*., 2009:1642). The IDF definition for MS specifies the inclusion of ethnic-specific WC; however, for Sub-Saharan Africa, the same cut-points are proposed as for other ethnic groups (Alberti *et al*., 2009:1642). Therefore, Prinsloo and colleagues (2011:4) proposed 90 cm for men, and 92 cm for women as cut-points (Alberti *et al*., 2009:1642) and that the cut-points for Caucasian South Africans were the same as for Europeans. The cut-points mentioned above for the diagnosis of MS were used in the current study.

Table 2.2: Definitions of cardio-metabolic syndrome (compiled from Alberti *et al.*, 2009:1642; Eckel *et al*., 2005:1415; Ehrman *et al*., 2010:142)

	NCEP ATP III (3+ criteria)	**WHO (impaired glucose, impaired fasting glucose or type 2 diabetes, + 2 or more criteria**	**IDF (central obesity + 2 of the remaining criteria**
Abdominal obesity	**WC** Men >102 cm Women >88 cm	**BMI** ≥30 kg/m^2 **WHR** Men >0.90 Women >0.85	**WC** European men ≥94 cm European women ≥80 cm, with ethnicity-specific values for other groups
Lipid profile	**High TG** ≥150 mg/dL (1.7 mmol/L) **Low HDL** Men: <40 mg/dL (1.0 mmol/L) Women: <50 mg/dL (1.3 mmol/L)	**High TG** ≥150 mg/dL (1.7 mmol/L) **Low HDL** Men <35 mg/dL (0.9 mmol/L) Women <39 mg/dL (1.0 mmol/L)	**High TG** ≥150 mg/dL (1.7 mmol/L) **Low HDL** Men <40 mg/dL (1.0 mmol/L) Women <50 mg/dL (1.3 mmol/L) or specific treatment for HDL abnormality
Blood pressure	≥130/85 mmHg	≥140/90 mmHg	130/85 mmHg or treatment for previously diagnosed hypertension
Glucose	Fasting glucose ≥110 mg/dL (6.1 mmol/L)	Impaired glucose regulation or type 2 diabetes Insulin resistance	Fasting glucose ≥100 mg/dL (5.6 mmol/L) or previously diagnosed with type 2 diabetes
Microalbuminuria		Urinary albumin excretion of 20 µg/min or albumin to creatinine ratio of ≥30 mg/g	

BMI = Body mass index; HDL = high-density lipoprotein cholesterol; IDF = International Diabetes Federation; NCEP ATP III = National Cholesterol Education Program Adult Treatment Panel iii; TG = triglycerides; WHR = waist-to-hip ratio; WHO = World Health Organization

Cardio-metabolic syndrome should not only be used to identify patients at risk but instead should define a specific group of patients with similar pathophysiology (Huang, 2009:233) and increased risk for the development of a CVD (Alberti *et al*., 2009:1641). With this syndrome, the focus is on interrelated conditions such as insulin resistance, central obesity, dyslipidaemia and hypertension (Huang, 2009:233) and the prevalence of the syndrome is increasing globally (Kirk & Klein, 2009:761; Motala *et al*., 2011:1032).

The increased prevalence of physical inactivity, type 2 diabetes and obesity can explain the increased prevalence of MS (Alberti *et al*., 2009:1641; Eckel *et al*., 2005:1417; Motala *et al*., 2011:1033; Saklayen, 2018:2). The prevalence of MS increases linearly with age from about 7% in 20–29 year-olds to

approximately 45% in people 60 years and older (Kirk & Klein, 2009:762). In the US, the prevalence of MS increased between 2003–2004 and 2011–2012 from 32.9% to 34.7%, and the prevalence was 33% higher in women compared with men (Aguilar *et al.*, 2015:1973). A review on MS indicated that the estimated global prevalence of MS ranges between 17% and 25 % and in South Africa varies between 0% and 50% depending on the definition of MS used (Okafor, 2012:58).

In a rural South African community in KwaZulu-Natal Province, using the JIS criteria for MS the overall prevalence of MS was 26.5% and, similar to the US data, the incidence was higher in women (30.2%) than in men (11.6%) (Motala *et al*., 2011:1033). This high prevalence was similar to results found in rural and urban communities of Free State Province, where 52.2% of the rural participants and 39.7% of the urban participants were diagnosed with three or more risk factors for cardio-metabolic disease (van Zyl *et al*., 2012:6). In Gauteng Province, 29% of Africans were diagnosed with MS (George *et al*., 2013:4). The incidence of MS is higher in developed countries due to the increased levels of physical inactivity and increased intake of energy-dense foods that increase the prevalence of overweight and obesity (Okafor, 2012:58).

The high prevalence of physical inactivity and obesity is associated with the prevalence of MS (Bankoski *et al.*, 2011:497). In a study using the National Health and Nutrition Examination Survey data in the USA (N=2656), the participants (aged 60 years and above) presenting with MS (ATP iii criteria) spent less time in moderate-to-vigorous PA and had a lower step count than those without the syndrome (Bankoski *et al*., 2011:499). The study also indicated that participants with MS, increased WC, high levels of triglycerides, and low HDL cholesterol levels had increased levels of sedentary time, more prolonged bouts of sedentary behaviour and a decreased average intensity of physical activities (Bankoski *et al.*, 2011:499). Furthermore, the probability of being diagnosed with MS is higher in persons in the most upper quartile of time spent being sedentary (Bankoski *et al.*, 2011:499). Several studies have suggested that low levels of PA are associated with MS (Baceviciene *et al*., 2013:280; Lee *et al*., 2013:137; Turi *et al*., 2016:1048). A meta-analysis of the association between sedentary behaviour and MS concluded that a physically inactive lifestyle could increase the odds of developing MS by 73% (Edwardson *et al.*, 2012:3). An Australian population-based study (N=168, mean age 53.4 years) indicated that more interruptions in sedentary time are beneficial to the relationship between metabolic risk variables, especially in adiposity measures, triglycerides and 2-hour fasting glucose (Healy *et al*., 2008:663), indicating the importance of regular breaks in sedentary time in reducing cardio-metabolic risk (Healy *et al*., 2008:663).

In a meta-analysis investigating the association between leisure-time PA and MS, higher levels of leisure-time PA were significantly associated with a decreased risk of developing MS, irrespective of sex and definition used, and moderate leisure-time PA was weakly associated with the incidence of MS compared with those who were inactive (He *et al*., 2014:238). In Malaysian adults (N=686, aged 34–74 years) moderate and high levels of PA were associated with reduced odds of developing MS, irrespective of sex (Chu & Moy, 2014:199).

The fundamental approach to treating MS should include weight reduction, dietary modifications and increasing PA, to lower several risk factors associated with MS and reduce the risk of developing a CVD (Huang, 2009:231; Monteiro & Azevedo, 2010:6; Roberts & Sindhu, 2009:709; Strasser, 2013:153). However, prescribing medication for the treatment of diabetes and reduction of CVD risk may be the proper treatment modality together with lifestyle modifications (Eckel *et al*., 2005:1415).

2.5 CAROTID INTIMA–MEDIA THICKNESS

Oxidative stress could lead to the risk of developing end-organ damage (Ceriello & Motz, 2004:820); for this study, a short explanation of the pathology of atherosclerosis is given. Atherosclerosis is an active inflammatory process leading to altered cell behaviour, lipid accumulation, cell death and fibrosis within the arteries (Alsheikh-Ali *et al.*, 2010:387; Goyal *et al*., 2012:150; Hansson & Libby, 2006:508; Libby *et al*., 2009:2137; Ne *et al*., 2017:171; Ross, 1999:115; Swain *et al*., 2014:110; Touboul *et al*., 2007:75). A strong link exists between endothelial dysfunction and oxidative stress in the development and progression of atherosclerosis (Heitzer *et al*., 2001:2673; Schleicher & Friess, 2007:18) that begins in childhood and manifests during adulthood with lipid accumulation in the intima of the arteries (Dawson *et al.*, 2009:2273). Risk factors for the development of atherosclerosis include high blood pressure, dyslipidaemia, oxidative stress, elevated plasma homocysteine, smoking, diabetes, infections and inflammation (Cachofeiro *et al.*, 2008:7; Chambless *et al*., 1997:483; Harrison *et al.*, 2003:7; Ross, 1999:116). As atherosclerosis is an inflammatory process, markers of inflammation such as C-reactive protein (CRP) may be seen as direct markers of endothelial cell dysfunction and may be predictors of coronary artery disease (Abdushi *et al*., 2013:271; Corrado *et al.*, 2009:8).

Atherosclerosis can be considered as the underlying cause of a CVD event (Cachofeiro *et al.*, 2008:7; Van Den Oord *et al*., 2013:2). For many individuals, the first signs of atherosclerosis may be acute myocardial infarction, sudden cardiac death or stroke (Alsheikh-Ali *et al.*, 2010:387). Atherosclerosis develops over time and one of the first signs to recognise is the thickening that occurs in the arterial walls (Van Den Oord *et al*., 2013:2).

Non-invasive vascular markers are valuable indicators of CVD risk and for identifying the subclinical risk (i.e. the risk before noticeable symptoms appear) of developing a CVD before a CVD event occurs (Parsons *et al*., 2016:194; Stein *et al*., 2008:105; Touboul *et al.*, 2007:76). CIMT, as measured through sonography, is considered a simple non-invasive marker for atherosclerosis, as changes within the arterial walls can be evaluated and measured (Ascenso *et al.*, 2016:391; Dawson *et al.*, 2009:2273; Inaba *et al*., 2011:128*;* Nezu *et al*., 2015:1; Touboul *et al*., 2007:75; Van Den Oord *et al*., 2013:2).

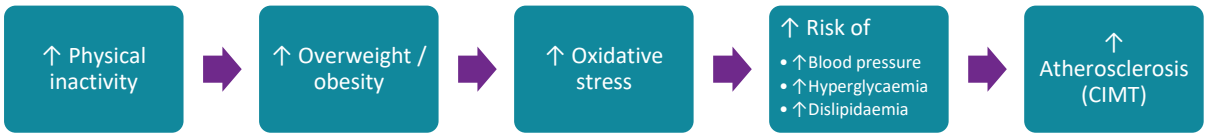
Carotid intimamedia thickness is commonly measured in the left and right common carotid artery, preferably in the carotid bulb or internal carotid artery (Inaba *et al*., 2011:128; Van Den Oord *et al*., 2013:4). Intima–media thickness (IMT) has been defined as "a double-line pattern visualised by echotomography on both of the common carotid artery walls in a longitudinal image. The IMT is formed by two parallel

lines, which consist of the leading edges of two anatomical boundaries: the lumen-intima and media-adventitia interfaces" (Ascenso *et al*., 2016:393; Nezo *et al*., 2015:2; Touboul *et al*., 2007:76). In analysing CIMT, the far wall of the CIMT should be used to assess thickening, rather than the near wall, as the near wall artery measurements are less reliable due to grain settings (Touboul *et al*., 2007:77; Van Den Oord *et al*., 2013:4). In measuring IMT, a value greater than 0.9 mm is regarded as subclinical atherosclerosis (Mancia *et al*., 2013:197). In the absence of atherosclerotic plaque, the sonographic representation will resemble that of a healthy artery that correlates with the anatomical layers; however, if there is any uniform thickening in straight arterial wall segments, it may be due to the natural ageing process (Touboul *et al*., 2007:76).

Risk factors for atherosclerosis, especially high blood pressure and inherited genetic factors, causes an acceleration in the thickening of the arterial wall (Touboul *et al*., 2007:76). Obesity and diabetes also play a role in the progression of atherosclerosis (Ortega-Loubon *et al*., 2019:5). In a study examining the association between IMT and obesity (N=3173), CIMT was higher in obese and overweight individuals compared with persons with a healthy BMI (Kotsis *et al*., 2006:1714); this suggests that overweight and obesity may play a significant role in the development of carotid atherosclerosis (Lo *et al*., 2006:1681). In a cohort of healthy women (N=100), obesity, especially abdominal obesity, was strongly associated with CIMT (Lo *et al*., 2006:1681). The relationship between abdominal obesity and CIMT remained significant even after adjusting for cholesterol (total cholesterol, triglycerides, LDL cholesterol and HDL cholesterol), age, visceral fat, adiponectin, CRP, smoking and blood pressure (Lo *et al*., 2006:1681). These findings suggest that abdominal obesity has an independent adverse effect on CIMT (Lo *et al*., 2006:1681). Intima-media thickness thickening may also occur due to increased pressure on the arteries from hypertension (Zieman *et al.*, 2005:934). The CIMT measurement is used to identify preclinical atherosclerosis and the normal ageing response (Touboul *et al*., 2007:76).

A positive association exists between CIMT and CVD risk (Nair *et al*., 2012:697; Van Den Oord *et al*., 2013:9), where an increased CIMT is associated with increased risk of CVDs such as myocardial infarction and stroke (Van Den Oord *et al*., 2013:9). Carotidintima media thickness is associated with increased CVD events, more specifically of stroke, independent of the common risk factors for the development of a stroke (Yang *et al*., 2011:107). Even though an increased CIMT is linked to a higher CVD risk, Van Den Oord *et al*. (2013:11) concluded that adding CIMT to CVD risk prediction models does not have clinical significance. A study in patients with acute coronary artery syndrome and stable coronary artery disease (N=143) indicated that CIMT was a predictor of the presence of coronary artery disease such as atherosclerosis, but could not predict future coronary events (Abdushi *et al.*, 2013:271). Nezu and colleagues (2015:9) concluded that a lack of standardised procedure for measuring IMT might result in controversy in using CIMT to identify CVD risk. Although though there is controversy around the measurement of CIMT as a predictor of CVD events, several studies indicate the clinical significance of using CIMT in the prediction of CVD (Kotsis *et al*., 2006:1713; Lorenz *et al*., 2006:89; Polak *et al*.,

2011:220; Van Den Oord *et al*., 2013:9; Yang *et al*., 2011:107). This controversy may be due to the lack of uniform methodology for measuring CIMT (Naqvi & Lee, 2014:1035). In a study conducted across a wide age range (19–90 years), IMT values were significantly predictive of myocardial infarction, stroke and death (Lorenz *et al*., 2006:89) and the risks associated with an increased CIMT were dependent on age, as younger participants with a higher CIMT value had a higher risk for myocardial infarction, stroke and death than the older participants. Despite its controversy, the measurement of CIMT is a valid and useful measure in detecting and monitoring the progression of atherosclerosis, and correlates with CVD risk factors and the severity of atherosclerosis (Nair *et al*., 2012:697). The CIMT measures can also be used to screen the immediate risk of developing a future CVD (Nair *et al*., 2012:697). According to Nair and colleagues (2012:697), IMT progression occurs at an average rate of <0.03 mm per year and that the rate of progress is directly related to the increased risk of a CVD event. By increasing a person level of PA, weight reduction, lowering salt intake, and moderate alcohol consumption arterial stiffness may be limited or reduced (Zieman *et al*., 2005:936).



CIMT = carotid intima-media thickness

Figure 2.1: Interaction between physical inactivity and atherosclerosis

Figure 2 is compiled from available literature regarding the interaction between the variables included in this study (Alessio & Hagerman, 2006:19; Biswas, 2016:1; Biswas & Lopes de Faria, 2007:223; Blair, 2009:1; Chambless *et al*., 1997:483; Dohrn *et al*., 2018:704; James *et al*., 2012:429; Kallio *et al*., 2018:1196; Pham-Huy *et al*., 2008:89,91; Roberts & Sindhu, 2009:706; Sies, 1985:6; Sies & Jones, 2007:45). Increased physical inactivity is significantly linked with the prevalence of overweight/obesity which in turn increases the risk of developing oxidative stress. Oxidative stress therefore, increases the risk of developing increased blood pressure values, hyperglycaemia, dyslipidaemia which in turn contributes to the development of atherosclerosis, which can be measured by CIMT.

2.6 PHYSICAL ACTIVITY AND HEALTH

Undeniable evidence exists that regular PA contributes to the prevention of several chronic diseases and risk factors for developing these diseases (Blair & Morris, 2009:255; Guthold *et al*., 2018:1077; Lyden *et al*., 2011:187; Vogel *et al*., 2009:316). Regular PA lowers the risk of developing a stroke (Li & Siegrist, 2012:403), risk for developing CVD (Akbartabartoori *et al.*, 2008:7), and of being diagnosed with various forms of cancer (Friedenreich & Cust, 2008:640; Wolin *et al*., 2009:614). PA improves the management of type 1 diabetes (Chimen *et al.*, 2012:549) and contributes to the prevention of type 2 diabetes (Gill & Cooper, 2008:822), increased bone density, bone mass (Nikander *et al*., 2010:61) and skeletal muscle mass (Park *et al*., 2010:956), which contribute to a higher quality of life.

In a cross-sectional health survey among adults (N=5460) in Scotland, regular PA reduced the risks associated with overweight/obesity, and in turn reduced the risk of developing CVD and MS, particularly in men, when compared with inactive participants (Akbartabartoori *et al.*, 2008:7). A systematic review of PA and fitness in a cohort of men, women, school-aged children and youth indicated that aerobic exercise was effective in lowering blood pressure, obesity and other CVD risk factors as well as in increasing bone mineral density (Janssen & Leblanc, 2010:53). Reiner *et al*. (2013:818) conducted a systematic review of longitudinal studies on the health benefits of PA which indicated various benefits that lowered the prevalence of NCDs, such as preventing weight gain and overweight/obesity, and reducing prevalence of CVD, the risk of type 2 diabetes mellitus and the incidence of Alzheimer's disease and dementia in healthy men and women.

A randomised trial on weight loss and cardio-metabolic risk factors in severely obese adults found a significant reduction in weight, body fat percentage, WC and blood pressure, as well as a significant improvement in fasting insulin and insulin resistance, after an intensive 6 and 12 months of a diet and a 5-day per week PA intervention (Goodpaster *et al*., 2010:1800). The PA intervention consisted of a 60-minute moderate intensity activity for at least 5 days of the week using a self-directed home-based approach, where participants were provided with pedometers and exercise videos to promote adhering to the behavioural intervention (Goodpaster *et al*., 2010:1796). Kallings *et al*. (2009:82) observed similar changes, with body composition parameters decreasing (WC by 3.1%, body fat percentage by 3.5%, body fat mass by 5.3%, trunk fat percentage by 3.4% and trunk fat mass by 5%). They also observed significant decreases in glucose values (3.4%), total cholesterol (4.7%), triglycerides (13.1%) and haemoglobin A1c (HbA1c) (1.5%) values in an overweight and obese population, after a 6-month PA intervention programme. The PA intervention was based on a prescription method, where each participant's goals were taken into consideration and specific types of PA and the reasons for using them were explained on the prescription, and consisted of both aerobic and strengthening exercises (Kallings *et al*., 2009:81). All participants were encouraged to participate in at least 30 minutes of moderate PA on most, preferably all, days of the week (Kallings *et al*., 2009:81).

Undeniable evidence exists that regular PA participation contributes to the prevention of several chronic diseases and minimises risk factors for developing these diseases (Kohl *et al*., 2012:303; Warburton *et al*., 2006:807). Lee *et al*. (2012:227) describe how an increase in 0.68 years in a physically inactive individual's life expectancy can occur when they engage in regular PA. This value may seem low, but it represents the gain in life expectancy of the entire population and not only the gain in the physically inactive individuals. Another study focusing on an increase in life expectancy in the USA found that participating in moderate-to-high levels of PA increased the participants' life expectancy by 1.3–3.5 years (Franco *et al*., 2005:2357). In South Africa, the gain in life expectancy is 1.26 years when a physically inactive person participates in PA (Lee *et al*., 2012:222). Recently, Li and colleagues (2018:348) revealed that adherence to the five low-lifestyle risk factors (i.e. never smoking, maintaining a healthy weight, participating in regular PA, consuming a healthy diet and moderately consuming alcohol) could prolong life expectancy at the age of 50 by 14 years in men and 12.2 years in women.

Physical activity offers physiological benefits (as listed in Table 2.3) and proposes psychological benefits. In American overweight/obese adults, depression risk lowered as moderate-to-vigorous intensity PA increased and sedentary time decreased (Vallance *et al*., 2011:286). The Scottish Health Survey (N=19 842) also indicated a dose-relationship between self-reported PA and a reduction in psychological stress and 20 minutes of any PA per week was sufficient to indicate mental health benefits (Hamer *et al*., 2008:1113). In a German cohort study (in older women, n=36), a 6-month combined aerobic endurance, strength and flexibility PA intervention programme (90 minutes of PA 3 days per week) resulted in positive changes in how these women felt about the natural ageing process (Klusmann *et al*., 2012:239). According to Lista and Sorrentino (2010:499), a robust force exists between PA and brain functions, including cognition, learning, memory and in decreasing cognitive decline from ageing. Physical activity is further linked to an increase in self-esteem, and physically active individuals appear less likely to suffer from mental health problems and may experience enhanced cognitive functioning (Biddle & Asare, 2011:894).

Physical activity and mental health have been proposed to be linked directly and indirectly to self-esteem and self-concept, and PA may offer relief from depressive symptoms (Zamani Sani *et al*., 2016:2623). Exercise may activate the human body's stress response, the hypothalamic-pituitary-adrenal (HPA) axis, and therefore discriminating between good stress (physical stress) and bad (psychological) stress is important (Heijnen *et al*., 2016:1). An understanding of the normal neuroendocrine response to physical stress is essential (Fig. 2.1). Figure 2.1 indicates that when physical stress is perceived, the hypothalamus releases a corticotrophin-releasing hormone, which travels to the anterior pituitary gland to induce the release of adrenocorticotropic hormone into the general circulation (Heijnen *et al*., 2016:2). After adrenocorticotropic hormone reaches the adrenal cortex, cortisol is released into the blood circulatory system and causes inhibition of the hypothalamus and pituitary and reduces stress-induced overexcitability of the amygdala (Heijnen *et al*., 2016:2).

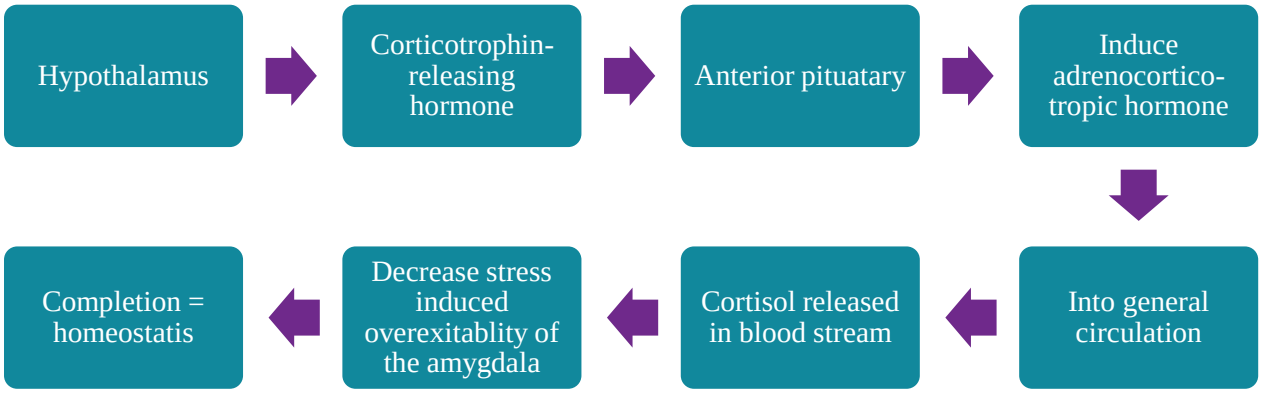


Figure 2.2: The neuroendocrine response of physical stress (compiled from Heijnen *et al*., 2016:2)

Another benefit of regular PA on the physiological mechanism is the relief of depressive and anxiety symptoms by the production of serotonin (Young, 2007:395), which is secreted by the brain stem. It acts as a pain pathway inhibitor in the nervous system, assists in the control of mood and assists in better sleeping patterns (Strasser *et al.*, 2016:56). Exercise is also associated with increased deactivation of cortisol into cortisone and increased levels of anandamide brain-derived neurotrophic factor (BDNF) and serotonin (Heijnen *et al*., 2016:4). Exercise makes more serotonin available, similar to the action of antidepressants, and partially mediates the relationship between PA and depression (Wipfli *et al*., 2011:479). Anandamide is a neurochemical that decreases depression and anxiety through regulation of amygdala hyperactivity (Marco *et al*., 2011:3). After participating in aerobic exercise, participants experience a positive mood; this may be explained by increased endorphin levels (Heijnen *et al*., 2016:2).

Interestingly, a single bout of PA in an outdoor, natural environment provides additional positive effects on mental health that do not occur when participating in the same activity indoors (Thompson Coon *et al*., 2011:1767). In a study by Aspinall *et al.* (2015:276), wireless electroencephalography technology was used to monitor participants' brain waves while walking through urban areas and a green space area. Walking from the urban area into the green zone brought a reduction in the level of frustration, arousal and engagement and an increase in meditation. A study (N=263) measuring the effects of outdoor PA, for example, walking, cycling, horse-riding, fishing, canal-boating and conservation activities, indicated that participants' mood and self-esteem improved after participating in outdoor physical activities, while anger, confusion, depression and tension decreased (Pretty *et al*., 2007:218). These studies indicate that the benefits of PA performed outdoors may entail even more mental health benefits than just merely participating in PA.

As indicated by the research discussed above, it is clear that regular PA confers both physical and psychological benefits and is associated with lower morbidity and mortality rates. In a large-scale

Taiwanese cohort study (N=416 175) reporting on reduced mortality and increased life expectancy, engaging in even 15 minutes of moderate-intensity physical exercise was found to have significant health benefits including a 14% decreased risk of death and 3-year increase in life expectancy, compared with inactive individuals (Wen *et al*., 2011:1249). Reimers and colleagues (2012:2) conducted a review of 13 studies on life expectancy in physically active individuals and in all the studies an increase in life expectancy was reported ranging from 0.43 to 6.9 additional years (men 2.9 years±1.3 years; women 3.9±11.8 years). Data including more than one million individuals indicated that participating in 60–75 minutes of moderate-intensity PA daily could eliminate the increased mortality risk associated with large amounts of sitting time and physical inactivity (Ekelund *et al.*, 2016:1308). The individuals who participated in 60–75 minutes of moderate-intensity PA daily, who spent about 8 hours per day sitting, had a significantly lower risk of dying than the individuals who spent less than 4 hours a day sitting but were less physically active (Ekelund *et al*., 2016:1308).

In a large community-based study (N=2455), participation in objectively measured moderate-to-vigorous PA was associated with lower arterial stiffness (Andersson *et al.*, 2015:8). Factors that may increase arterial stiffness include hypertension, increased age, diabetes, atherosclerosis and inflammation (Andersson *et al*., 2015:8). Laursen *et al*. (2015:6) concluded that in an elderly population without any CVD and low levels of PA, higher levels of PA were associated with lower levels of aortic stiffness, indicating that regular habitual PA lowers the risk of developing CVD. Regular PA may prevent or counteract the development of atherosclerosis by assisting in weight management, better glucose control, weight loss, improved insulin sensitivity and increased cardiorespiratory fitness (Kadoglou *et al*., 2008:269). A summary of the benefits of regular PA participation is provided in Table 2.3.

Table 2.3: Benefits of physical activity (adapted from Kadoglou *et al*., 2008:269; Lee *et al*., 2012:220; Physical Activity Guidelines Advisory Committee, 2018:D5; Seals *et al*., 2009:5547; Swain *et al*., 2014:336; Vogel *et al*., 2009:316; WHO, 2010:1)

Benefits of physical activity	Effect of physical activity	Increase (↑) / Decrease (↓)
All-cause mortality	Lower risk	↓
Cardio-metabolic conditions	Lower incidence and mortality (heart disease and stroke) Lowering blood pressure or preventing hypertension Lowering incidence and prevention of type 2 diabetes mellitus Improved glucose control Improved lipid profile Increase high-density lipoprotein cholesterol Lowered rates of cardio-metabolic syndrome Increased cardiorespiratory and muscular fitness Decrease formation of atherosclerotic plaque	↓ ↓ ↓ ↑ ↑ ↑ ↓ ↑ ↓

continued

Table 2.3: Benefits of physical activity (adapted from Kadoglou *et al*., 2008:269; Lee *et al*., 2012:220; Physical Activity Guidelines Advisory Committee, 2018:D5; Seals *et al*., 2009:5547; Swain *et al*., 2014:336; Vogel *et al*., 2009:316; WHO, 2010:1) *(continued)*

Benefits of physical activity	Effect of physical activity	Increase (↑) / Decrease (↓)
Cancer	Prevention of cancers (breast, bladder, endometrium, oesophagus, kidney, stomach, lung and colon)	↓
Psychological health	Reduced prevalence and risk of dementia Improved cognitive function Improved quality of life Improved sleep Reduced feelings of anxiety and depression Enhance feelings of wellbeing	↓ ↑ ↑ ↑ ↓ ↑
Weight status	Reduction in body fat and excessive weight gain Maintain healthy body weight and body composition	↓
Older adults	Reduction in age-related sarcopenia Reduced incidence and risk of falls Reduced rate of fall-related injuries (example hip fracture) Reduction of age-related decline in peak oxygen consumption Improved bone health (reduce the risk of fractures) Reduced age-related arterial stiffness	↓ ↓ ↓ ↓ ↑ ↓

Furthermore, regular PA is important in the regulation of oxidative stress. Moderate amounts of oxidants serve as signals activating adaptive responses (Di Meo *et al.*, 2019:2). Acute bouts of exercise may contribute to the development of ROS which cause tissue damage and dysfunction, but regular exercise increases the adaptive responses of the muscles to protect against exercise-induced oxidative stress (Alessio & Hagerman, 2006:34; Di Meo *et al.*, 2019:2; Steinbacher & Eckl, 2015:367) by increasing antioxidants and antioxidant activity (Steinbacher & Eckl, 2015:362). Regular or chronic exercise increases the activity of antioxidants and the levels of ROS that are needed to perform during exercise sessions (Radak *et al*., 2008:38). Powers and Jackson (2008:1265) indicated in a review of exercise-induced oxidative stress that physiological levels of ROS are essential in skeletal muscle force production, but high levels of ROS may influence muscular force negatively resulting in muscular fatigue.

Beneficial low-to-moderate levels of oxidative stress contribute to muscular adaptations during exercise (Powers *et al*., 2011:947). In a study conducted in community-dwelling adults (N=998), adults who had a greater perceived fitness and participated in PA more frequently had lower inflammatory and oxidative stress biomarkers, indicating that regular PA contributes to a protective role against oxidative stress and enhances endothelial function in adults, promoting a reduction in cardio-metabolic risk factors and affecting the progression of atherosclerosis (Camarillo-Romero *et al.*, 2012:6; Di Francescomarino *et al*., 2009:798; Shanely *et al*., 2013:220). Optimal levels of ROS are needed to improve health status (Fisher-Wellman & Bloomer, 2009:16) by stimulating upregulation of antioxidant vital systems that provide protection from

future cardio-metabolic diseases (Fisher-Wellman & Bloomer, 2009:17). During regular PA and exercise the main goal is for the body to adapt to the demands of the activity; the same is true for the ROS and antioxidant systems (Radak *et al*., 2008:35).

Regular PA and exercise cause increased blood flow through the blood vessels and shear stress, leading to increased nitric oxide, causing vasodilation in the blood vessels. Resulting in an increase in the antioxidant activity and enzymes to repair the damage, which ultimately results in lower levels of oxidative damage (Radak *et al*., 2008:37). Regular PA thus plays a vital role in ROS adaptation that will lower the risk of developing cardio-metabolic diseases, atherosclerosis, stroke, Alzheimer's disease and cancer (Radak *et al*., 2008:38).

Although there are several benefits to regular participation in PA, these are still undervalued (Kohl *et al*., 2012:303). The WHO suggests that several environmental factors linked to urbanisation, such as violence and outdoor crime; traffic, pollution and poor air quality; lack of parks and sidewalks; and lack of opportunity for sport or recreational activities act as barriers to participation in PA (WHO, 2018a). Rees-Punia *et al*. (2018:312) concluded that individuals who feel safe in their environment have a higher rate of PA participation.

2.6.1 Physical activity and carotid intima–media thickness

The association between objectively measured PA and CIMT has been sparsely investigated. Little is known about how often sedentary time should be interrupted to reduce the risk of developing CVD (Parsons *et al*., 2016:194). In a study in older community-dwelling British men (N=1216), higher levels of PA and lower levels of sedentary time were associated with a lower mean CIMT (Parsons *et al*., 2016:198). All PA was associated with a lower risk of developing CVD, regardless of the continuous time spent in sedentary or moderate-to-vigorous PA patterns (Parsons *et al*., 2016:198). Ried-Larsen *et al*. (2015:112) indicated that moderate-to-vigorous PA might play a protective role in the development of atherosclerosis in apparently healthy individuals. A longitudinal study observing the relationship between moderate and vigorous PA and the change in atherosclerosis from adolescence to adulthood indicated that an increase in moderate and vigorous PA from youth to adulthood was associated with lower levels of carotid stiffness, irrespective of the participants' blood pressure, body fat, demographics and lifestyle factors (Ried-Larsen *et al*., 2015:112). Increased moderate and vigorous PA is also associated with lower metabolic CVD risk in adulthood (Ried-Larsen *et al*. 2015:110). In healthy adults without a heightened CVD risk (N=614), sedentary time was associated with an increased CIMT, independent of age and other established atherosclerotic risk factors (Kozàkovà *et al*., 2010:1517). CIMT was measured in healthy adults, and after 3 years, participants engaging in short bouts of vigorous PA had a slower progression in IMT thickness than their light-to-moderate PA counterparts (Kozàkovà *et al*., 2010:1517). Indicating that vigorous PA contributed to decreased IMT (Kozàkovà *et al*., 2010:1517). Studies in Australian (N=1787) and Finnish (N=2169) young and middle-aged adults have indicated that participation in vigorous leisure-time PA may

be associated with a delay in age-related arterial stiffening, due to lowering of the resting heart rate of participants (Huynh *et al*., 2015:357).

Contrary to the findings described previously in this section, in a comparison between marathon runners and their sedentary domestic partners, CIMT values did not vary significantly between the runners and non-runners, which may suggest that chronic endurance training improves CVD risk profile but does not inhibit the formation of age-related carotid atherosclerosis (Taylor *et al*., 2014:6). Although there were no significant differences in CIMT between the runners and their sedentary partners, the study had a considerable limitation in that the control (inactive) group also participated in similar amounts of moderate-intensity PA as the participants (Taylor *et al*., 2014:6). However, a longitudinal study evaluating IMT and PA in adolescents indicated that regular moderate leisure-time PA decreased the rate at which aortic IMT increased (Pahkala *et al*., 2011:1961).

In a randomised controlled trial in Geneva, prepubertal obese children (N=22; mean age: 9.1±1.4 years) participated in a combined aerobic and strength exercise intervention programme, while the obese control group (N=22; mean age: 8.8±1.5 years) and a lean group (N=22; mean age: 8.5±1.5 years) were asked to continue with their regular PA routine for a period of 3 months (Farpour-Lambert *et al*., 2009:2397). The baseline results indicated that both the obese exercise and obese control groups had higher values of IMT than the lean group of children (Farpour-Lambert *et al*., 2009:2401). After the PA intervention, there was a significant reduction in the blood pressure and arterial stiffness of the children, measured by IMT and stabilisation of the IMT after 6 months (Farpour-Lambert *et al*., 2009:2402). This indicated that regular PA does promote a decrease in IMT. Additionally, a systematic review of exercise and carotid atherosclerosis suggested that exercise may prevent the development of atherosclerosis through various mechanisms including weight reduction, glucose regulation, fat loss, improved endothelial function, improved insulin sensitivity and increased cardiorespiratory fitness, possibly through lipid control, lowering blood pressure and modifying CVD risk factors (Kadoglou *et al*., 2008:269). Table 2.4 provides a summary of the literature on the relationship between objectively measured PA and CIMT.

Table 2.4: A summary of the relationship between objectively measured physical activity and carotid intima–media thickness

Reference:	Objective:	Participants:	Measurement of PA:	Results:	Conclusion:
(Kozàkovà *et al*., 2010:1511-1519)	To investigate if ST and PA levels are independently associated with CIMT	The cross-sectional study included healthy Caucasian men and women (N=614) with a mean age of 44 years as a subgroup of the Relationship Between Insulin Sensitivity and Cardiovascular Risk (RISK) Cohort Study.	Accelerometer (single-axis model AM7164) at the small of the back from waking until sleep time over 7 days; IPAQ.	PA = ST, LPA, MPA and VPA. 98.6% of the time spent was in ST or LPA. Age, weight, SBP, fasting plasma glucose and smoking were independent correlates of CIMT. CIMT positively associated with ST/LPA ratio and negatively associated with the average intensity of PA.	The study concluded that in a healthy young to middle-aged population without risk factors for CVD, the proportion of ST is directly associated with CCA. ST and CIMT might be due to ageing and established atherosclerotic risk factors and seemed to be representative of the physiological arterial remodelling induced by an inactivity-related increase in body size, rather than atherosclerotic process.
(Ried-Larsen *et al*., 2013:168–177)	To investigate the associations between MVPA, VPA and CRF level and CIMT or arterial stiffness, in a population-based sample of Danish adolescents from the European Youth Heart Study (EYHS)	A cross-sectional study based on the EYHS in 2009–2010 follow-up data (N=397), mean age 15.6±0.4 years.	ActiGraph model GT3X or model GT1M for at least five consecutive days and removed while showering, bathing and swimming or during sleep time. ST expressed as < 1.5 METs. MVPA expressed as ~4 METs. VPA expressed as ~6 METs.	Time spent in MVPA and VPA was not significantly associated with IMT or the measures of arterial stiffness. No differences were observed between quartiles of time in MVPA or VPA and IMT; however, sex differences were observed ($p < 0.1$). Adjustments for ST slightly attenuated the differences observed in the MVPA. Adjustment for adiposity did not change the differences across the groups for MVPA.	There was a significant association between CRF and measures for carotid artery stiffness in boys but not in girls. Unfit boys had significantly lowered CD and higher carotid stiffness compared to the boys that were more physically fit. Boys in the lower quartile of MVPA had significantly stiffer arteries compared to the most active boys.

BMI = Body mass index; CCA = common carotid artery; CD = carotid dispensability; CIMT = carotid intima–media thickness; CRF = cardiorespiratory fitness; CVD = cardiovascular disease; DBP = diastolic blood pressure; EYHS = European Youth Heart Study; HR = heart rate; IMT = intima–media thickness; IPAQ = International Physical Activity Questionnaire; LPA = light physical activity; METs = metabolic equivalent of task; MPA = moderate physical activity; MS = cardio-metabolic syndrome; MVPA = moderate-to-vigorous physical activity; PA= physical activity; RISK = Relationship between insulin sensitivity and cardiovascular risk; SBP = systolic blood pressure; ST = sedentary time; VPA = vigorous-intensity physical activity.

(continued)

Table 2.4: A summary of the relationship between objectively measured physical activity and carotid intima–media thickness *(continued)*

Reference:	Objective:	Participants:	Measurement of PA:	Results:	Conclusion:
(Ried-Larsen *et al*., 2014:1502–1507)	To investigate the association between PA and subclinical carotid CVD across childhood	A cross-sectional study based on the EYHS in 2009–2010 follow-up data (N=254) mean age boys: 9.8±0.5 years; girls: 9.7±0.4 years.	ActiGraph model GT3X or model GT1M for at least five consecutive days and removed while showering, bathing and swimming or during sleep time.	No associations were observed between MVPA or VPA and CIMT or any measures of arterial stiffness.	The study did not observe any associations between PA across childhood and CIMT or carotid stiffness in adolescence. High exposure to VPA was associated with decrease metabolic CVD risk in adolescence.
(Gomez-Marcos *et al*., 2014:366–372)	To determine the relationship between regular PA and vascular structure and function-based CIMT	The cross-sectional study formed part of the EVIDENT study measuring 263 healthy men and women with a mean age of 55.85±12.21 years.	PA recall estimated by ActiGraph (GT3X) MVPA was considered as activity accumulated from all bouts lasting at least 1 minute.	CIMT and vigorous-intensity PA day time were negatively and statistically significantly related (r = -0.74; $p < 0.01$). However, PA counts/min (r = 0.077), LPA (r = -0.087) and PA in METs/hour/week (r = -0.017) were negatively correlated to CIMT, although not significant. The study indicated that MPA (r = 0.028) was positively associated with CIMT, although not significant.	PA assessed by counts/min and time spent in MPA, VPA indicated a negative association with central and peripheral augmentation index.

BMI = Body mass index; CCA = common carotid artery; CD = carotid dispensability; CIMT = carotid intima–media thickness; CRF = cardiorespiratory fitness; CVD = cardiovascular disease; DBP = diastolic blood pressure; EYHS = European Youth Heart Study; HR = heart rate; IMT = intima–media thickness; IPAQ = International Physical Activity Questionnaire; LPA = light physical activity; METs = metabolic equivalent of task; MPA = moderate physical activity; MS = cardio-metabolic syndrome; MVPA = moderate-to-vigorous physical activity; PA= physical activity; RISK = Relationship between insulin sensitivity and cardiovascular risk; SBP = systolic blood pressure; ST = sedentary time; VPA = vigorous-intensity physical activity.

(continued)

Table 2.4: A summary of the relationship between objectively measured physical activity and carotid intima–media thickness *(continued)*

Reference:	Objective:	Participants:	Measurement of PA:	Results:	Conclusion:
(Huynh *et al*., 2015:355–360)	To determine the association of different types of PA with carotid dispensability and the mechanisms involved	This study formed part of both the Childhood Determinants of Adult Health (Australian; N=1787) study and Cardiovascular Risk in Young Finns study (Finland; N=2169) mean age for men 35.1±5.0 years and women 35.0±5.1 years.	Australian: Yamax Digi walker SW-200 pedometers for 7 days Finland: Omron Walking Style One (HJ-152 R-E) pedometers.	Vigorous leisure time was positively associated with CD (men: r = 0.07, p < 0.01; women: r = 0.05, p < 0.05) Total PA was not associated with CD (men: r = -0.02; p >0.05; women: r = -0.01; p >0.05) Steps per day not associated with CD (men: r = 0.00; p >0.05; women r = 0.03; p >0.05) Men lower CD (1.82±0.64 %/10 mmHg) than women (2.15±0.78 % / 10 mmHg).	Vigorous leisure-time PA, but not total PA or LPA, was associated with CD in young and mid-aged adults.
(Ried-Larsen *et al*., 2015:107–112)	To determine the associations between mean exposure to or the change in MVPA from adolescence to adulthood and subclinical atherosclerosis in adulthood	A prospective cohort study in Danish boys and girls (N=277) followed up after 12 years as part of EYHS. Mean age = 15.7 years boys; 15.6 years girls.	ActiGraph model AM7164 (Pensacola, Florida, USA) in 1997–1998 and GT3X or GT1M used in 2009–2010 was worn for at least five consecutive days and only removed when showering, bathing, swimming or during sleep time. MVPA expressed as >4 METs at age 15 years.	MVPA decreased by 6.1 (22.0) min/day from adolescence to adulthood; mean MVPA = 20.6 (11.7) min/day, there was no significant change (p > 0.05) between men and women. Men spent more time in MVPA than women. Baseline MVPA positively associated with adult IMT (std.β= 0.12, p = 0.02). Adjusted for sex, height and cohort. At follow-up MVPA was marginally associated	High mean exposure to and increased levels of MVPA from adolescence to adulthood were independently associated with lower levels of carotid arterial stiffness and metabolic CVD risk in adulthood. Mean exposure to MVPA was positively associated with CIMT in adulthood.

BMI = Body mass index; CCA = common carotid artery; CD = carotid dispensability; CIMT = carotid intima–media thickness; CRF = cardiorespiratory fitness; CVD = cardiovascular disease; DBP = diastolic blood pressure; EYHS = European Youth Heart Study; HR = heart rate; IMT = intima–media thickness; IPAQ = International Physical Activity Questionnaire; LPA = light physical activity; METs = metabolic equivalent of task; MPA = moderate physical activity; MS = cardio-metabolic syndrome; MVPA = moderate-to-vigorous physical activity; PA= physical activity; RISK = Relationship between insulin sensitivity and cardiovascular risk; SBP = systolic blood pressure; ST = sedentary time; VPA = vigorous-intensity physical activity.

(continued)

Table 2.4: A summary of the relationship between objectively measured physical activity and carotid intima–media thickness *(continued)*

Reference:	Objective:	Participants:	Measurement of PA:	Results:	Conclusion:
				with CIMT (std.β= 0.10, p = 0.07).Mean exposure to MVPA activities were significant with all outcomes (IMT) (p < 0.05) adjusted for sex and cohort Only the participants with the highest mean exposure to MVPA had a significantly higher CIMT compared with the least active group (p < 0.05). 1 min/day decline in MVPA was associated with 0.04-unit increased MS, z-score in adulthood when adjusted for sex, cohort and baseline MVPA.	
(Parsons *et al*., 2016:194–199)	To determine the association between objectively measured PA, sedentary time and non-invasive vascular measures, markers for CVD	A cross-sectional study including 1213 men that partook in the British Regional Heart Study was used for data analysis. Mean age 78.5 years.	CT3X accelerometer (ActiGraph, Pensacola, Florida) was worn over the right hip for 7 days, during waking hours, removing the device for swimming and bathing. Categorised according to sedentary time (ST) (<1.5 MET), light activity (1.5–3 MET) and moderate and vigorous activity (≥3 MET).	The average time spent sedentary was 72%, light intensity 23% and time spent in moderate-to-vigorous intensity was 5%. 8% of men wore the ActiGraph for more than 7 days (96% wore ≥5 days) More ST included older men, living alone, smoking, using hypertensive medication, had diabetes, high BMI and HR, but lower SBP and DBP.	Higher levels of PA and lower levels of ST are associated with lower CVD risk, as indicated by non-invasive markers of arterial stiffness and atherosclerosis. The study did not find that bouts ≥10 min MVPA were important over and above the total amount of time spent in PA. The study concluded that all activity matters.

BMI = Body mass index; CCA = common carotid artery; CD = carotid dispensability; CIMT = carotid intima–media thickness; CRF = cardiorespiratory fitness; CVD = cardiovascular disease; DBP = diastolic blood pressure; EYHS = European Youth Heart Study; HR = heart rate; IMT = intima–media thickness; IPAQ = International Physical Activity Questionnaire; LPA = light physical activity; METs = metabolic equivalent of task; MPA = moderate physical activity; MS = cardio-metabolic syndrome; MVPA = moderate-to-vigorous physical activity; PA= physical activity; RISK = Relationship between insulin sensitivity and cardiovascular risk; SBP = systolic blood pressure; ST = sedentary time; VPA = vigorous-intensity physical activity.

(continued)

Table 2.4: A summary of the relationship between objectively measured physical activity and carotid intima–media thickness *(continued)*

Reference:	Objective:	Participants:	Measurement of PA:	Results:	Conclusion:
				Sedentary men had significantly higher CIMT ($p < 0.001$). Men with higher levels of MVPA had a lower CIMT. PA is inversely and ST positively associated with CIMT after adjusting for confounders. More steps were associated with a lower CIMT. 10 min extra MVPA associated with a 0.0031 mm lower CIMT (95% CI= -0.0061, -0.0001).30 min extra MVPA associated with a 0.0075 mm lower CIMT (95% CI= -0.0122, - 0.0029). Association with ST and LPA means increased CIMT.	
(Ascenso *et al*., 2016:391–398)	To determine the associations between sedentary behaviour, PA and CRF, with CIMT in obese adolescents	Caucasian adolescents (N=54) with a BMI above the 95th percentile. Mean age 15.24 ± 1.39 years in boys; 15.08 ± 1.48 years in girls.	ActiGraph GT3X worn above the right hip, near the iliac crest, for seven consecutive days, except during sleep, bathing or swimming.	ST did not correlate with CIMT; LPA correlated positively with CIMT (r = 0.36, p = 0.024) and MVPA; MPA correlated positively with mean (r = 0.37, p = 0.018 r = 0.37, p = 0.018) and maximum (r = 0.33, p = 0.039; r = 0.32, p = 0.044) CIMT	PA, but not ST, seems to be associated with CIMT. Increasing PA time, rather than deducing ST, should be the focus of intervention studies to prevent CIMT development in obese individuals.

BMI = Body mass index; CCA = common carotid artery; CD = carotid dispensability; CIMT = carotid intima–media thickness; CRF = cardiorespiratory fitness; CVD = cardiovascular disease; DBP = diastolic blood pressure; EYHS = European Youth Heart Study; HR = heart rate; IMT = intima–media thickness; IPAQ = International Physical Activity Questionnaire; LPA = light physical activity; METs = metabolic equivalent of task; MPA = moderate physical activity; MS = cardio-metabolic syndrome; MVPA = moderate-to-vigorous physical activity; PA= physical activity; RISK = Relationship between insulin sensitivity and cardiovascular risk; SBP = systolic blood pressure; ST = sedentary time; VPA = vigorous-intensity physical activity.

(continued)

Table 2.4: A summary of the relationship between objectively measured physical activity and carotid intima–media thickness *(continued)*

Reference:	Objective:	Participants:	Measurement of PA:	Results:	Conclusion:
				Weight (r = 0.39, p = 0.008; r = 0.37, p = 0.012), trunk fat (r = 0.36, p = 0.041; r = 0.35, p = 0.048), and trunk peripheral fat (r = 0.36, p = 0.041; r = 0.37, p = 0.039) correlated positively with both mean and maximum CIMT, respectively. MPA and weight predictors of CIMT.	

BMI = Body mass index; CCA = common carotid artery; CD = carotid dispensability; CIMT = carotid intima–media thickness; CRF = cardiorespiratory fitness; CVD = cardiovascular disease; DBP = diastolic blood pressure; EYHS = European Youth Heart Study; HR = heart rate; IMT = intima–media thickness; IPAQ = International Physical Activity Questionnaire; LPA = light physical activity; METs = metabolic equivalent of task; MPA = moderate physical activity; MS = cardio-metabolic syndrome; MVPA = moderate-to-vigorous physical activity; PA= physical activity; RISK = Relationship between insulin sensitivity and cardiovascular risk; SBP = systolic blood pressure; ST = sedentary time; VPA = vigorous-intensity physical activity.

2.7 SUMMARY

The literature review has indicated that high levels of physical inactivity globally and in South Africa are present (WHO, 2010:9). Due to the variety of measurement techniques for PA, global comparisons of physical inactivity are not always possible (Ding *et al*., 2017:15). South Africa was ranked as one of the countries with the highest levels of inactivity, possibly due to urbanisation and migration to a westernised diet (Assah *et al.*, 2011:495; Guthold *et al.*, 2008:489). The different methods of measuring PA have been reviewed and discussed, elaborating on the advantages and disadvantages of the common measuring instruments.

A physically inactive and sedentary lifestyle leads to an increased risk of developing NCDs and MS, possibly due to oxidative stress. Non-communicable diseases are chronic diseases of lifestyle that cannot be transmitted to another person, and contribute 71% to the global mortality rate (Bradshaw *et al*., 2011:1; WHO, 2018b). From the literature review, CVD can clearly be seen as one of the major NCDs, contributing to 19% of South African NCD mortalities (WHO, 2018c). A cluster of NCD risk factors is known as MS (Huang, 2009:231; Kirk & Klein, 2009:761). People with MS are at twice the risk of developing a CVD in the following 5–10 years and a fivefold increased risk of developing type 2 diabetes mellitus (Alberti *et al*., 2009:1641; Eckel *et al*., 2005:1417). In order to determine the presence of atherosclerosis, an underlying cause of CVD, CIMT is measured. CIMT is a valid and useful measure for monitoring the progression of atherosclerosis (Nair *et al*., 2012:697).

At the end of the literature review the undeniable benefits of PA and health are expressed and related to the development of oxidative stress. Thereafter the limited information on objectively measured PA and CIMT is explained, indicating controversial results from various studies. It can be concluded, therefore, that research studies are required to investigate the relationship between PA, cardio-metabolic risk factors and CIMT in the South African context. Findings from this cross-sectional study may inform the Department of Education about potential implementation of PA intervention programmes for teachers to participate in to improve their cardio-metabolic risk profile. The health benefits of PA lead to a decreased risk in developing a CVD and improve feelings of wellbeing and self-esteem.

Due to the paucity in literature pertaining to objectively measured PA data, NCD risk factors and CIMT among South African teachers there is a need for cross-sectional studies on PA, cardio-metabolic risk factors and CIMT in the South African context, to indicate the relationships among them. Studies should try to focus on a homogenous population. In the next chapters (Chapters 3, 4 & 5) the reviewed literature of this chapter will be integrated by research studies. These chapters will also aim to answer the research question presented in Chapter 1.

REFERENCES

Abdushi, S.A., Kryeziu, F.U. & Nazreku, F.D. 2013. Increased carotid intima-media thickness associated with high hs-CRP levels is a predictor of unstable coronary artery disease. *Cardiovascular Journal of Africa*, 24(7):270–273. doi:10.5830/CVJA-2013-061

Aguilar, M., Bhuket, T., Torres, S., Liu, B. & Wong, R.J. 2015. Prevalence of the metabolic syndrome in the United States, 2003-2012. *Journal of the American Medical Association*, 313(19):1973–1974.

AHA (American Heart Association). 2017. *American Heart Association Recommendations for Physical Activity in Adults*. https://www.heart.org/en/healthy-living/fitness/fitness-basics/aha-recs-for-physical-activity-in-adults#.WrTES4huaUl Date of access: 23 Mar. 2018.

Ainsworth, B.E. 2008. How do I measure physical activity in my patients? Questionnaires and objective methods. *British Journal of Sports Medicine*, 43(1):6–9. doi:10.1136/bjsm.2008.052449

Ainsworth, B.E., Caspersen, C.J., Matthews, C.E., Mâsse, L.C., Baranowski, T. & Zhu, W. 2012. Recommendations to improve the accuracy of estimates of physical activity derived from self-report. *Journal of Physical Activity and Health*, 9(1):76–84. https://doi.org/10.1123/jpah.9.s1.s76

Ainsworth, B.E., Haskell, W.I., Herrman, S.D., Meckes, N., Bassett, D.R., Tudor-Locke, C., … Leon, A.S. 2011. Compendium of physical activities: a second update of codes and MET values. *Medicine and Science in Sports and Exercise*, 43(8):1575–1581. doi:10.1249/MSS.0b013e31821ece12

Ainsworth, B.E., Haskell, W.L., Whitt, M.C., Irwin, M.L., Swartz, A.M., Strath, S.J., … Leon, A.S. 2000. Compendium of physical activities: an update of activity codes and MET intensities. *Medicine and Science in Sports and Exercise*, 32(9):498–504. doi:0195-9131/00/3209-0498/0

Akbartabartoori, M., Lean, M.E.J. & Hankey, C.R. 2008. The associations between current recommendation for physical activity and cardiovascular risk associated with obesity. *European Journal of Clinical Nutrition*, 62(1):1–9. doi:10.1038/sj.ejcn.1602693

Alberti, K.G.M.M., Eckel, R.H., Grundy, S.M., Zimmet, P.Z., Cleeman, J.I., Donato, K.A., … Smith, S.C. 2009. Harmonising 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. https://doi.org/10.1161/CIRCULATIONAHA.109.192644

Alessio, H.M. & Hagerman, A.E., eds. 2006. *Oxidative stress, exercise and ageing.* Miami: Imperial College Press.

Alsheikh-Ali, A.A., Kitsios, G.D., Balk, E.M., Lau, J. & Ip, S. 2010. The vulnerable atherosclerotic plaque: scope of the literature. *Annals of Internal Medicine,* 153(6):387–395. doi: 10.7326/0003-4819-153-6-201009210-00272

Andersson, C., Lyass, A., Larson, M.G., Spartano, N.L., Vita, J.A., Benjamin, E.J., … Vasan, R.S. 2015. Physical activity measured by accelerometry and its associations with cardiac structure and vascular function in young and middle-aged adults. *The Journal of the American Heart Association,* 4(3), e001528. doi:10.1161/JAHA.114.001528

Archer, E. & Blair, S.N. 2011. Physical activity and the prevention of cardiovascular disease: from evolution to epidemiology. *Progress in Cardiovascular Disease,* 53(6):387–396. doi:10.1016/j.pcad.2011.02.006

Armstrong, T & Bull, F. 2006. Development of the World Health Organization Global Physical Activity Questionnaire (GPAQ). *Journal of Public Health,* 14(2):66–70. doi:10.1007/s10389-006-0024-x

Ascenso, A., Palmeira, A., Mendes Pedro, L., Martins, S. & Fonseca, H. 2016. Physical activity and cardiorespiratory fitness, but not sedentary behaviour, are associated with carotid intima-media thickness in obese adolescents. *European Journal of Paediatrics,* 175(3):391–398. doi:10.1007/s00431-015-2654-x

Aspinall, P., Mavros, P., Coyne, R. & Roe, J. 2015. The urban brain: analysing outdoor physical activity with mobile EEG. *British Journal of Sports Medicine,* 49(4):272–276. doi:10.1136/bjsports-2012-091877

Assah, F.K., Ekelund, U., Brage, S., Mbanye, J.C. & Wareham, N.J. 2011. Urbanisation, physical activity, and metabolic health in Sub-Saharan Africa. *Diabetes Care,* 34(2):491–496. doi:10.2337/dc10-0990

Baceviciene, M., Luksiene, D.I., Cesnaitiene, V.J., Raubaite, S., Peasey, A. & Tamosiunas, A. 2013. Dose-response association between physical activity and metabolic syndrome. *Central European Journal of Medicine,* 8(2):273–282. doi:10.2478/s11536-012-0123-8

Bankoski, A., Harris, T.B., McClain, J.J., Brychta, R.J., Caserotti, P., Chen, K.Y., … Koster, A. 2011. Sedentary activity associated with metabolic syndrome independent of physical activity. *Diabetes Care,* 34(2):497–503. doi:10.2337/dc10-0987

Barreira, T., Kang, M. & Caputo, J. 2009. Validation of the Actiheart monitor for the measurement of physical activity. *International Journal of Exercise Science,* 2(1):60–71.

Bauman, A., Bull, F., Chey, T., Craig, C.L., Ainsworth, B.E., Sallis, J.F., … IPS Group. 2009. The international prevalence study on physical activity: results from 20 countries. *International Journal of Behavioural Nutrition and Physical Activity,* 6(21):1–11. doi:10.1186/1479-5868-6-21

Bauman, A., Phongsavan, P., Schoeppe, S. & Owen, N. 2006. Physical activity measurement – a primer for health promotion. *International Union for Health Promotion and Education,* 13(2):92–103.

Biddle, S.J.H. & Asare, M. 2011. Physical activity and mental health in children and adolescents: a review of reviews. *British Journal of Sports Medicine,* 45(11):886–895. doi:10.1136/bjsports-2011-090185

Biswas, S.K. 2016. Does the Interdependence between oxidative stress and inflammation explain the antioxidant paradox? *Oxidative Medicine and Cellular Longevity*, art. 5698931. http://dx.doi.org/10.1155/2016/5698931

Biswas, S.K. & Lopes de Faria, J. 2007. Which comes first: Renal inflammation or oxidative stress in spontaneously hypertensive rats? *Free Radical Research,* 41(2):216–224. doi: 10.1159/000109993

Blair, S.N. 2009. Physical inactivity: the biggest public health problem of the 21st century. *British Journal of Sports Medicine,* 43(1):1–2.

Blair, S.N. & Morris, J.N. 2009. Healthy hearts and the universal benefits of being physically active: Physical activity and health. *Annals of Epidemiology,* 19(4):253–256. doi:10.1016/j.annepidem.2009.01.019

Bloomer, R.J., Larson, D.E., Fisher-Wellman, K.H., Galpin, A.J. & Schilling, B.K. 2009. Effect of eicosapentaenoic and docosahexaenoic acid on resting and exercise-induced inflammatory and oxidative stress biomarkers: a randomized, placebo controlled, cross-over study. *Lipids in Health and Disease*, 8(36):1–12. doi:10.1186/1476-511X-8-36

Bornfeldt, K.E. & Tabas, I. 2011. Insulin resistance, hyperglycemia, and atherosclerosis. *Cell Metabolism,* 14(5):575–585. doi 10.1016/j.cmet.2011.07.015

Bouchard, C. & Katzmarzyk, P.T., eds. 2010. *Physical activity and obesity.* 2nd ed. Louisiana: Human Kinetics.

Bouchard, C., Blair, S.N. & Haskell, W.L., eds. 2012. *Physical activity and health.* 2nd ed. Champaigne: Human Kinetics.

Bradshaw, D., Steyn, K., Levitt, N. & Nojilana, B. 2011. Non-communicable diseases – a race against time. *Medical Research Council of South Africa.* http://www.health.uct.ac.za/usr/health/research/groupings/cdia/downloads/MRC_policy_brief.pdf Date of access: 1 Feb. 2020.

Brage, S., Brage, N., Franks, P.W., Ekelund, U. & Wareham, N.J. 2005. Reliability and validity of the combined heart rate and movement sensor ActiHeart. *European Journal of Clinical Nutrition,* 59(4):561–570. doi:10.1038/sj.ejcn.1602118

Bruwer, E.J. 2014. *Physical activity status, chronic stress, cardiovascular risk factors and telomere length in an urban South African teachers' cohort: the SABPA study.* Potchefstroom: North-West University. (Doctoral thesis).

Bull, F.C., Maslin, T.S. & Armstrong, T. 2009. Global Physical Activity Questionnaire (GPAQ): nine country reliability and validity study. *Journal of Physical Activity and Health,* 6(6):790–804. doi:10.1123/jpah.6.6.790

Butte, N.F., Ekelund, U. & Westerterp, K.R. 2012. Assessing physical activity using wearable monitors: measures of physical activity. *Medicine and Science in Sports and Exercise,* 44(1S):5–12. doi:10.1249/MSS.0b013e3182399c0e

Cachofeiro, V., Goicochea, M., de Vinuesa, S.G., Oubiña, P., Lahera, V. & Luño, J. 2008. Oxidative stress and inflammation, a link between chronic kidney disease and cardiovascular disease. *Kidney International,* 74:4–9. doi:10.1038/ki.2008.516

Camarillo-Romero, E., Dominguez-Garcia, M.V., Amaya-Chavez, A., Camarillo-Romero, M. del S., Talavera-Piña, J., Huitron-Bravo, G. & Majluf-Cruz, A. 2012. Effects of a physical activity program on markers of endothelial dysfunction, oxidative stress, and metabolic status in adolescents with metabolic syndrome. *Endorinology,* 2012, art. 970629. doi:10.5402/2012/970629

Campbell, N., Prapavessis, H., Gray, C., Mcgowan, E., Rush, E. & Maddison, R. 2012. The ActiHeart in adolescents: a doubly labelled water validation. *Pediatric Exercise Science,* 24(4):589–602. https://doi.org/10.1123/pes.24.4.589

Caspersen, C.J., Powell, K.E. & Christenson, G.M. 1985. Physical activity, exercise, and physical fitness: definitions, distinctions for health-related research. *Public Health Reports,* 100(2):126-131.

Ceriello, A. & Motz, E. 2004. Is oxidative stress the pathogenic mechanism underlying insulin resistance, diabetes and cardiovascular disease? The common soil hypothesis revisited. *Journal of the American Heart Association,* 24(5):816-823.

Chambless, L.E., Heiss, G., Folsom, A.R., Rosamond, W., Szklo, M., Sharrett, A.R. & Clegg, L.X. 1997. Association of coronary heart disease incidence with carotid arterial wall thickness and major risk factors: the Atherosclerosis Risk in Communities (ARIC) study, 1987–1993. *American Journal of Epidemiology,* 146(6):483–494. https://doi.org/10.1093/oxfordjournals.aje.a009302

Chimen, M., Kennedy, A., Nirantharakumar, K., Pang, T.T., Andrews, R. & Narendran, P. 2012. What are the health benefits of physical activity in type 1 diabetes mellitus? A literature review. *Diabetologia,* 55(3):542–551. doi:10.1007/s00125-011-2403-2

Chu, A.H.Y. & Moy, F.M. 2014. Association between physical activity and metabolic syndrome among Malay adults in a developing country, Malaysia. *Journal of Science and Medicine in Sport,* 17(2):195–200. http://dx.doi.org/10.1016/j.jsams.2013.04.003

Cleland, C.L., Hunter, R.F., Kee, F., Cupples, M.E., Sallis, J.F. & Tully, M.A. 2014. Validity of the global physical activity questionnaire (GPAQ) in assessing levels and change in moderate-vigorous physical activity and sedentary behaviour. *Biomed Central,* 14(1):1255–1266. http://www.biomedcentral.com/1471-2458/14/1255

Colbert, L.H., Matthews, C.E., Havighurst, T.C., Kim, K. & Schoeller, D.A. 2011. Comparative validity of physical activity measures in older adults. *Medicine and Science in Sport and Exercise,* 43(5):867–876. https://dx.doi.org/10.1249%2FMSS.0b013e3181fc7162

Corrado, E., Rizzo, M., Coppola, G., Fattouch, K., Novo, G., Marturana, I., Ferrara, F. & Novo, S. 2010. An update on the role of markers of inflammation in atherosclerosis. *Journal of Atherosclerosis and Thrombosis*, 17(1):1–11. https://doi.org/10.5551/jat.2600

Crouter, S., Churilla, J. & Bassett, D. 2008. Accuracy of the ActiHeart for the assessment of energy expenditure in adults. *European Journal of Clinical Nutrition*, 62(6):704–711. doi:10.1038/sj.ejcn.1602766

Dawson, J.D., Sonka, M., Blecha, M.B., Lin, W. & Davis, P.H. 2009. Risk factors associated with aortic and carotid intima-media thickness in adolescents and young adults. *Journal of American College of Cardiology*, 53(24):2273–2279. doi:10.1016/j.jacc.2009.03.026

DeLany, J.P. 2012. Measurement of energy expenditure. *Pediatric Blood Cancer*, 58(1):129–134. doi:10.1002/pbc.23369

Demeyer, H. & Watz, H. 2018. Assessment of physical activity. (*In* Clini, E., Holland, A.E, Pitta, F. & Troosters, T., *eds*. *Textbook of pulmonary rehabilitation.* Switzerland: Springer. p. 109–119).

Den Ruijter, H.M., Peters, S.A.E., Anderson, T.J., Britton, A.R., Dekker, J.M., Eijkemans, M.J., … Bots, M.L. 2012. Common carotid intima-media thickness measurements in cardiovascular risk prediction. *Journal of the American Medical Association*, 308(8):796–803. doi:10.1001/jama.2012.9630

Di Francescomarino, S., Sciartilli, A., Di Valerio, V., Di Baldassarre, A. & Gallina, S. 2009. The effect of physical exercise on endothelial function. *Sports Medicine*, 39(10):797–812.

Di Pietro, L., Dziura, J. & Blair, S.N. 2004. Estimated change in physical activity level (PAL) and prediction of 5-year weight change in men: the aerobics center longitudinal study. *International Journal of Obesity*, 28(12):1541–1547. https://doi.org/10.1038/sj.ijo.0802821

Di Meo, S., Napolitano, G. & Venditti, P. 2019. Mediators of physical activity protection against ros-linked skeletal muscle damage. *International Journal of Molecular Sciences*, 20(12): art. 3024. http://dx.doi.org/10.3390/ijms20123024

Ding, D., Kolbe-Alexander, T., Nguyen, B., Katzmarsyk, P.T., Pratt, M. & Lawson, K.D. 2017. The economic burden of physical inactivity: a systematic review and critical appraisal. *British Journal of Sports Medicine*, 51(19):1–19. doi:10.1136/bjsports-2016-097385

Ding, D., Lawson, K.D., Kolbe-Alexander, T.L., Finkelstein, E.A., Katzmarsyk, P.T., van Mechelen, W. & Pratt, M. 2016. The economic burden of physical inactivity: a global analysis of major non-communicable diseases. *Lancet*, 388(10051):1311–1324. https://doi.org/10.1016/S0140-6736(16)30383-X

Dohrn, I.-M., Sjöström, M., Kwak, L., Oja, P. & Hagströmer, M. 2018. Accelerometer-measured sedentary time and physical activity—A 15-year follow-up of mortality in a Swedish population-based cohort. *Journal of Science and Medicine in Sport*, 21(7):702–707. https://doi.org/10.1016/j.jsams.2017.10.035

Dumith, S.C., Hallal, P.C., Reis, R. & Kohl, H.W. 2011. Worldwide prevalence of physical inactivity and its association with human development index in 76 countries. *Preventive Medicine*, 53(1–2):24–28. http://dx.doi.org/10.1016/j.ypmed.2011.02.017

Eckel, R.H., Grundy, S.M. & Zimmet, P.Z. 2005. The metabolic syndrome. *Lancet*, 365(9468):1415–1428. https://doi-org.nwulib.nwu.ac.za/10.1016/S0140-6736(05)66378-7

Edwardson, C.L., Gorely, T., Davies, M.J., Gray, L.J., Khunti, K., Wilmot, E.G., Yates, T. & Biddle, S.J.H. 2012. Association of sedentary behaviour with metabolic syndrome: a meta-analysis. *PloS One*, 7(4), e34916. doi:10.1371/journal.pone.0034916

Ehrman, J.K., deJong, A., Sanderson, B., Swain, D., Swank, A. & Womack, C., eds. 2010. *ACSM's resource manual for exercise testing and prescription.* 6th ed. Philedelphia: Lippincott Williams & Wilkens.

Ekelund, U., Steene-Johannessen, J., Brown, W.J., Fagerland, M.W., Owen, N., Powell, K.E., Bauman, A. & Lee, I.-M. 2016. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. *Lancet*, 388(10051):1302–1310. https://doi.org/10.1016/S0140-6736(16)30370-1

Farpour-Lambert, N.J., Aggoun, Y., Marchand, L.M., Martin, X.E., Herrmann, F.R. & Beghetti, M. 2009. Physical activity reduces systemic blood pressure and improves early markers of atherosclerosis in pre-pubertal obese children. *Journal of the American College of Cardiology*, 54(25):2396–2406. doi:10.1016/j.jacc.2009.08.030

Fisher-Wellman, K. & Bloomer, R.J. 2009. Acute exercise and oxidative stress: a 30-year history. *Dynamic Medicine*, 8(1):1–25. https://doi.org/10.1186/1476-5918-8-1

Fox, K.R. 1999. The influence of physical activity on mental well-being. *Public Health Nutrition*, 2(3):411–418. https://doi.org/10.1017/S1368980099000567

Franco, O.H., De Laet, C., Peeters, A., Jonker, J., Mackenbach, J. & Nusselder, W. 2005. Effects of physical activity on life expectancy with cardiovascular disease. *Archives of Internal Medicine*, 165(20):2355–2360. doi:10.1001/archinte.165.20.2355

Friedenreich, C.M. & Cust, A.E. 2008. Physical activity and breast cancer risk: impact of timing, type and dose of activity and population subgroup effects. *British Journal of Sports Medicine*, 42(8):636–647. doi:10.1136/bjsm.2006.029132

Friendenreich, C.M. & McNeil, J. 2018. Mapping the historical development of research in physical activity and health: providing a platform for future research. *Preventive Medicine*, 111:473–475. https://doi.org/10.1016/j.ypmed.2017.11.027

George, J.A., Norris, S.A., van Deventer, H.E. & Crowther, N.J. 2013. The association of 25 hydroxyvitamin d and parathyroid hormone with metabolic syndrome in two ethnic groups in South Africa. *PLoS One*. 8(4), e61282. doi:10.1371/journal.pone.0061282

Gill, J.M.R. & Cooper, A.R. 2008. Physical activity and the prevention of type 2 diabetes mellitus. *Sports Medicine*, 38(10):807–824. https://doi.org/10.2165/00007256-200838100-00002

Gomez-Marcos, M.A., Recio-Rodríguez, J.I., Patino-Alonso, M.C., Agudo-Conde, C., Lasaosa-Medina, L., Rodriguez-Sanchez, E., Maderuelo-Fernandez, J.A. & García-Ortiz, L. 2014. Relationship between objectively measured physical activity and vascular structure and function in adults. *Atherosclerosis*, 234(2):366–372. http://dx.doi.org/10.1016/j.atherosclerosis.2014.02.028

Goodpaster, B.H., Delany, J.P., Otto, A.D., Kuller, L., Vockley, J., South-paul, J.E., … Jakicic J.M. 2010. Effects of diet and physical activity interventions on weight loss and cardio-metabolic risk factors in severely obese adults. *Journal of the American Medical Association*, 304(16):1795–1802. doi:10.1001/jama.2010.1505

Goyal, T., Mitra, S., Khaidakov, M., Wang, X., Singla, S., Ding, Z., Liu, S. & Mehta, J.L. 2012. Current concepts of the role of oxidised LDL receptors in atherosclerosis. *Current Atherosclerosis Reports*, 14(2):150–159. doi:10.1007/s11883-012-0228-1

Graig, C.L., Marshall, A.L., Sjöström, M., Bauman, A, E, Booth, M.L., Ainsworth, B.E., … Oja, P. 2003. International physical activity questionnaire: 12 country reliability ad validity. *Medicine and Science in Sport and Exercise*, 35(8):1381–1395. doi: 10.1249/01.MSS.0000078924.61453.FB

Guthold, R., Ono, T., Strong, K.L., Chatterji, S. & Morabia, A. 2008. Worldwide variability in physical inactivity: a 51-country survey. *American Journal of Preventive Medicine*, 34(6):486–494. doi:10.1016/j.amepre.2008.02.013

Guthold, R., Stevens, G.A., Riley, L.M. & Bull, F.C. 2018. Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1·9 million participants. *Lancet Global Health*, 6(10):1077–1086. https://doi.org/10.1016/S2214-109X(18)30357-7

Hagströmer, M., Oja, P. & Sjöström, M. 2006. The International Physical Activity Questionnaire (IPAQ): a study of concurrent and construct validity. *Public Health Nutrition*, 9(6):755–762. doi:10.1079/PHN2005898

Hallal, P.C., Anderson, L.B., Bull, F.C., Guthold, R., Haskell, W. & Ekelund, U. 2012. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet*, 380(9838):247–257. https://doi.org/10.1016/S0140-6736(12)60646-1

Hallal, P.C., Gomez, L.F., Parra, D.C., Lobelo, F., Mosquera, J., Florindo, A.A., … Sarmiento, O.L. 2010. Lessons learned after 10 Years of IPAQ use in Brazil and Colombia. *Journal of Physical Activity and Health*, 7(s2):259–264. https://doi.org/10.1123/jpah.7.s2.s259

Hamer, M., Stamatakis, E. & Steptoe, A. 2008. Dose-response relationship between physical activity and mental health: the Scottish Health Survey. *British Journal of Sports Medicine*, 43(14):1111–1114. doi:10.1136/bjsm.2008.046243

Han, T.S. & Lean, M.E. 2015. Metabolic syndrome. *Medicine*, 43(2):80–87. https://doi.org/10.1016/j.mpmed.2014.11.006

Hansson, G.K. & Libby, P. 2006. The immune response in atherosclerosis: a double-edged sword. *Nature Reviews Immunology*, 6(7):508–519. https://doi.org/10.1038/nri1882

Harrison, D., Griendling, K.K., Landmesser, U., Hornig, B. & Drexler, H. 2003. Role of oxidative stress in atherosclerosis. *American Journal of Cardiology*, 91(3):7–11. https://doi.org/10.1016/S0002-9149(02)03144-2

Haskell, W.L., Lee, I., Powell, R.R. & Blair, S.N. 2007. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation,* 116:1081–1093. doi:10.1161/CIRCULATIONAHA.107.185649

He, D., Xi, B., Xue, J., Huai, P., Zhang, M. & Li, J. 2014. Association between leisure time physical activity and metabolic syndrome: a meta-analysis of prospective cohort studies. *Endocrine,* 46(2):231–240. doi:10.1007/s12020-013-0110-0

Healy, G.N., Dunstan, D.W., Salmon, J., Cerin, E., Shaw, J., Zimmet, P. & Owen, N. 2008. Beneficial associations with metabolic risk. *Diabetes Care,* 31(4):661–666. doi:10.2337/dc07-2046

Heijnen, S., Hommel, B., Kibele, A. & Colzato, L.S. 2016. Neuromodulation of aerobic exercise – a review. *Frontiers in Psychology,* 6. art. 1890. https://doi.org/10.3389/fpsyg.2015.01890

Heitzer, T., Schlinzig, T., Krohn, K., Meinertz, T. & Münzel, T. 2001. Endothelial dysfunction, oxidative stress, and risk of cardiovascular events in patients with coronary artery disease. *Circulation,* 104(22):2673–2678. https://doi.org/10.1161/hc4601.099485

Helmerhorst, H.J., Brage, S., Warren, J., Besson, H. & Ekelund, U. 2012. A systematic review of reliability and objective criterion-related validity of physical activity questionnaires. *International Journal of Behavioural Nutrition and Physical Activity,* 9(103):1–55. https://doi.org/10.1186/1479-5868-9-103

Herrmann, S.D., Heumann, K.J., Der Ananian, C.A. & Ainsworth, B.E. 2013. Validity and reliability of the global physical activity questionnaire (GPAQ). *Measurement in Physical Education and Exercise Science,* 17(3):221–235. https://doi.org/10.1080/1091367X.2013.805139

Hills, A.P., Mokhtar, N., Byrne, N.M., Nagy, T.R. & Willig, A. 2014. Assessment of physical activity and energy expenditure: an overview of objective measures. *Frontiers in Nutrition,*1:1–5. https://doi.org/10.3389/fnut.2014.00005

Huang, P.L. 2009. A comprehensive definition for metabolic syndrome. *Disease Models and Mechanisms,* 2(5–6):231–237. doi:10.1242/dmm.001180

Huynh, Q.L., Blizzard, C.L., Raitakari, O., Sharman, J.E., Magnussen, C.G., Dwyer, T., … Venn, A.J. 2015. Vigorous physical activity and carotid distensibility in young and mid-aged adults. *Hypertension Research,* 38(5):355–360. doi:10.1038/hr.2015.9

Inaba, Y., Chen, J.A. & Bergmann, S.R. 2011. Carotid plaque, compared with carotid intima-media thickness, more accurately predicts coronary artery disease events: a meta-analysis. *Atherosclerosis,* 220(1):128–133. doi:10.1016/j.atherosclerosis.2011-.06.044

IPAQ (International Physical Activity Questionnaire). 2005. *Guidelines for data processing and analysis of the International Physical Activity Questionnaire (IPAQ).* https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnx0aGVpcGFxfGd4OjE0NDgxMDk3NDU1YWRlZTM Date of access: 21 Feb. 2020.

Isomaa, B., Almgren, P. & Tuom, T. 2001. Cardiovascular morbidity and mortality. *Diabetes Care*, 24(4):683–689.

James, A.M., Collins, Y., Logan, A. & Murphy, M.P. 2012. Mitochondrial oxidative stress and the metabolic syndrome. *Trends in Endocrinology and Metabolism*, 23(8):429–434. https://doi.org/10.1016/j.tem.2012.06.008

Janssen, I. & Leblanc, A.G. 2010. A systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioural Nutrition and Physical Activity*, 7(1):40–56. https://doi.org/10.1186/1479-5868-7-40

Jetté, M., Sidney, K. & Blümchen, G. 1990. Metabolic equivalents (METs) in exercise testing, exercise prescription, and evaluation of functional capacity. *Clinical Cardiology*, 13(8):555–565. https://doi.org/10.1002/clc.4960130809

Johansson, G. & Westerterp, K. 2008. Assessment of the physical activity level with two questions: validation with doubly labelled water. *International Journal of Obesity*, 32(6):1031–1033. doi:10.1038/ijo.2008.42

Joubert, J. 2015. Chronic non-communicable diseases – Where to now in Africa? *Journal of Neurological sciences*, 348(1):3–5. http://dx.doi.org/10.1016/j.jns.2014.11.021

Kadoglou, N.P.E., Iliadis, F. & Liapis, C.D. 2008. Exercise and carotid atherosclerosis. *European Journal for Vascular and Endovascular Surgery*, 35(3):264–272. doi:10.1016/j.ejvs.2007.08.022

Kaiyala, K.J. & Ramsay, D.S. 2011. Direct animal calorimetry, the underused gold standard for quantifying the fire of life. *Comparative Biochemistry and Physiology*, 158(3):252–264. https://doi.org/10.1016/j.cbpa.2010.04.013

Kallings, L. V., Johnson, J.S., Fisher, R.M., De Faire, U., Ståhle, A., Hemmingsson, E. & Hellénius, M.-L. 2009. Beneficial effects of individualised physical activity on prescription on body composition and cardio-metabolic risk factors: results from a randomised controlled trial. *European Journal of Cardiovascular Prevention and Rehabilitation*, 16(1):81–84. doi:10.1097/HJR.0b013e32831e953a

Kallio, P., Pahkala, K., Heinonen, O.J., Tammelin, T., Hirvensalo, M. Telama, R., … Raitakari, O.T. 2018. Physical inactivity from youth to adulthood and the risk of impaired glucose metabolism. *Medicine and Science in Sports and Exercise,* 50(6):1192–1198. https://doi.org/10.1249/MSS.0000000000001555

Kassi, E., Pervanidou, P., Kaltsas, G. & Chrousos, G. 2011. Metabolic syndrome: definitions and controversies. *BMC Medicine,* 9(1):48–61. https://doi.org/10.1186/1741-7015-9-48

Keaney, J.F. 2000. *Oxidative stress and vascular disease.* New York: Springer.

Kelly, P., Fitzsimons, C. & Baker, G. 2016. Should we reframe how we think about physical activity and sedentary behaviour measurement? Validity and reliability reconsidered. *International Journal of Behavioural Nutrition and Physical Activity,* 13(23):1–10. doi:10.1186/s12966-016-0351-4

Kenny, G.P., Notley, S.R. & Gagnon, D. 2017. Direct calorimetry: a brief historical review of its use in the study of human metabolism and thermoregulation. *European Journal of Applied Physiology,* 117(9):1765–1785. https://doi.org/10.1007/s00421-017-3670-5

Kim, Y., Park, I. & Kang, M. 2012. Convergent validity of the international physical activity questionnaire (IPAQ): a meta-analysis. *Public Health Nutrition,* 16(3):440–452. doi:10.1017/S1368980012002996

Kirk, E.P. & Klein, S. 2009. Pathogenesis and pathophysiology of the cardio-metabolic syndrome. *The Journal of Clinical Hypertension,* 11(12):761–765. doi:10.1111/j.1559-4572.2009.00054.x

Klusmann, V., Evers, A., Schwarzer, R. & Heuser, I. 2012. Views on ageing and emotional benefits of physical activity: effects of an exercise intervention in older women. *Psychology of Sport and Exercise,* 13(2):236–242. doi:10.1016/j.psychsport.2011.11.001

Kohl, H.W., Craig, C.L., Lambert, E.V., Inoue, S., Alkandari, J.R., Leetongin, G. & Kahlmeier, S. 2012. The pandemic of physical inactivity: global action for the public. *Lancet,* 380(9838):294–305. https://doi.org/10.1016/S0140-6736(12)60898-8

Kotsis, V.T., Stabouli, S. V., Papamichael, C.M. & Zakopoulos, N.A. 2006. Impact of obesity in intima media thickness of carotid arteries. *Obesity,* 14(10):1708–1715. https://doi.org/10.1038/oby.2006.196

Kozàkovà, M., Palombo, C., Morizzo, C., Nolan, J.J., Konrad, T., Balkau, B. & RISC Investigators. 2010. Effect of sedentary behaviour and vigorous physical activity on segment-specific carotid wall thickness and its progression in a healthy population. *European Heart Journal,* 31(12):1511–1519. https://doi.org/10.1093/eurheartj/ehq092

Kresser, C. 2018. *What really causes oxidative damage?* https://kresserinstitute.com/what-really-causes-oxidative-damage/ Date of access: 30 Jan. 2020.

Lakka, H.M., Laaksonen, D.E., Lakka, T.A., Niskanen, L.K., Kumpusalo, E., Tuomilehto, J. & Salonen, J.T. 2002. The metabolic syndrome and total and cardiovascular disease mortality in middle-aged men. *Journal of the American Medical Association,* 288(21):2709–2716.

Laursen, A.S.D., Hansen, A.L.S., Wiinberg, N., Brage, S., Sandbæk, A., Lauritzen, T., … Johansen, N.B. 2015. Higher physical activity is associated with lower aortic stiffness but not with central blood pressure: the ADDITION-Pro Study. *Medicine,* 94(5), e485. doi:10.1097/MD.0000000000000485

Lee, I.M., Shiroma, E.J., Lobelo, F., Puska, P., Blair, S.N. & Katzmarzyk, P.T. 2012. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet,* 380(9838):219–229. http://dx.doi.org/10.1016/ S0140-6736(12)61031-9

Lee, D.H., Kim, Y.M., Jekal, Y., Park, S., Kim, K.C., Naruse, M., … Jeon, J.Y. 2013. Low levels of physical activity are associated with increased metabolic syndrome risk factors in Korean adults. *Diabetes Metabolism Journal,* 37(2):132–139. http://dx.doi.org/10.4093/dmj.2013.37.2.132

Lee, P.H., Macfarlane, D.J., Lam, T.H. & Stewart, S.M. 2011. The validity of the international physical activity questionnaire short form (IPAQ-SF): a systematic review. *International Journal of Behavioural Nutrition and Physical Activity,* 8(1):115–126. https://doi.org/10.1186/1479-5868-8-115

Li, J. & Siegrist, J. 2012. Physical activity and risk of a cardiovascular disease – a meta-analysis of prospective cohort studies. *International Journal of Environmental Research and Public Health,* 9(2):391–407. https://doi.org/10.3390/ijerph9020391

Li, R., Jia, Z. & Trush, M.A. 2016. Defining ROS in biology and medicine. *Reactive Oxygen Species,* 1(1):9–21. doi:10.20455/ros.2016.803

Li, Y., Pan, A., Wang, D.D., Liu, X., Dhana, K., Franco, O.H., … Hu, F.B. 2018. Impact of healthy lifestyle factors on life expectancies in the US population. *Circulation,* 138(4):345–355. https://doi.org/10.1161/CIRCULATIONAHA.117.032047

Libby, P., Ridker, P.M. & Hansson, G.K. 2009. Inflammation in atherosclerosis: from pathophysiology to practice. *Journal of the American College of Cardiology,* 54(23):2129–2138. doi:10.1016/j.jacc.2009.09.009

Lista, I. & Sorrentino, G. 2010. Biological mechanisms of physical activity in preventing cognitive decline. *Cellular and Molecular Neurobiology,* 30(4):493–503. https://doi.org/10.1007/s10571-009-9488-x

Lo, J., Dolan, S.E., Kanter, J.R., Hemphill, L.C., Connelly, J.M., Lees, R.S. & Grinspoon, S.K. 2006. Effects of obesity, body composition, and adiponectin on carotid intima-media thickness in healthy women. *The Journal of Clinical Endocrinology and Metabolism*, 91(5):1677–1682. doi:10.1210/jc.2005-2775

Lorenz, M.W., Von Kegler, S., Steinmetz, H., Markus, H.S. & Sitzer, M. 2006. Carotid intima-media thickening indicates a higher vascular risk across a wide age range: prospective data from the Carotid Atherosclerosis Progression Study (CAPS). *Stroke*, 37(1):87–92. https://doi.org/10.1161/01.STR.0000196964.24024.ea

Lyden, K., Kozey, S.L., Staudenmeyer, J.W. & Freedson, P.S. 2011. A comprehensive evaluation of commonly used accelerometer energy expenditure and MET prediction equations. *European Journal of Applied Physiology*, 111(2):187–201. doi:10.1007/s00421-010-1639-8

Mancia, G., Fagard, R., Narkiewicz, K., Redon, J., Zanchetti, A., Böhm, M., … Zannad, F. 2013. 2013 ESH/ ESC guidelines for the management of arterial hypertension. *Blood Pressure*, 22(4):193–278. doi:10.3109/08037051.2014.868629

Marco, E.M., García-Gutiérrez, M.S., Bermúdez-Silva, F.J., Moreira, F.A., Guimarães, F., Manzanares, J. & Viveros, M.P. 2011. Endocannabinoid system and psychiatry: in search of a neurobiological basis for detrimental and potential therapeutic effects. *Frontiers in Behavioral Neurosciene*, 5, art.63. doi:10.3389/fnbeh.2011.00063

Mayosi, B.M., Flisher, A.J., Lalloo, U.G., Sitas, F., Tollman, S.M. & Bradshaw, D. 2009. The burden of non-communicable diseases in South Africa. *Lancet*, 374(9693):934–947. https://doi.org/10.1016/S0140-6736(09)61087-4

Monteiro, R. & Azevedo, I. 2010. Chronic inflammation in obesity and the metabolic syndrome. *Mediators of Inflammation*, 2010, art. 289645. doi:10.1155/2010/289645

Motala, A.A., Esterhuizen, T., Pirie, F.J. & Omar, M.A.K. 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. doi:10.2337/dc10-1921

Motala, A.A., Mbanya, J.C. & Ramaiya, K.L. 2009. Metabolic syndrome in sub-Saharan Africa. *Ethnicity and Disease*, 19(2):8–10.

Mottillo, S., Filion, K.B., Genest, J., Joseph, L., Pilote, L., Poirier, P., … Eisenberg, M.J. 2010. The metabolic syndrome and cardiovascular risk: a systematic review and meta-analysis. *Journal of the American College of Cardiology*, 56(14):1113–1132. doi:10.1016/j.jacc.2010.05.034

Murray, C.J.L., Forouzanfar, M.H., Afshin, A., Alexander, L.T., Anderson, H.R., Bhutta, Z.A. … Zuhlke, L.J. 2016. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the global burden of diseases study 2015. *Lancet,* 388(10053):1659–1724.

Nair, S.B., Malik, R. & Khattar, R.S. 2012. Carotid intima-media thickness: ultrasound measurement, prognostic value and role in clinical practice. *Postgraduate Medical Journal,* 88(1046):694–699. doi:10.1136/postgradmedj-2011-130214

Naqvi, T.Z. & Lee, M.-S. 2014. Carotid intima-media thickness and plaque in cardiovascular risk assessment. *Journal of the American College of Cardiology,* 7(10):1025–1038. http://dx.doi.org/10.1016/jjcmg.2013.11.014

Ndahimana, D. & Kim, E. 2017. Measurement methods for physical activity and energy expenditure: a review. *Clinical Nutrition Research,* 6(2):68–80. https://doi.org/10.7762/cnr.2017.6.2.68

Ne, J.Y.A., Cai, T.Y., Celermajer, D.S., Caterson, I.D., Gill, T., Lee, C.M.Y. & Skilton, M.R. 2017. Obesity, arterial function and arterial structure – a systematic review and meta-analysis. *Obesity Science and Practice,* 3(2):171–184. https://doi.org/10.1002/osp4.108

Nezu, T., Hosomi, N., Aoki, S. & Matsumoto, M. 2015. Carotid intima-media thickness for atherosclerosis. *Journal of Atherosclerosis and Thrombosis,* 22:1–14. doi:10.5551/jat.31989

Nikander, R., Sievänen, H., Heinonen, A., Daly, R.M., Uusi-Rasi, K. & Kannus, P. 2010. Targeted exercise against osteoporosis: a systematic review and meta-analysis for optimising bone strength throughout life. *BMC Medicine,* 8(1):47–63. http://www.biomedcentral.com/1741-7015/8/47

Okafor, C. 2012. The metabolic syndrome in Africa: current trends. *Indian Journal of Endocrinology and Metabolism,* 16(1):56–66. doi:10.4103/2230-8210.91191

Ortega-Loubon, C., Fernández-Molina, M., Singh, G. & Correa, R. 2019. Obesity and its cardiovascular effects. *Diabetes Metabolism Research and Review Journal,* 35(4), e3135. https://doi.org/10.1002/dmrr.3135

Pahkala, K., Heinonen, O.J., Simell, O., Jorma, Viikari, J.S.A., Rönnemaa, T., … O.T. 2011. Association of physical activity with vascular endothelial function and intima-media thickness: a longitudinal study in adolescents. *Circulation,* 124(18):1956–1963. doi:10.1161/CIRCULATIONAHA.111.043851

Park, H., Park, S., Shephard, R.J. & Aoyagi, Y. 2010. Yearlong physical activity and sarcopenia in older adults: the Nakanojo Study. *European Journal of Applied Physiology,* 109(5):953–961. doi:10.1007/s00421-010-1424-8

Park, J., Kazuko, I.-T., Kim, E., Kim, J. & Yoon, J. 2014. Estimating free-living human energy expenditure: practical aspects of the doubly labelled water method and its applications. *Nutrition Research and Practice,* 8(3):241–248. doi:10.4162/nrp.2014.8.3.241

Parsons, T.J., Sartini, C., Ellins, E.A., Halcox, J.P.J., Smith, K.E., Ash, S., … Jefferis, B.J. 2016. Objectively measured physical activity, sedentary time and subclinical vascular disease: cross-sectional study in older British men. *Preventive Medicine,* 89:194–199. http://dx.doi.org/10.1016/j.ypmed.2016.05.031

Pate, R.R., O'Neill, J.R. & Lobelo, F. 2008. The evolving definition of "sedentary". *Exercise Sport Science Reviews,* 36(4):173–178. doi:0091-6331/3604/173Y178

Pate, R.R., Pratt, M., Blair, S.N., Haskell, W.L., Macera, C.A., Bouchard, C. … Wilmore, J.H. 1995. Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *Journal of the American Medical Association,* 273(5):402–407. doi:10.1001/jama.1995.03520290054029

Pham-Huy, L.A., He, H. & Pham-Huy, C. 2008. Free radicals, antioxidants in disease and health. *International Journal of Biomedical Science*, 4(2):89–96.

Physical Activity Guidelines Advisory Committee. 2018. *Physical Activity Guidelines Advisory Committee scientific report.* https://health.gov/paguidelines/second-edition/report/pdf/PAG_Advisory_Committee_Report.pdf Date of access: 25 Jun. 2018.

Plasqui, G. & Westerterp, K.R. 2007. Physical activity assessment with accelerometers: an evaluation against doubly labelled water. *Obesity*, 5(10):2371–2379. https://doi.org/10.1038/oby.2007.281

Polak, J.F., Pencina, M.J., Pencina, K.M., O'Donnell, C.J., Wolf, P.A. & D'Agostino, R.B. 2011. Carotid-wall intima-media thickness and cardiovascular events multiplicity adjustments in testing for bioequivalence view project machine learning applications in cardiovascular genomics view project carotid-wall intima-media thickness and cardiovascular events. *New England Journal of Medicine,* 365(3):213–221. doi:10.1056/NEJMoa1012592

Powers, S.K. & Jackson, M.J. 2008. Exercise-induced oxidative stress: cellular mechanisms and impact on muscle force production. *Physiology Review,* 88(4):1243–1276. doi:10.1152/physrev.00031.2007

Powers, S.K., Nelson, W.B. & Hudson, M.B. 2011. Exercise-induced oxidative stress in humans: cause and consequences. *Free Radical Biology and Medicine,* 51(5):942–950. doi:10.1016/j.freeradbiomed.2010.12.009

Pretty, J., Peacock, R., Hine, R., Sellens, M., South, N. & Griffin, M. 2007. Green exercise in the UK countryside: effects on health and psychological well-being, and implications for policy and planning. *Journal of Environmental Planning and Management,* 50(2):211–231. doi:10.1080/09640560601156466

Prinsloo, J., Malan, L., De Ridder, J.H., Potgieter, J.C. & Steyn, H.S. 2011. Determining the waist circumference cut off which best predicts the metabolic syndrome components in urban Africans: the SABPA study. *Experimental Clinical Endocrinology and Diabetes,* 119(10):599–603. http://dx.doi.org/10.1055/s-0031-1280801

Radak, Z., Chung, H.Y., Koltai, E., Taylor, A.W. & Goto, S. 2008. Exercise, oxidative stress and hormesis. *Ageing Research Reviews,* 7(1):34–42. doi:10.1016/j.arr.2007.04.004

Rees-Punia, E., Hathaway, E.D. & Gay, J.L. 2018. Crime, perceived safety and physical activity: a meta-analysis. *Preventive Medicine,* 111:307–313. https://doi.org/10.1016/j.ypmed.2017.11.017

Reimers, C.D., Knapp, G. & Reimers, A.K. 2012. Does physical activity increase life expectancy? A review of the literature. *Journal of Ageing Research,* 2012:1–9. https://doi.org/10.1155/2012/243958

Reiner, M., Niermann, C., Jekauc, D. & Woll, A. 2013. Long-term health benefits of physical activity – a systematic review of longitudinal studies. *Biomed Central Public Health,* 13(1):813–827. https://doi.org/10.1186/1471-2458-13-813

Riebe, D., Ehrman, J.K., Liguori, G., Magal, M., eds. 2018. *ACSM's Guidelines for Exercise Testing and Prescription.* 10th ed. Philadelphia: Wolters Kluwer.

Ried-Larsen, M., Grøntved, A., Froberg, K., Ekelund, U. & Andersen, L.B. 2013. Physical activity intensity and subclinical atherosclerosis in Danish adolescents: the European Youth Heart Study. *Scandinavian Journal of Medicine and Science in Sports,* 23(3):168–177. doi: 10.1111/sms.12046

Ried-Larsen, M., Grøntved, A., Kristensen, P.L., Froberg, K. & Andersen, L.B. 2015. Moderate-and-vigorous physical activity from adolescence to adulthood and subclinical atherosclerosis in adulthood: prospective observations from the European Youth Heart Study. *British Journal of Sports Medicine,* 49(2):107–113. doi:10.1136/bjsports-2013-092409

Ried-Larsen, M., Grøntved, A., Møller, C.N., Larsen, K.T., Froberg, K. & Bo Andersen, L. 2014. Associations between objectively measured physical activity intensity in childhood and measures of subclinical cardiovascular disease in adolescence: prospective observations from the European Youth Heart Study. *British Journal of Sports Medicine*, 48(20):1502–1507. doi:10.1136/bjsports-2012-091958

Ross, R. 1999. Atherosclerosis – an inflammatory disease. *Mechanisms of Disease,* 340(2):115–126. doi:10.1056/NEJM199901143400207

Roberts, C.K. & Sindhu, K.K. 2009. Oxidative stress and metabolic syndrome. *Life Sciences*, 84(21–22):705–712. https://doi.org/10.1016/j.lfs.2009.02.026

Rothney, M.P., Brychta, R.J., Meade, N.N., Chen, K.Y. & Buchowski, M.S. 2010. Validation of the ActiGraph two–regression model for predicting energy expenditure. *Medicine and Science in Sport and Exercise*, 42(9):1785–1792. doi:10.1249/MSS.0b013e3181d5a984

Saklayen, M.G. 2018. The global epidemic of the metabolic syndrome. *Current Hypertension Reports*, 20(2):1–8. https://doi.org/10.1007/s11906-018-0812-z

SBRN (Sedentary Behaviour Research Network). 2017. *SBRN terminology consensus project.* https://www.sedentarybehaviour.org/sbrn-terminology-consensus-project/#consensus-definitions Date of access: 9 Feb. 2020.

Schleicher, E. & Friess, U. 2007. Oxidative stress, age, and atherosclerosis. *International Society of Nephrology*, 72:17–26.

Schoeller, D.A. & van Santen, E. 1982. Measurement of energy expenditure in humans by doubled labelled water method. *Journal of Applied Physiology*, 53(4):955–959.

Seals, D.R., Walker, A.E., Pierce, G.L. & Lesniewski, L.A. 2009. Habitual exercise and vascular ageing. *Journal of Physiology*, 587(23):5541–5549. https://doi.org/10.1113/jphysiol.2009.178822

Shanely, R.A., Nieman, D.C., Henson, D.A., Jin, F., Knab, A.M. & Sha, W. 2011. Inflammation and oxidative stress are lower in physically fit and active adults. *Scandinavian Journal of Medicine and Science in Sports*, 23(2):215–223. doi:10.1111/j.1600-0838.2011.01373.x

Sies, H. 1985. Oxidative stress: Introductory remarks. (In: Sies, H., ed. *Oxidative stress.* London: Academic Press, pp. 1–7).

Sies, H. & Jones, D. 2007. Oxidative stress. (In: Fink, G. ed. *The encyclopedia of stress*. vol 3. San Diego: Academic Press pp. 45–48).

Sirard, J.R., Forsyth, A., Oakes, J.M. & Schmitz, K.H. 2011. Accelerometer test-retest reliability by data processing algorithms: results from the twin cities walking study. *Journal of Physical Activity and Health*, 8(5):668–674.

Spierer, D.K., Hagins, M., Rundle, A. & Pappas, E. 2011. A comparison of energy expenditure estimates from the Actiheart and Actical physical activity monitors during low intensity activities, walking and jogging. *European Journal of Applied Physiology,* 111(4):659–667. doi:10.1007/s00421-010-1672-7

Stein, J.H., Korcarz, C.E., Hurst, R.T., Lonn, E., Kendall, C.B., Mohler, E.R., … W.S. 2008. Use of carotid ultrasound to identify subclinical vascular disease and evaluate cardiovascular disease risk: a consensus statement from the American society of echocardiography carotid intima-media thickness task force endorsed by the society for vascular medicine. *Journal of the American Society of Echocardiography,* 21(2):93–111. https://doi.org/10.1016/j.echo.2007.11.011

Steinbacher, P. & Eckl, P. 2015. Impact of oxidative stress on exercising skeletal muscle. *Biomolecules,* 5(2):356–377. https://doi.org/10.3390/biom5020356

Strasser, B. 2013. Physical activity in obesity and metabolic syndrome. *Annals of the New York Academy of Science,* 1281(1):141–159. doi:10.1111/j.1749-6632.2012.06785.x

Strasser, B., Gostner, J.M. & Fuchs, D. 2016. Mood, food, and cognition: role of tryptophan and serotonin. *Current Opinion in Clinical Nutrition and Metabolic Care,* 19(1):55–61. doi:10.1097/MCO.0000000000000237

Swain, D.P., Braner, C.A., Chambliss, H.O., Nagelkirk, P.R., Bayles, M.P., Swank, A.M., eds. 2014. *ACSM's resource manual for guidelines for exercise testing and prescription.* 7th ed. Philadelphia: Lippincott Williams & Wilkens.

Taylor, B.A., Zaleski, A.L., Capizz, J.A., Ballard, K.D., Troyanos, C., Baggish, A.L., … Thompson, P.D. 2014. Influence of chronic exercise on carotid atherosclerosis in marathon runners. *BMJ Open,* 4(2), e004498. doi:10.1136/bmjopen-2013-004498

Thompson Coon, J., Boddy, K., Stein, K., Whear, R., Barton, J. & Depledge, M.H. 2011. Does participating in physical activity in outdoor natural environments have a greater effect on physical and mental wellbeing than physical activity indoors? a systematic review. *Environmental Science and Technology,* 45(5):1761–1772. https://doi.org/10.1021/es102947t

Touboul, P.-J., Hennerici, M.G., Meairs, S., Adams, H., Amarenco, P., Bornstein, N., … Zureik, M. 2007. Mannheim carotid intima-media thickness consensus (2004–2006). *Cerebrovascular Disease,* 23(1):75–80. doi:10.1159/000097034

Tremblay, M.S., Aubert, S., Barnes, J.D., Saunders, T.J., Carson, V., Latimer-Cheung, A.E., … SBRN terminology consensus prject participants. 2017. Sedentary Behavior Research Network (SBRN) – Terminology consensus project process and outcome. *Inernational Jounral of Behavioral Nutrition and Physical Activity,* 14(1), art. 75. doi:10.1186/s12966-017-0525-8

Tucker, J.M., Welk, G.J. & Beyler, N.K. 2011. Physical activity in U.S. adults: compliance with the physical activity guidelines for Americans. *American Journal of Preventive Medicine,* 40(4):454–461. https://doi.org/10.1016/j.amepre.2010.12.016

Turi, B.C., Codogna, A.S., Fernandes, R.A. & 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):1043–1505. doi: 10.1590/1413-81232015214.23042015

Vallance, J.K., Winkler, E.A.H., Gardiner, P.A., Healy, G.N., Lynch, B.M. & Owen, N. 2011. Associations of objectively-assessed physical activity and sedentary time with depression: NHANES (2005–2006). *Preventive Medicine*, 53(4–5):284–288. https://doi.org/10.1016/j.ypmed.2011.07.013

Van Den Oord, S.C.H., Sijbrands, E.J.G., Ten Kate, G.L., Van Klaveren, D., Van Domburg, R.T., Van Der Steen, A.F.W. & Schinkel, A.F.L. 2013. Carotid intima-media thickness for cardiovascular risk assessment: systematic review and meta-analysis. *Atherosclerosis*, 228(1):1–11. http://dx.doi.org/10.1016/j.atherosclerosis.2013.01.025

Van Poppel, M.N.M., Chinapaw, M.J.M., Mokkink, L.B., Van Mechelen, W. & Terwee, C.B. 2010. Physical activity questionnaires for adults: a systematic review of measurement properties. *Sports Medicine*, 40(7):565–600. https://doi.org/10.2165/11531930-000000000-00000

Van Zyl, S., van der Merwe, L.J., Walsh, C.M., Groenewald, A.J. & van Rooyen, F.C. 2012. Risk-factor profiles for chronic diseases of lifestyle and metabolic syndrome in an urban and rural setting in South Africa. *African Journal of Primary Health Care and Family Medicine*, 4(1), art. 346. doi:10.4102/phcfm.v4i1.346

Vanhelst, J., Hurdiel, R., Mikulovic, J., Bui-Xuân, G., Fardy, P., Theunynck, D. & Béghin, L. 2012. Validation of the vivago wrist-worn accelerometer in the assessment of physical activity. *BMC Public Health*, 12(1):690–696. https://doi.org/10.1186/1471-2458-12-690

Vogel, T., Brechat, P.H., Leprête, P.M., Klatenbach, G., Berthel, M. & Lonsdorfer, J. 2009. Health benefits of physical activity in older patients: a review. *International Journal of Clinical Practice*, 63(2):303–320. doi:10.1111/j.1742-1241.2008.01957.x

Wanner, M., Hartman, C., Pestoni, G., Martin, B.W., Siegrist, M. & Martin-Diener, E. 2017. Validation of the Global Physical Activity Questionnaire for self-administration in a European context. *British Medical Journal Open Sport and Exercise Medicine*, 3, e000206. doi:10.1136/bmjsem-2016-000206

Warburton, D.E.R., Nicol, C.W. & Bredin, S.S.D. 2006. Health benefits of physical activity: the evidence. *Canadian Medical Association Journal*, 174(6):801–809. doi:10.1503/cmaj.051351

Warren, J.M., Ekelund, U., Besson, H., Mezzani, A., Geladas, N. & Vanhees, L. 2010. Assessment of physical activity–a review of methodologies with reference to epidemiological research: a report of the exercise physiology section of the European Association of Cardiovascular Prevention and Rehabilitation. *European Journal of Cardiovascular Prevention and Rehabilitation*, 17(2):127–139.

Wen, C.P., Wai, J.P.M., Tsai, M.K., Yang, Y.C., Cheng, T.Y.D., Lee, M., … Wu, X. 2011. Minimum amount of physical activity for reduced mortality and extended life expectancy: a prospective cohort study. *Lancet*, 378(9798):1244–1253. https://doi.org/10.1016/S0140-6736(11)60749-6

Westerterp, K.R. 1999. Obesity and physical activity. *International Journal of Obesity*, 23(1):59–64. https://doi.org/10.1038/sj.ijo.0800797

Westerterp, K.R. 2001. Pattern and intensity of physical activity. *Nature*, 410(6828):539. https://doi.org/10.1038/35069142

Westerterp, K.R. 2009. Assessment of physical activity: a critical appraisal. *European Journal of Applied Physiology*, 105(6):823–828. https://doi.org/10.1007/s00421-009-1000-2

Westerterp, K.R. 2017. Control of energy expenditure in humans. *European Journal of Clinical Nutrition*, 71(3):340–344. doi:10.1038/ejcn.2016.237

WHO (World Health Organization). 2010. *Global recommendations on physical activity for health*. http://apps.who.int/iris/bitstream/10665/44399/1/9789241599979_eng.pdf Date of access: 24 Apr. 2016.

WHO (World Health Organization). 2018a. *Physical activity.* http://www.who.int/mediacentre/factsheets/fs385/en/ Date of access: 9 Feb. 2020.

WHO (World Health Organization). 2018b. *Noncommunicable disease*. http://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases Date of access: 13 Aug. 2019.

WHO (World Health Organization). 2018c. *Noncommunicable disease (NCD) country profiles*. https://www.who.int/nmh/countries/zaf_en.pdf?ua=1 Date of access: 13 Aug. 2019.

WHO (World Health Organization). 2018d. *The global action plan on physical activity 2018–2030*. http://www.who.int/ncds/prevention/physical-activity/gappa/action-plan Date of access: 25 Jun. 2018.

WHO (World Health Organization). 2019. *Noncommunicable diseases and their risk factors*. https://www.who.int/ncds/en/ Date of access: 26 Aug. 2019.

WHO (World Health Organization). 2000. Obesity: preventing and managing the global epidemic. http://whqlibdoc.who.int/trs/WHO_TRS_894.pdf Date of access: 22 Feb. 2020.

Wipfli, B., Landers, D., Nagoshi, C. & Ringenbach, S. 2011. An examination of serotonin and psychological variables in the relationship between exercise and mental health. *Scandinavian Journal of Medicine and Science in Sports*, 21(3):474–481. doi: 10.1111/j.1600-0838.2009.01049.x

Wolin, K., Yan, Y., Colditz, G. & Lee, I.-M. 2009. Physical activity and colon cancer prevention: a meta-analysis. *British Journal of Cancer*, 100(4):611–616. https://doi.org/10.1038/sj.bjc.6604917

Yang, E.Y., Chambless, L., Sharrett, A.R., Virani, S.S., Liu, X., Tang, Z., … Nambi, V. 2011. Carotid arterial wall characteristics are associated with incident ischemic stroke but not coronary heart disease in the Atherosclerosis Risk in Communities (ARIC) Study. *Stroke*, 43(1):103–108. https://doi.org/10.1161/STROKEAHA.111.626200

Yavari, A., Javadi, M., Mirmiran, P. & Bahadoran, Z. 2015. Exercise-induced oxidative stress and dietary antioxidants. *Asian Journal of Sports Medicine*, 6(1), e24898. https://dx.doi.org/10.5812%2Fasjsm.24898

Young, S.N. 2007. How to increase serotonin in the human brain without drugs. *Journal of Psychiatry and Neuroscience*, 32(6):394–399.

Zamani Sani, S.H., Fathirezaie, Z., Brand, S., Pühse, U., Holsboer-Trachsler, E., Gerber, M. & Talepasand, S. 2016. Physical activity and self-esteem: testing direct and indirect relationships associated with psychological and physical mechanisms. *Neuropsychiatric Disease and Ttreatment*, 12:2617–2625. http://dx.doi.org/10.2147/NDT.S116811

Zieman, S.J., Melenovsky, V. & Kass, D.A. 2005. Mechanisms, pathophysiology, and therapy of arterial Stiffness. *Atherosclerosis, Thrombosis and Vascular Biology*, 25(5):932–943. https://doi.org/10.1161/01.ATV.0000160548.78317.29

CHAPTER 3:
ARTICLE 1

Relationship between physical activity and carotid intima–media thickness among teachers in South Africa: the SABPA-study

Tamrin Veldsman[1] (MSc), Mariette Swanepoel[1] (PhD), Makama Andries Monyeki[1] (PhD), Johanna Sanette Brits[2] (PhD), Leoné Malan[2] (RN, PhD)

[1]*Physical Activity, Sport and Recreation Research Focus Area (PhASRec), Faculty of Health Sciences, North-West University, Potchefstroom, South Africa*

[2]*Hypertension in Africa Research Team (HART), North-West University, Potchefstroom, South Africa*

Authors' information:

***Corresponding author:**

Ms Tamrin Veldsman (Biokinetics)*
Telephone: +27 18 299 2187
Cell phone: +27 82 577 1602
Tamrin.Veldsman@nwu.ac.za
Private Bag X6001, North-West University,
Potchefstroom, South Africa, 2531

Dr Mariette Swanepoel (Biokinetics)
Telephone: +27 18 285 2282
Cell phone: +27 73 144 2242
12262404@nwu.ac.za

Prof Makama A Monyeki
(Body composition and physical activity)
Telephone: +27 18 299 1790
Cell phone: +27 82 644 4342
Andries.Monyeki@nwu.ac.za

Prof Johanna S Brits (Physiology)
Telephone: +27 18 285 2789
Cell phone: +27 84 533 4555
10069917@nwu.ac.za

Prof Leoné Malan (Physiology)
Telephone: +27 18 299 2438
Cell phone: +27 73 376 5321
Leone.Malan@nwu.ac.za

This article is submitted to: *Cardiovascular Journal of Africa (CVJA).*

ABSTRACT

Objective: To determine the relationship between objectively measured physical activity (PA) and carotid intima–media thickness (CIMT) in South African teachers.

Methods: A cross-sectional study was conducted among 215 teachers aged 25–65 years (mean age 49.67±8.43 years) who participated in the Sympathetic Activity and Ambulatory Blood Pressure in Africans (SABPA) prospective cohort study. CIMT was measured using SonoSite Micromaxx ultrasound, and PA over seven consecutive days using the ActiHeart. Other measurements obtained included; body mass index (BMI), waist circumference (WC), 24-hour ambulatory blood pressure (AMBP), C-reactive protein (CRP) and fasting blood total cholesterol (TC). Independent t-test, analysis of variance and chi-square compared the variables studied between sex and groups. Pearson correlation coefficient determined the relationships between CIMT and PA. Statistical significance was set at $p \leq 0.05$. Data were analysed using Statistical Package for Social Sciences (SPSS) version 26.

Results: The prevalence of obesity according to body mass index (BMI) and sedentary behaviour was above 30%; hypertension 38.9% and 41.1% elevated CRP. Male teachers showed higher mean values for CIMT than female teachers (0.75±0.16 mm vs 0.66±0.12 mm; $p \leq 0.05$). In the light PA group a significant weak positive association existed between waist to height ratio and physical activity level ($r = 0.17$; $p = 0.04$). A weak inconclusive borderline negative association existed between CIMT and mean 7-day awake metabolic equivalent of task ($r = -0.19$; $p = 0.08$) in female teachers in the light PA group. Carotid intima-media thickness was moderate and inversely associated with total energy expenditure ($r = -0.31$; $p = 0.05$) in sedentary male teachers.

Conclusion: Participation in light PA was negative and weakly associated with lower CIMT values in female teachers. Given the health implications of cardiovascular disease risk among teachers, PA intervention studies are recommended to determine effective interventions to provide information on how to decrease the progression of subclinical atherosclerosis in this population.

Keywords:

Carotid intima-media thickness, physical activity, South Africa

INTRODUCTION

Undeniable evidence exists about the protective role of regular physical activity (PA) in the development of chronic diseases; [1-4] however, high levels of physical inactivity continue to be a major public health concern in the 21st century. [5] The global recommendation for adult participation in PA is at least 150 minutes of accumulated moderate-intensity activity per week for at least 10 continuous minutes. [6] One in five adults globally does not meet the PA recommendations. [7] In South Africa, more than one-third (38.2%) of the population does not participate in sufficient PA, [8] and in a 51-country survey the country was ranked as having the third-highest prevalence of physical inactivity. [9] Physical inactivity, obesity and hypertension are directly associated with the risk of developing cardiovascular disease (CVD) and atherosclerosis. [10-12]

Atherosclerosis is an active inflammatory process involving changes in cell behaviour and lipid accumulation in arteries and can be considered as one of the underlying causes of coronary heart disease events. [13-16] Additionally, C-reactive protein (CRP) as a biomarker for atherosclerosis [17] has been linked to an increase in carotid intima-media thickness (CIMT) progression. [18] Weingärtner and colleagues [19] also revealed that serum cholesterol was positively associated with CIMT among the healthcare workers at the Saarland University Hospital in Homburg/Saar, Germany. Of concern are the results of a study by Laurence and colleagues [20] in 489 teachers from Cape Town, which reported that 18.7% of the teachers was at a high risk of developing a heart attack or stroke within 10 years according to the Farmingham risk calculations.

A non-invasive sonographic measurement of atherosclerosis, CIMT, may enable the prediction of future vascular events such as stroke and myocardial infarction, [16] before they occur. Koolhaas *et al.* [21] conducted the population-based Rotterdam Study including 5344 adults, suggested that the beneficial impact of regular PA on CVD might outweigh the negative effect of high body mass index (BMI) values among middle-aged and older adults. Conversely, a study by Zulkepli *et al.* [22] using subjective measures of PA revealed no significant correlation between PA level and CVD risk factors. One study found that higher levels of moderate-to-vigorous PA was associated with lower CIMT, and participants who were sedentary had an increased CIMT. [23] A study in Caucasian men and women indicated a positive association between CIMT and time spent sedentary and a negative association with light PA, [24] while another study in Danish adolescents did not find any associations between moderate-to-vigorous PA or vigorous PA and CIMT. [25]

Teachers are considered to be in a high-stress profession, where sub-optimal facilities, lack of support, unsupportive parents, teaching evaluation and time management issues, changes in curricula, organisational policies, heavy workload, overcrowded classes, limited resources, high accountability, uncertainties over job security, low salaries, fatigue and parental expectations all contribute to the stress associated with the profession. [26-29] Due to the workload and nature of the occupation, teachers spend a lot of their time sedentary and little time at higher levels of PA. [30] The high job demands together with a lack of PA may lead to high blood pressure, heart disease, stroke, diabetes and cancer. [27,28] Cardiovascular disease and physical inactivity are among the significant causes of mortality and morbidity in both the general

population [31,32] and in teachers. [20] The environment, as well as the prevalence of increased cardiovascular disease may increase the development of atherosclerosis in teachers and may be idenitfied in the investigation of CIMT. We aimed, therefore, to investigate the relationship between objectively measured PA over seven consecutive days and CIMT among teachers in South Africa.

METHODS

Design and participants

This research formed part of the Sympathetic Activity and Ambulatory Blood Pressure in Africans (SABPA) prospective cohort study, which commenced in 2008/2009 (phase 1) and was followed up in 2011/2012 (phase 2). Phase 2 data were collected similarly to phase 1 baseline measures.[33] Given the objective of the study, a cross-sectional study design was followed using the second phase of measurement. Urban-dwelling South African school teachers residing in the Dr Kenneth Kaunda Education District (Potchefstroom and Klerksdorp), North West Province, South Africa, were recruited to participate in the SABPA-study (N=2170). The SABPA-study excluded pregnant or lactating female teachers, users of α- and *β*-blockers, psychotropic substance abusers, blood donors or people vaccinated in the last 3 months, or individuals with tympanum temperature higher than 37.5° C. Preliminary screening identified eligible participants (N=409), all of whom were well educated school teachers (aged 25–65 years) which ensured participants similar socioeconomic standing. Participants who wore the ActiHeart (GBO/67703, CamNtech Ltd., Cambridgeshire, UK) for a full 7 days or had less than 40 minutes of daily non-contact time during awake hours (N=216) in phase 2 were included. All participants provided voluntary written informed consent before participation. The SABPA-study was approved by the Health Research Ethics Committee (HREC) of the North-West University (Potchefstroom campus: NWU-0036-07-S6) and adhered to the principles outlined in the Declaration of Helsinki (2004). Permission to conduct this study was obtained from the North West Department of Education, as well as the South African Democratic Teachers Union.

Protocol

Each participant's data were collected over 8 days. During the first 2 days, 24-h ambulatory blood pressure, a given 24-h standardised diet and information on lifestyle risk factors, and cardiovascular and biochemical measures were collected. For the following 7 days, an ActiHeart recorded the participant's PA. The participants stayed over at the Metabolic Unit research facility at North-West University, where they were introduced to the experimental setup and were assigned a private bedroom. Before resuming their normal activities on day 1, the Cardiotens ambulatory blood pressure (AMBP) monitor (Meditech, Budapest, Hungary) was fitted to measure 24-h BP. Hypertension was categorised as systolic blood pressure (SBP) and diastolic blood pressure (DBP) as 130/80 mmHg. [34] On the second day of measurement, body composition and CIMT were measured. The ActiHeart was fitted to each participant and worn for seven consecutive days to measure PA. Participants' height (cm), body weight (kg) and waist circumference (WC; cm) were measured by two level two kinanthropometrists according to the International Society for the

Advancement of Kinanthropometry (ISAK). [35] Waist-to-height ratio (WHtR) of the participants was calculated as weight (kg)/height (m). Body mass index was calculated as weight (kg)/height $(m)^2$ and expressed in kg/m^2. [36] The participants BMI were classified according to the cut-off points of the American College of Sports Medicine (ACSM)[36] as follows: underweight = BMI <18.5 kg/m^2; normal weight = BMI between 18.5–24.9 kg/m^2; overweight = BMI between 25.0–29.9 kg/m^2; and obesity = BMI ≥30 kg/m^2. Intra- and inter-observer variability were less than 5%.

The participants PA was measured using a combined heart rate and accelerometer – the ActiHeart – over seven consecutive days. Participants were requested to continue with their daily activities continuously wearing the ActiHeart monitor while awake or asleep. Individual step test calibration was not performed due to the high cardiovascular risk profiles of various participants [37] and time restrictions during clinical data collection. Therefore, self-reported PA was used to programme the ActiHeart for each participant. [38] The resting heart rate of the participants was obtained from a resting 12-lead electrocardiogram (NORAV Medical Ltd PC 1200, software v5.030, Kiryat Bialik, Israel), performed under the supervision of a registered nurse, and was used to calculate the sleeping heart rate required to be entered into the ActiHeart program when the device was being fitted to each participant.

The 7-day recordings for each participant were visually assessed to distinguish between time spent awake (awake time) and time spent asleep. Heart rate, metabolic equivalent of task (METs) and activity levels were used to distinguish between time spent awake and asleep. When the heart rate gradually decreased (with a period of 15 or more epochs) in the evening to less than the average heart rate in a selected awake-time sedentary sample period, and the activity level was equal to zero, the participant was considered to be sleeping. The end of sleeping time could clearly be seen by an immediate increase in heart rate of more than 10–20 beats per minute, as well as increased METs and increased activity level. The ActiHeart software was used to derive daily time spent in various MET categories according to activity energy expenditure (AEE). The derived daily time spent in multiple MET categories was grouped according to daily awake time being sedentary (≤1.5 METs) and time participating in light-intensity PA (1.5–3 METs). [39] Activity energy expenditure, total energy expenditure (TEE) and PA level (PAL) were also determined by the ActiHeart using inbuilt equations based on a branched model approach, calculated based on the combination of heart rate and accelerometer. [40] The participants PAL was calculated as TEE/resting energy expenditure (REE). [41] Ultimately, after the data were analysed, participants were allocated to one of two PA groups for analysis purposes, sedentary (≤1.5 METs) or light-intensity PA (1.5–3 METs), depending on their total activity levels. Only one participant was classified as moderate-to-high PA (>3 METs) and based on statistical power principles this individual was excluded from the statistical analyses.

Subclinical atherosclerosis

High-resolution ultrasound CIMT scans were used to determine structural changes or subclinical atherosclerosis. Carotid intima-media thickness images from two ideal angles of the left and right common

carotid artery segments were captured using a SonoSite Micromaxx ultrasound system (SonoSite Inc., Bothell, WA, USA) and a 6–13 MHz linear display transducer, using previously described protocols. [14] Images were digitised and imported to Artery Measurement Systems automated software (AMS, Gothenburg, Sweden, v1.130) for analysing CIMT. [42-43] A maximal 10-cm segment with good quality imaging was used for analysis. The program automatically detects the borders of the intima-media of the near and far wall, as well as the inner diameter of the vessel, and calculates CIMT. For this study, the far wall left CIMT measurements were used. Intra-observer variability was 0.04 mm between two measurements taken 4 weeks apart on the same 10 participants. CIMT of >0.9 mm was regarded as subclinical atherosclerosis. [44] The images were also examined for the presence of plaque at the right and left bifurcation of the internal carotid artery. Plaque was defined as a focal structure encroaching into the arterial lumen by at least 0.5 mm or by 50% of the surrounding intima-media thickness (IMT) or demonstrating a thickness >1.5 mm. [14]

Biochemical analysis

A registered nurse obtained fasting resting blood samples with a winged infusion set from the brachial vein branches of the dominant arm, handled according to standardised methods and stored at -80˚C until analyses. Serum high sensitive C-reactive protein (CRP) were analysed with a timed, end-point method (UniCel® DxC 800, Beckman and Coulter, Germany). Inter-and intra-variability was less than 5 %. A CRP value greater or equal to 3 mg/L is regarded as high risk for CVD. [45] Serum cholesterol blood sample analysis was done using the Konelab™ 20i (Thermo Scientific, Vantaa, Finland).

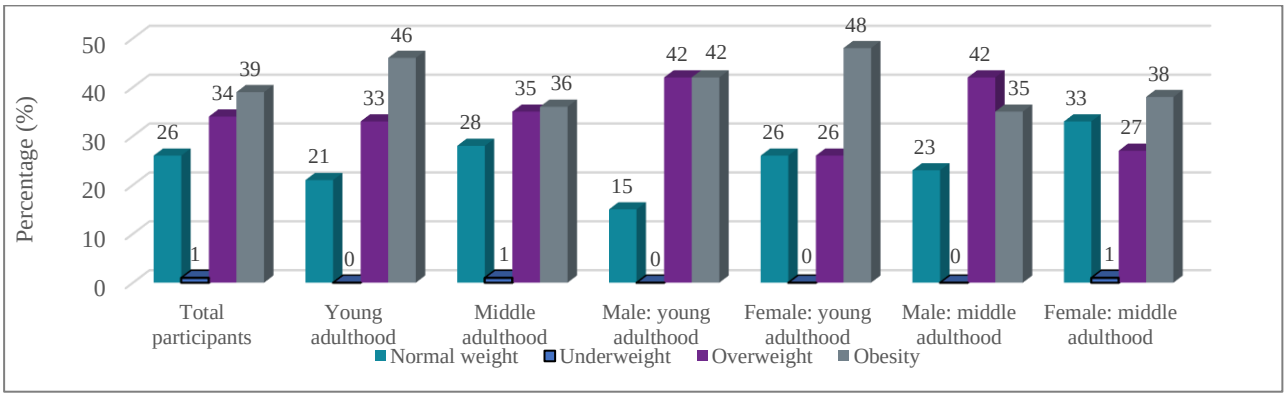
Statistical analysis

Statistical analyses were performed on the data of the 215 participants using SPSS v.26 (Inc., Chicago, IL, USA). Normality of the data was done using the Shapiro-Wilk test and Quantile-Quantile plots. Independent *t*-test and analysis of variance (ANOVA) were used to determine sex and group differences. Additionally, chi-square was used to compare proportions. Analyses for the entire group and specific age groups were also done in BMI categories. The age groups were determined according to the guidelines suggested by Statistics: Provisional Guidelines on Standard International Age Classification of 1982 [46] with age 25–44 years representing 'young adulthood', and 45–64 years representing 'adulthood' (further referred to as 'middle adulthood'). Analyses were done according to the two PA categories of sedentary (≤1.5 METs) and light-intensity PA (1.5–3 METs) for CIMT, blood pressure, CRP and anthropometric variables. Pearson correlation coefficient (*rho* [*r*]) was used to assess the relationship between CIMT and objectively measured PA. Partial correlations followed to determine: 1) the relationship between CIMT, mean 7-day awake METs, AEE, TEE and PAL for both the sedentary and light PA groups, considering the confounders age, sex, BMI and WC; and 2) associations between CIMT, mean 7-day awake METs, AEE, TEE and PAL for sedentary and light PA groups in separate male and female groups controlling for age group, serum cholesterol, AMBP 24 hours blood pressure, CRP and WC. Correlation coefficient values were classified

as follow; <0.10 indicates a weak correlation and values of 0.30 – <0.5 indicates a moderate correlation and ≥ 0.50 indicates a strong correlation.[47] The statistical significance was set at $p \leq 0.05$.

RESULTS

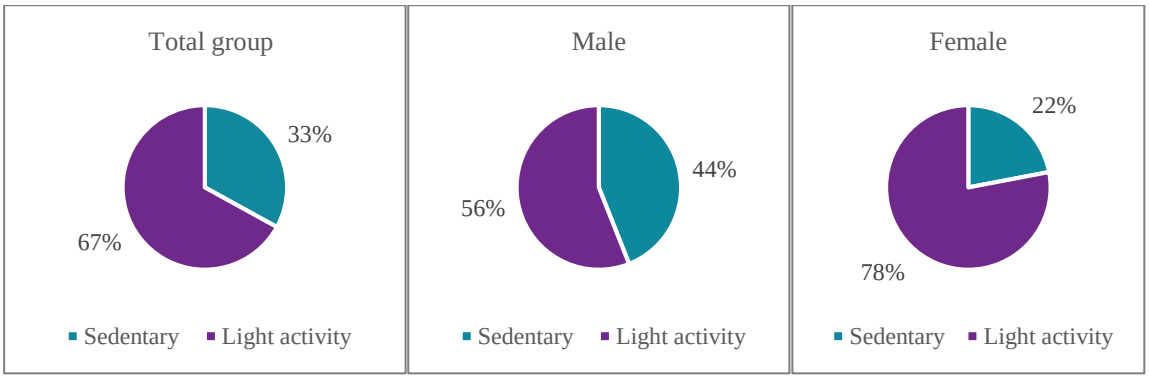
The participants were classified according to age groups consisting of young adulthood (25–44 years) and middle adulthood (45–64 years). Figure 1 indicates that the prevalence of overweight (34%) and obesity (39%) was high among the entire group of teachers, especially obesity in the young adult group (46%). Almost half of the young adult female teachers (48%) were obese.



Young adulthood = 25–44 years, middle adulthood = 45–64 years; normal weight = 18.5–24.9 kg/m^2, underweight = ≤18.5 kg/m^2, overweight 25–29.9 kg/m^2, obesity = ≥30 kg/m^2

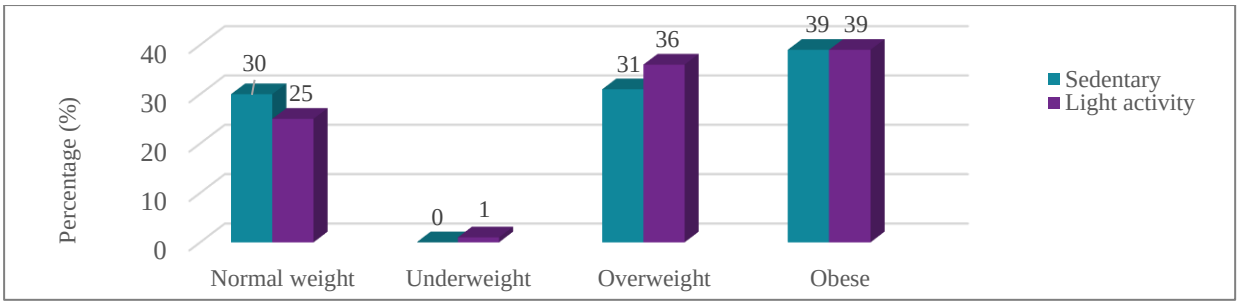
Figure 1: Percentage of total participants according to body mass index categories, age group and sex/age group combined

The PA classification, according to the mean 7-day awake METs showed that 67% and 33% of the total participants were respectively classified in the sedentary and light physically active categories (Fig. 2). Figure 3 shows that 39% of the participants that were grouped in the sedentary classification were obese, and 31% were overweight. Therefore, more than two-thirds of the sedentary participants were overweight/obese. In the light PA classification, 36% of the participants were overweight and 39% obese.



Time spent sedentary = <1.5 METs; light-intensity physical activity (PA) = 1.5–3 METs

Figure 2: Activity classification for the entire group and male and female according to mean 7-day awake metabolic equivalents of task



Normal weight = 18.5–24.9 kg/m^2; underweight = ≤18.5 kg/m^2; overweight 25–29.9 kg/m^2; obesity = ≥30 kg/m^2. Sedentary = ≤1.5 METs; light physical activity = 1.5–3 METs

Figure 3: Percentage of participants in body mass index categories according to physical activity classification

In the analysis of CIMT in the two age groups (Table 1), a significantly higher CIMT was found for the middle adulthood group compared with the young adult group (0.73±0.14 vs 0.64±0.16 mm; $p < 0.001$). For the total group, male teachers had a significantly higher mean CIMT compared to female teachers ($t = 4.971$; $df = 193.82$; $p < 0.05$). When male teachers and female teachers were divided into young and middle adulthood groups, the middle adulthood group showed a significantly higher mean CIMT ($t = -3.614$; $df = 87.309$; $p = 0.001$). Similarly, the young and middle adulthood male teachers presented with significantly higher mean CIMT ($t = 3.330$; $df = 40.33$; $p = 0.002$) compared with the young and middle adulthood females ($t = 3.702$; $df = 143.21$; $p < 0.05$).

In the analysis of CIMT according to sex in the two age groups (Table 1), a significantly higher CIMT ($t = 4.616$; $df = 54.81$; $p < 0.001$) was found in the middle adulthood female teachers (0.69±0.11 mm) compared with the young adult female teachers (0.58±0.11 mm).

Table 1: Differences in carotid intima-media thickness between young and middle adulthood and male and female teachers

	Group (N=215)	n	Mean±SD	*t*	*df*	*p*-value
CIMT (mm)	Male	104	0.74±0.16	4.930	193.82	<0.001*
	Female	111	0.66±0.12			
	Young adult (total group)	57	0.64±0.16	-3.614	87.309	0.001*
	Middle adult (total group)	158	0.73±0.14			
	Young adult males	26	0.71±0.18	3.330	40.33	0.002*
	Young adult females	31	0.58±0.11			
	Middle adult males	78	0.77±0.15	3.702	143.21	<0.001*
	Middle adult females	80	0.69±0.11			
Female	**Age group**					
CIMT (mm)	Young adulthood	31	0.58±0.11	-4.616	54.81	<0.001*
	Middle adulthood	80	0.69±011			
Males						
CIMT (mm)	Young adulthood	26	0.71±0.18	-1.335	37.09	0.19
	Middle adulthood	78	0.77±0.15			

Young adulthood = 25–44 years; middle adulthood = 45–64 years.
CIMT = Carotid intima-media thickness; *df* = degree of freedom; SD = standard deviation; *t* = t-test of the equality means.
*Level of significance was set at p ≤ 0.05.

Out of 216 participants (Table 2), 38.9% were hypertensive, more middle-aged adults were hypertensive (39.6%) than young adults (36.8%). Participants who were sedentary (53.5%) had a higher incidence of hypertension compared with the ones who participated in light physical activity (31.7%). The results also show that 41.1% of the participants had an increased CRP values with higher percentage scores in the sedentary groups.

Table 2: Percentage scores and chi-square *p*-values for hypertension and CRP for the total group and according to PA and age group categories

	Hypertensive n(%)	**Normotensive n(%)**	**Chi-square**	***p*-value**
Total group (N=216)	84(38.9)	132(61.1)	10.667	0.001*
Young adults (n=57)	21(36.8)	36(63.2)	3.947	0.05*
Middle adults (n=159)	63(39.6)	96(60.4)	6.849	0.01*
Sedentary (n=71)	38(53.5)	33(46.5)	0.352	0.55
Light PA (n=145)	46(31.7)	99(68.3)	19.372	<0.001*
Sedentary males (n=46)	30(65.2)	16(34.8)	4.261	0.04*
Sedentary females (n=25)	8(32.0)	17(68.0)	3.240	0.07
Light PA males (n=58)	28(48.3)	30(51.7)	0.069	0.80
Light PA females (n=87)	18(20.7)	69(79.3)	28.897	<0.001*
	Increased CRP	**No risk CRP**	**Chi-square**	***p*-value**
Total group (n=214)	88(41.1)	126(58.9)	6.748	0.01*
Young adults (n=56)	30(53.6)	26(46.4)	0.286	0.59
Middle adults (n=158)	58(36.7)	100(63.3)	11.165	0.001*
Sedentary (n=71)	34(47.9)	37(52.1)	0.127	0.72
Light PA (n=143)	54(37.8)	89(62.2)	8.566	0.003*
Sedentary males (n=46)	22(48.0)	24(52.0)	0.087	0.77
Sedentary females (n=25)	12(48.0)	13(52.0)	0.040	0.84
Light PA males (n=58)	14(24.0)	44(76.0)	15.517	<0.001*
Light PA females (n=87)	40(47.0)	45(53.0)	0.294	0.59

Sedentary = <1.5METs; Light physical activity (PA) =10.5–3 METs
* Level of significance was set at $p \leq 0.05$

The characteristics of the participants based on their PA status are presented in Table 3. AEE, TEE, mean 7-day awake METs and PAL differed significantly ($p < 0.001$). Sedentary participants had an inconclusive borderline significant ($p = 0.06$) larger WC (99.32±17.90 cm) than participants in the light PA group (94.97±17.71 cm). Sedentary participants had significantly higher ambulatory systolic blood pressure (SBP) ($p = 0.02$) and diastolic blood pressure (DBP) ($p = 0.001$) than those who participated in light PA. No significant CIMT differences ($p = 0.13$) and WHtR ($p = 0.73$) was observed between the sedentary and light PA groups.

Table 3: Descriptive statistics of the total group of participants according to physical activity categories and *p*-value for between groups

	Activity classification	n	Mean±SD	*p*-value
Age (years)	Sedentary	71	48.73±9.32	0.26
	Light PA	145	50.12±7.96	
Height (cm)	Sedentary	71	170.04±10.32	0.36
	Light PA	145	168.67±10.12	
Weight (kg)	Sedentary	71	85.96±21.94	0.26
	Light PA	145	82.52±18.36	
BMI (kg/m^2)	Sedentary	71	29.58±6.89	0.74
	Light PA	145	29.26±6.30	
WC (cm)	Sedentary	71	99.32±17.90	0.08[#]
	Light PA	145	94.97±14.71	
WHtR	Sedentary	71	0.58±0.10	0.13
	Light PA	145	0.56±0.09	
Total cholesterol (mmol/L)	Sedentary	71	4.59±1.13	0.20
	Light PA	144	4.39±0.97	
CRP (mg/dl)	Sedentary	71	4.87±6.29	0.16
	Light PA	143	3.69±4.34	
AMBP SBP (mmHg)	Sedentary	71	135.04±19.43	0.02[*]
	Light PA	145	126.62±15.68	
AMBP DP (mmHg)	Sedentary	71	83.48±11.24	0.001[*]
	Light PA	145	78.07±10.18	
CIMT (mm)	Sedentary	70	0.70±0.17	0.74
	Light PA	145	0.71±0.14	
Mean 7-day awake METs	Sedentary	71	1.32±0.10	<0.001[*]
	Light PA	145	2.28±0.62	
AEE (kcal/wk)	Sedentary	71	796.85±722.17	<0.001[*]
	Light PA	145	1476.97±1124.39	
TEE (kcal/wk)	Sedentary	71	2814.87±843.07	<0.001[*]
	Light PA	145	3482.10±1478.56	
PAL	Sedentary	71	1.49±0.14	<0.001[*]
	Light PA	145	2.34±0.62	

AEE = Activity energy expenditure; AMBP SBP = ambulatory systolic blood pressure; AMBP DBP = ambulatory diastolic blood pressure BMI = body mass index; CIMT = carotid intima-media thickness; CRP = C-reactive protein Light PA = light physical activity (1.5–3 METs); METs = metabolic equivalent of task; Sedentary = time spent sedentary (<1.5 METs); TEE = total energy expenditure; PAL= physical activity level; WC = waist circumference; WHtR = waist-to-height ratio.
*Level of significance was set at $p \leq 0.05$.
[#] Borderline significance

Analysis of differences among PA groups (Table 4) in male teachers indicated a significant difference in PA status and AEE ($p < 0.001$), TEE ($p < 0.001$), mean 7-day awake METs ($p < 0.001$) and PAL ($p < 0.001$). Sedentary male teachers had significantly higher CRP values ($p = 0.01$), ambulatory SBP ($p = 0.01$) and ambulatory DBP ($p = 0.02$) than males who participated in light PA. Among female teachers, there was a significant difference in CIMT ($p = 0.01$) between the sedentary and light physically active groups.

Table 4: Differences in the characteristics of the participants according to physical activity categories

	Sex	Males			Females		
		n	Mean±SD	*p*-value	n	Mean±SD	*p*-value
Age (years)	Sedentary	46	49.22±9.57	0.55	25	47.84±8.98	0.28
	Light PA	58	50.24±7.57		87	50.05±8.26	
Height (cm)	Sedentary	46	175.01±8.69	0.07	25	160.90±5.90	0.25
	Light PA	58	177.95±7.02		87	162.49±6.48	
Weight (kg)	Sedentary	46	90.60±18.82	0.93	25	77.42±24.95	0.93
	Light PA	58	90.88±14.60		87	76.95±18.56	
BMI (kg/m^2)	Sedentary	46	29.43±5.52	0.50	25	29.85±9.01	0.89
	Light PA	58	28.77±4.11		87	29.58±7.42	
WHtR	Sedentary	46	0.59±0.08	0.12	25	0.57±0.13	0.73
	Light PA	58	0.57±0.06		87	0.56±0.10	
WC (cm)	Sedentary	46	103.42±14.52	0.37	25	91.78±21.17	0.84
	Light PA	58	101.09±11.26		87	90.88±15.37	
TC (mmol/L)	Sedentary	46	4.72±1.15	0.10	25	4.36±1.08	0.83
	Light PA	58	4.38±0.84		87	4.41±1.04	
CRP (mg/dL)	Sedentary	46	5.25±7.03	0.01*	25	4.18±4.72	0.62
	Light PA	58	2.17±2.36		85	4.72±5.04	
AMBP SBP (mmHg)	Sedentary	46	138.91±17.94	0.01*	25	127.92±20.39	0.42
	Light PA	58	130.22±11.99		87	124.22±17.38	
AMBP DBP (mmHg)	Sedentary	46	86.15±9.90	0.02*	25	78.56±12.09	0.27
	Light PA	58	81.81±8.74		87	75.57±10.36	
CIMT (mm)	Sedentary	46	0.75±0.16	0.99	25	0.59±0.12	0.01*
	Light PA	58	0.75±0.16		87	0.68±0.12	
AEE (kcal/wk)	Sedentary	46	808.39±752.47	<0.001*	25	775.62±677.33	0.01*
	Light PA	58	1839.40±1439.69		87	1235.34±771.65	
TEE (kcal/wk)	Sedentary	46	2952.07± 810.30	<0.001*	25	2562.43±859.94	0.01*
	Light PA	58	4032.46±1722.01		87	3115.20±1163.92	
Mean 7-day awake METs	Sedentary	46	1.29±0.10	<0.001*	25	1.36±0.09	<0.001*
	Light PA	58	2.43±0.79		87	2.17±0.47	
PAL	Sedentary	46	1.46±0.13	<0.001*	25	1.55±0.14	<0.001*
	Light PA	58	2.47±0.76		87	2.25±0.49	

AEE = activity energy expenditure; AMBP SBP = ambulatory systolic blood pressure; AMBP DBP = ambulatory diastolic blood pressure; BMI = body mass index; CIMT = carotid intima-media thickness; CRP = C-reactive protein; METs = metabolic equivalent of task; PAL= physical activity level; TC = total cholesterol; TEE = total energy expenditure; WC = waist circumference; WHtR = waist-to-height ratio.
*Level of significance was set at $p \leq 0.05$.

The value of correlation matrix *rho* indicated that within the sedentary group (Table 5), there was a moderate significant inverse relationship between CIMT and PAL (r = -0.30; p = 0.01). In the light PA group, weak significant positive relationships between WC and CIMT (r = 0.19; p = 0.02); TEE (r = 0.24; $p < 0.001$); and PAL (r = 0.19; p = 0.02) were found. When a partial correlation was performed to control for age group, sex, serum cholesterol, AMBP 24 hours blood pressure, CRP and WC, a moderate significant inverse relationship was found between CIMT and TEE (r = -0.31; p = 0.05), and a weak inconclusive borderline inverse relationship was found between CIMT and AEE (r = -0.28; p = 0.07) in sedentary male teachers (Table 6). Furthermore, a weak inconclusive borderline significant relationship was found between CIMT and mean 7-day METs (r = -0.19; p = 0.08), controlled for age, sex, serum cholesterol, AMBP 24 hours blood pressure and WC. When CRP was added amongst the controlled variables, the inconclusive

borderline significant correlation diminished, as such, CRP was excluded in the analyses. No significant relationships were observed between CIMT and PA for female teachers in the sedentary group.

Table 5: Correlations matrix *rho* (*r)* for anthropometric measurements, AEE and CIMT by activity groups

		Sedentary group				Light physical activity group			
		CIMT (mm)	**BMI (kg/m^2)**	**WC (cm)**	**WHtR**	**CIMT (mm)**	**BMI (kg/m^2)**	**WC (cm)**	**WHtR**
CIMT (mm)	*r*	_	-0.05	0.14	0.05	–	0.09	0.19*	0.12
	p	–	0.66	0.25	0.70	–	0.27	0.02	0.14
AEE (kcal/wk)	*r*	-0.17	0.02	-0.02	0.04	0.11	-0.01	0.10	-0.05
	p	0.15	0.86	0.86	0.75	0.20	0.88	0.24	0.54
Mean 7-day awake METs	*r*	-0.20	0.07	-0.06	0.01	-0.02	0.05	0.12	0.04
	p	0.11	0.57	0.64	0.93	0.81	0.58	0.16	0.66
TEE (kcal/wk)	*r*	-0.05	0.14	0.18	0.14	0.15	0.10	0.24**	0.06
	p	0.66	0.23	0.13	0.24	0.08	0.25	<0.001	0.45
PAL	*r*	-0.30*	0.13	-0.02	0.14	-0.001	0.20*	0.19*	0.17*
	p	0.01	0.30	0.89	0.24	0.99	0.02	0.02	0.04

AEE = Activity energy expenditure; BMI = body mass index; CIMT = carotid intima-media thickness; METs = metabolic equivalent of task; TEE = total energy expenditure; PAL = physical activity level; WC= waist circumference; WHtR = Waist-to-height ratio

* Level of significance is set at $p \leq 0.05$.

** Level of significance is set at $p \leq 0.001$

Table 6: Partial correlation coefficient (*r*) for the relationship between CIMT and PA, controlled for age group, waist circumference, CRP, 24-h SBP and cholesterol

		Sedentary									
		Males (n=41)					Females (n=19)				
		Mean 7-day awake METs	AEE (kcal/wk)	TEE (kcal/wk)	PAL 7 days	CIMT (mm)	Mean 7-day awake METs	AEE (kcal/wk)	TEE (kcal/wk)	PAL 7-day	CIMT (mm)
Mean 7-day awake METs	*r*	–	0.06	0.09	0.64	0.09	–	0.43	0.37	0.80	0.21
	p	–	0.68	0.55	<0.001*	0.58	–	0.05*	0.10	<0.001*	0.35
AEE (kcal/wk)	*r*	0.06	–	0.95	0.40	-0.28	0.43	–	0.97	0.55	0.18
	p	0.68	–	<0.001*	0.01*	0.07#	0.05*	–	<0.001*	0.01*	0.44
TEE (kcal/wk)	*r*	0.09	0.95	–	0.28	-0.31	0.37	0.97	–	0.53	0.16
	p	0.55	<0.001*	–	0.06#	0.05*	0.10	<0.001*	–	0.01*	0.48
PAL 7-day	*r*	0.64	0.39	0.28	–	-0.08	0.80	0.55	0.53	–	0.09
	p	<0.001*	0.01*	0.06#	–	0.59	<0.001*	0.01*	0.01*	–	0.71
CIMT (mm)	*r*	0.09	-0.28	-0.31	-0.08	–	0.21	0.18	0.16	0.09	–
	p	0.58	0.07#	0.05*	0.59	–	0.35	0.44	0.48	0.71	–
		Light PA									
		Males (n=53)					**Females (n=82)**				
Mean 7-day awake METs	*r*	–	0.66	0.64	0.95	0.02	–	0.50	0.37	0.88	-0.19
	p	–	<0.001*	<0.001*	<0.001*	0.90	–	<0.001*	<0.001*	<0.001*	0.08#
AEE (kcal/wk)	*r*	0.66	–	0.99	0.54	0.10	0.50		0.92	0.45	-0.03
	p	<0.001*	–	<0.001*	<0.001*	0.44	<0.001*	–	<0.001*	<0.001*	0.75
TEE (kcal/wk)	*r*	0.64	0.99	–	0.50	0.12	0.37	0.92	–	0.38	-0.001
	p	<0.001*	<0.001*	–	<0.001*	0.38	<0.001*	<0.001*	–	<0.001*	0.99
PAL 7-day	*r*	0.95	0.54	0.50	–	0.002	0.88	0.45	0.38	–	-0.16
	p	<0.001*	<0.001*	<0.001*	–	0.99	<0.001*	<0.001*	<0.001*	–	0.14
CIMT (mm)	*r*	0.08	0.10	0.12	0.01	–	-0.19	-0.03	-0.001	-0.16	–
	p	0.90	0.44	0.38	0.99	–	0.08#	0.75	0.99	0.14	–

Sedentary = ≤1.5 METs; light physical activity (PA) = 1.5–3 METs.

AEE = activity energy expenditure; CIMT = carotid intima-media thickness; CRP = c-reactive protein; METs = Metabolic equivalent of task; PAL= physical activity level; SBP; systolic blood pressure; TEE = total energy expenditure * Level of significance was set at $p \leq 0.05$; # = borderline significance.

DISCUSSION

This study aimed to investigate the relationship between objectively measured PA and CIMT among teachers in South Africa. A weak inconclusive borderline negative association between CIMT and mean 7-day awake METs in female teachers in the light PA group was found. The weak observed relationship between PA and CIMT was also observed in a somewhat similar study. [48]

Physical activity was measured using a combined accelerometer and heart rate monitor, the ActiHeart. One of the main observations of the study was the high level of sedentary behaviour in adults, which is in agreement with other studies. [8-9,49] The participants' occupation might explain the high percentage of teachers being classified as physically inactive or lightly physically active, as most of their working time is spent either standing, sitting or slowly walking, which are all forms of sedentary or light energy-cost activity. [39] Physical inactivity may lead to the development of cardiovascular disease risk factors, such as overweight and obesity, [50] and this was evident in the present study. The observed high prevalence of overweight and obesity found in this sample of teachers is consistent with the statistics for South Africa noted in the World Health Organization's 2017 Overweight and Obesity report. [51]

The inverse relationship between CIMT and PA in the sedentary group of teachers is similar to the study of Parsons *et al.* [23] found in older males (age 78 years), and the study of Gomez-Marcos *et al*. [52] in healthy adults (56 years). The potential beneficial effect of PA and therefore increased energy expenditure on lowering subclinical atherosclerosis levels is apparent. [12] Contrastingly, Ascenso *et al.* [53] indicated that the effect of PA was not observed in sedentary obese adolescents but was present in individuals who were classed as lightly physically active. Conflicting results from Kozàkovà *et al.* [24] indicated a significant positive relationship with a sedentary/light PA ratio and CIMT in a healthy adult population (44 years).

The relationship between CIMT and PA has not been well established; different studies have reported controversial results about the relationship between CIMT and PA. This controversy may be explained by several influential factors in the relationship, such as age, sex, previous disease, measurement instruments and methods, and PA intensity. [52] Huynh *et al.* [54] indicated that sedentary behaviour and low levels of PA were not associated with carotid dispensability. However, in a systematic review, Kadoglou and colleagues [55] suggested that although the influence of PA on CIMT was inconsistent among healthy individuals, physical inactivity was associated with an increased CIMT. The association between PAL and CIMT in our cohort may be significant due to the levels of TEE and REE in the equation, taking into account not only the energy expenditure due to activity-induced energy expenditure (AEE) and the TEE but also the REE. We can speculate that the observed prevalence of overweight and obesity might be a contributor to the lack of a significant relationship between AEE and CIMT, in the sense that obese individuals' average daily metabolic rate, not non-basal energy expenditure, is positively related to body size. [56]

Westerterp [56] stated that AEE is the energy expenditure associated with muscular contractions involved in performing body postures and movements. We may assume that our study participants with mean BMIs

almost equal to 30kg/m^2 regardless of their PA levels might have struggled to achieve a 5- to 20-fold increase in metabolic rate compared with non-obese individuals. [57] Westerterp [56] argued that the ratio of energy cost for low:moderate:high-intensity activity is 1:2:4, and the contribution of high-intensity activity to AEE is about 25%. Most teachers move around or walk when teaching sessions take place, [58] but this might not be enough to reach an AEE equal to or above 25%. Unfortunately, in our study only one participant (0.9%), who was not included in the analyses, participated at moderate-to-high intensity, and that could also be a reason for not finding a significant relationship between AEE and CIMT. It should also be noted that sedentary behaviour that is measured at one time point to capture a participant's typical weekly PA might have contributed to the observed associations. [59]

The mean WC values for male and female teachers in our study were greater than the measurements classified as at risk of disease according to the ACSM (males ≥102 cm; females ≥88cm). [36] The non-significant relationship between CIMT and WC in this study is congruent with the findings of one study conducted in apparently healthy adults. [21] Contradictory evidence from Ascenso *et al.* [53] indicates no correlation between sedentary time and WC; however, their study was conducted in obese adolescents, which may explain the reason for the disparity. Though inconclusive, it was evident that a teacher with a high waist circumference was likely to have elevated CIMT.

In our study, we also found significant sex differences in CIMT, with male teachers in both the sedentary and light physically active groups having higher CIMT than female teachers. This can be explained by risk factor classification, with males at higher risk of developing CVD at an earlier age. [36] The results can be affirmed by similar studies in youth populations, Ried-Larsen *et al.* [60] also found significantly higher CIMT in Danish boys than in girls. Furthermore, Ascenso *et al.* [53] stated similar sex differences in CIMT; however, the results were not significant. This result was similar to Jain *et al.*, [61] who found that males had a significantly higher burden of subclinical disease, measured by non-invasive imaging.

An unexplained moderate significant negative relationship observed in our study between CIMT and TEE was also shown by Walker *et al.* [59] in males who were classified in a sedentary group. The findings might in part be explained by the 56% of participants classified as light PA who presented with overweight and obesity in our study. This finding was inconsistent with findings in obese children and adolescents in other studies; however, they did not focus on adults or teachers and revealed insignificant correlations between sedentary behaviour and CIMT. However, light PA was positively correlated with CIMT. [53] In a study by Kozàkovà *et al.* [24] among Caucasian males and females, a positive association existed between CIMT and time spent sedentary whereas an inverse relationship was found between light PA and CIMT. Conversely, Ried-Larsen and colleagues, [25] studying Danish adolescents, reported no associations between CIMT and moderate-to-vigorous PA or vigorous PA. Studies in British adults and young Indian adults have reported inverse associations between CIMT and PA; [23, 62] while Ebrahim *et al.* [63] reported no relationship in British adults. Inconsistent findings were most likely due to considerable variation in PA measurement protocols and variability of the study populations, using arbitrary cut-offs. [55,59]

In our study, male teachers had higher AEE, mean 7-day awake METs and PAL than female teachers in the sedentary group as well as higher TEE than females in the light physically active group. The results are comparable to those of Guthold and colleagues, [9] who reported a higher prevalence of physical inactivity among South African females compared with males. Additionally, the participants in the current study presented with a high prevalence of hypertension (>30%) and CRP. The observed hypertension among the teachers is similar to the previous findings in South Africa [64], and most recently to a study by Muluvhu and colleagues [65] which reported a 25% prevalence of hypertension among employees of Vhembe district municipality, Limpopo province. Hypertension in the current study was positively correlated with CRP ($r = 0.27$, $p < 0.001$), and the correlation was relatively strong ($r = 0.30$, $p = 0.01$) in sedentary group compared with those participating in light physical activity ($r = 0.22$; $p = 0.009$). The observed positive relationship between hypertension and CRP are congruent with a US Adults study from 1999 to 2010. [66]

Although our study provides valuable information, it is not without limitations. The cross-sectional design limited data collection to one point in time; future longitudinal studies will need to investigate the progression of CIMT over time. The sample size was relatively small and consisted only of teachers in North West Province, and this was not a representative of teachers in South Africa at large. Individual calibrations of the ActiHeart were not performed for each participant but should be part of a future standard protocol. The South African climate in terms of heat and humidity may have influenced the accuracy of the ActiHeart. Additionally, clear PA cut-off points that are population and country specific would have clarified some of the observed relationships between CIMT and PA.

The main strengths of the study were that CIMT and PA were objectively measured in an urban South African context. Habitual PA for awake time (over 17 hours) was measured, and only participants who wore the ActiHeart for the full 7 days were included in the analysis. Furthermore, adding to the uniqueness of the study was that the analysis was conducted within a South African context, among teachers. The inclusion of CRP and ambulatory bloodpressure in the analysis of the participants risk factors contribute to the strengths of this study.

CONCLUSION

In conclusion, both male and female teachers in the study were overweight/obese, hypertensive, had increased CRP values and were physically inactive. Male teachers presented with greater CIMT than female teachers, a significant concern given the consequences of elevated CIMT. In the overweight/obese teachers classified as sedentary, PAL was limited in the benefits of lowering CIMT. However, female teachers who participated in light activity revealed an inconclusive borderline weak negative association between CIMT and mean 7-day METs. As such, light participation in physical activity though inconclusive may be helpful in guarding against the development of an increased CIMT. Given the health implications of these findings, in particular the risk of CVD among teachers, critical strategic PA intervention studies are recommended.

ACKNOWLEDGEMENTS AND SOURCES OF FUNDING

The authors acknowledge the assistance of all members of the SAPBA research team. The SABPA-study is funded by HART (North-West University); the North West Education Department; the Medical Research Council (MRC) of South Africa; the National Research Foundation (NRF) of South Africa; Roche Diagnostics, South Africa; and the Metabolic Syndrome Institute, France. The funding institutions played no role in the design and implementation of the study; collection, management, analysis and interpretation of the data; or preparation of the manuscript. The views expressed in this article are those of the authors and not necessarily those of the funding bodies.

DISCLAIMER

Any opinions, findings and conclusions or recommendations expressed in this material are those of the author, and therefore the NRF and MRC do not accept any liability in this regard.

REFERENCES

1. Blair SN, Morris JN. Healthy hearts and the universal benefits of being physically active: physical activity and health. Ann Epidemiol 2009; 19(4): 253–256. DOI:10.1016/j.annepidem.2009.01.019
2. Vogel T, Brechat PH, Leprêtre PM, Kaltenbach G, Berthel M, Lonsdorfer J. Health benefits of physical activity in older patients: A review. Int J Clin Pract 2009; 63(2): 303–320. DOI:10.1111/j.1742-1241.2008.01957.x
3. Lyden K, Kozey SL, Staudenmeyer JW, Freedson PS. A comprehensive evaluation of commonly used accelerometer energy expenditure and MET prediction equations. Eur J Appl Physiol 2011(2); 111: 187–201. DOI:10.1007/s00421-010-1639-8
4. Guthold R, Stevens GA, Riley LM, Bull FC. Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1.9 million participants. Lancet Glob Health 2018; 6(10): 1077–1086. http://dx.doi.org/10.1016/ S2214-109X(18)30357-7
5. Blair SN. Physical inactivity: the biggest public health problem of the 21st century. Br J Sports Med 2009; 43(1): 1–2.
6. World Health Organization. Global recommendations on physical activity for health. Geneva; 2010. Available from: [https://apps.who.int/iris/bitstream/handle/10665/44399/9789241599979_eng.pdf;jsessionid=04C423D4CAE804D52D889A6E370BA2ED?sequence=1]. Accessed 16 July 2019
7. Dumith SC, Hallal PC, Reis RS, Kohl HW. Worldwide prevalence of physical inactivity and its association with human development index in 76 countries. Prev Med 2011(1–2); 53: 24–28. http://dx.doi.org/10.1016/j.ypmed.2011.02.017
8. World Health Organization. Prevalence of insufficient physical activity among adults. Geneva; 2018. Available from [http://apps.who.int/gho/data/view.main.2463?lang=en]. Accessed on 16 July 2019.
9. Guthold R, Ono T, Strong KL, Chatterji S, Morabia A. Worldwide variability in physical inactivity. A 51-country survey. Am J Prev Med 2008; 34(6): 486–494. DOI:10.1016/j.amepre.2008.02.013
10. Kotsis VT, Stabouli SV, Papamichael CM, Zakopoulos NA. Impact of obesity in intima media thickness of carotid arteries. Obesity 2006; 14(10): 1708–1715.
11. Arsenault BR, Rana J, Lemieux I, Després J, Kastelein J, Boekholdt S, Wareham N, et al. Physical inactivity, abdominal obesity and risk of coronary heart disease in apparently healthy men and women. Int J of Obes 2010; 34(2): 340–347.
12. Andersson C, Lyass A, Larson MG, Spartano NL, Vita JA, Benjamin EJ, et al. Physical activity measured by accelerometry and its associations with cardiac structure and vascular function in young and middle-aged adults. J Am Heart Assoc 2015; 4(3): 1–11. DOI:10.1161/JAHA.114.001528
13. Hansson GK, Libby P. The immune response in atherosclerosis: A double-edged sword. Nat Rev

Immunol 2006; 6(7): 508–519. DOI:10.1038/nri1882

14. Touboul P-J, Hennerici MG, Meairs S, Adams H, Amarenco P, Bornstein N, et al. Mannheim Carotid Intima-Media Thickness Consensus (2004–2006). Cerebrovasc Dis 2007; 23(1): 75–80. DOI:10.1159/000097034
15. Alsheikh-Ali AA, Kitsios GD, Balk EM, Lau J, Ip S. The vulnerable atherosclerotic plaque: scope of the literature. Ann Intern Med 2010; 153(6): 387–395.
16. Van Den Oord SCH, Sijbrands EJG, Ten Kate GL, Van Klaveren D, Van Domburg RT, Van Der Steen AFW, et al. Carotid intima-media thickness for cardiovascular risk assessment: Systematic review and meta-analysis. Atherosclerosis 2013; 228(1): 1–11. DOI:10.1016/j.atherosclerosis.2013.01.025
17. Libby P, Ridker PM, Hansson GK. Inflammation in atherosclerosis: from pathophysiology to practice. J Am Coll Cardiol. 2009; 54(23): 2129–2138. DOI:10.1016/j.jacc.2009.09.009
18. Liao H, Li Z, Zheng D, Liu J, Liu Y, Xiao C, Wang H. Increased Hs-CRP/adiponectin ratio is associated with increase carotid intima-media thickness. Lipids in health and disease. 2014; 13(1):120–125. DOI:10.1186/1476-511X-13-120
19. Weingärtner O, Pinsdorf T, Rogacev KS, Blömer L, Grenner Y, Gräber S, Ulrich C, Girndt M, Böhm M, Fliser D, Laufs U. The relationships of markers of cholesterol homeostasis with carotid intima-media thickness. PLoS One. 2010; 5(10): 13467–13475. DOI:10.1371/journal.pone.0013467
20. Laurence EC, Volmink J, Esterhuizen TM, Dalal S, Holmes MD. Risk of cardiovascular disease among teachers in Cape Town: Findings of the South African PaCT pilot study. South African Med J 2016; 106(10): 996–1001. DOI:10.7196/SAMJ.2016.v106i10.10869
21. Koolhaas CM, Dhana K, Schoufour JD, Ikram MA, Kavousi M, Franco OH. Impact of physical activity on the association of overweight and obesity with cardiovascular disease: The Rotterdam Study. Eur J Prev Cardiol 2017; 24(9): 934–941. DOI:10.1177/2047487317693952
22. Zulkepli Z, Saat NZ, Fauzi NF, Hanawi SA, Zin NM. Relationship between physical activity level and cardiovascular risk factors among teachers. Asian Journal of Epidemiology 2019; 12(1): 1–8. DOI:10.3923/aje.2019.1.8
23. Parsons TJ, Sartini C, Ellins EA, Halcox JPJ, Smith KE, Ash S, et al. Objectively measured physical activity, sedentary time and subclinical vascular disease: Cross-sectional study in older British men. Prev Med 2016; 89: 194–199. http://dx.doi.org/10.1016/j.ypmed.2016.05.031
24. Kozakova M, Palombo C, Morizzo C, Nolan JJ, Konrad T, Balkau B. Effect of sedentary behaviour and vigorous physical activity on segment-specific carotid wall thickness and its progression in a healthy population. Eur Heart J 2010; 31(12): 1511–1519. DOI:10.1093/eurheartj/ehq092
25. Ried-Larsen M, Grøntved A, Christian Møller N, Traberg Larsen K, Froberg K, Bo Andersen L. Associations between objectively measured physical activity intensity in childhood and measures of subclinical cardiovascular disease in adolescence: prospective observations from the European

Youth Heart Study. Br J Sports Med 2014; 48(20): 1502–1507. DOI:10.1136/bjsports-2012-091958

26. Ravichandran R, Rajendran R. Perceived sources of stress among the teachers. J Indian Acad Appl Psychol 2007; 33(1): 133–136.
27. Peltzer K, Shisana O, Zuma K, Van Wyk B, Zungu-Dirwayi N. Job stress, job satisfaction and stress-related illnesses among South African educators. Stress Health 2009; 25(3): 247–257. DOI:10.1002/smi.1244
28. Nagra V, Arora S. Occupational stress and health among teacher educators. Int J Adv Res Manage Soc Sci 2013; 2(8): 1–13.
29. Le Roux S, Lotter GA, Steyn HS, Malan L. Cultural coping as a risk for depression and hypertension: the SABPA prospective study. Cardiovasc J Afr 2018; 29(6): 366–373. DOI:10.5830/CVJA-2018-045
30. Bruwer EJ. Physical activity status, chronic stress, cardiovascular risk factors and telomere length in an urban South African teachers' cohort: the SABPA study. Unpublished doctoral dissertation. Potchefstroom, South Africa: North-West University; 2014.
31. Den Ruijter HM, Peters SA, Anderson TJ, Britton AR, Dekker JM, Eijkemans MJ, et al. Common carotid intima-media thickness measurements in cardiovascular risk prediction: a meta-analysis. JAMA 2012; 308(8): 796–803. DOI:10.1001/jama.2012.9630
32. World Health Organization. Global strategy on diet, physical activity and health. Geneva; 2019 [https://www.who.int/dietphysicalactivity/pa/en/] Accessed on 22 August 2019.
33. Malan L, Hamer M, Frasure-Smith N, Steyn HS, Malan NT. Cohort Profile: Sympathetic activity and Ambulatory Blood Pressure in Africans (SABPA) prospective cohort study. Int J Epidemiol 2015; 44(6): 1814–1822. https://doi.org/10.1093/ije/dyu199
34. Mancia G, Fagard R, Narkiewicz K, Redon J, Zanchetti A, Böhm M, Christiaens T, Cifkova R, De Backer G, Dominiczak A, Galderisi M. 2013 ESH/ESC Practice guidelines for the management of arterial hypertension: ESH-ESC The Task Force for the management of arterial hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). Blood pressure. 2014; 23(4):3–16.
35. Stewart A, Marfell-Jones M, Olds, T, De Ridder JH. International standard for anthropometric assessment, 3rd edn. New Zealand: ISAK, 2011:137
36. Riebe D, Ehrman JK, Liguori G, Magal M, eds. ACSM's guidelines for exercise testing and prescription, 10th ed. Philadelphia: Wolhuters Kluwer, 2018: p48;70;73
37. Malan L, Hamer M, Schlaich MP, Lambert GW, Harvey BH, Reimann M, et al. Facilitated defensive coping, silent ischaemia and ECG left-ventricular hypertrophy: The SABPA study. J Hypertens 2012; 30(3): 543–550. DOI:10.1097/HJH.0b013e32834fcf82
38. Hamer M, Bruwer EJ, De Ridder JH, Swanepoel M, Kengne AP, Cockeran M, et al. The association between seven-day objectively measured habitual physical activity and 24 h ambulatory blood pressure: the SABPA study. J Hum Hypertens 2017; 31: 409–414.

DOI:10.1038/jhh.2016.93

39. Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR, Tudor-Locke C, et al. Compendium of physical activities: A second update of codes and MET values. Med Sci Sports Exerc 2011; 43(8): 1575–1581. DOI:10.1249/MSS.0b013e31821ece12
40. Brage, S, Brage, N, Franks, PW., Ekelund, U, Wong, MY, Andersen, LB, Froberg, K, Wareham, NJ. Branched equation modeling of simultaneous accelerometry and heart rate monitoring improves estimate of directly measured physical activity energy expenditure. Journal of applied physiology 2004; 96(1), 343-351. DOI: 10.1152/japplphysiol.00703.2003.
41. Westerterp, K.R. 2017. Control of energy expenditure in humans. European Journal of Clinical Nutrition; 71(3):340–344. DOI:10.1038/ejcn.2016.237
42. Wendelhag I, Liang Q, Gustavsson T, Wikstrand J. A new automated computerized analyzing system simplifies readings and reduces the variability in ultrasound measurement of intima-media thickness. Stroke 1997; 28(11):2195–2200. Available from: https://www.ahajournals.org/doi/10.1161/01.STR.28.11.2195
43. Liang, Q., Wendelhag, I., Wikstrand, J. & Gustavsson T. A multiscale dynamic programming procedure for boundary detection in ultrasonic artery images. IEEE Trans Med Imaging 2000; 19(2): 127. Available from: https://www.researchgate.net/publication/12533060
44. Piepoli MF, Hoes AW, Agewall S, Albus C, Brotons C, Catapano AL, et al. 2016 European Guidelines on cardiovascular disease prevention in clinical practice: The Sixth Joint Task Force of the European Society of Cardiology and Other Societies on Cardiovascular Disease Prevention in Clinical Practice. Eur J Prev Cardiol 2016; 23(11): 1–96. DOI:10.1177/2047487316653709
45. Ridker PM. Clinical application of C-reactive protein for cardiovascular disease detection and prevention. Circulation. 2003; 107(3): 363–369. https://doi.org/10.1161/01.CIR.0000053730.47739.3C
46. Department of International Economic and Social Affairs. Statistics: provisional guidelines on standard international age classification of 1982. Statistics Papers Series M no 74. New York: Publishing Service United Nations, 1982:28.
47. Cohen, J.W. 1988. Statistical power analysis for behavioural sciences. 2nd edn. Hillsdale, NJ:Lawrence Erlbaum Associates.
48. Rombaldi AJ, Pellanda LC, Bielemann RM, Gigante DP, Hallal PC, Horta BL. Cross-sectional and prospective associations between physical activity and C-reactive protein in males. PloS one. 2015; 10(5):e0125984. DOI:10.1371/journal.pone.0125984
49. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U, Lancet Physical Activity Series Working Group. Global physical activity levels: surveillance progress, pitfalls, and prospects. Lancet 2012; 380(9838): 247–257. http://dx.doi.org/10.1016/S0140-6736(12)60646-1
50. Archer E, Blair SN. Physical activity and the prevention of cardiovascular disease: From Evolution to Epidemiology. Prog Cardiovasc Dis 2011; 53(6): 387–396. http://dx.doi.org/10.1016/j.pcad.2011.02.006

51. World Health Organization. Overweight and Obesity. Geneva; 2017. Available from: https://www.who.int/gho/ncd/risk_factors/overweight/en/ Accessed on 22 August 2019.
52. Gomez-Marcos MA, Recio-Rodríguez JI, Patino-Alonso MC, Agudo-Conde C, Lasaosa-Medina L, Rodriguez-Sanchez E, et al. Relationship between objectively measured physical activity and vascular structure and function in adults. Atherosclerosis 2014; 234(2): 366–372. DOI: http://dx.doi.org/10.1016/j.atherosclerosis.2014.02.028
53. Ascenso A, Palmeira A, Pedro LM, Martins S, Fonseca H. Physical activity and cardiorespiratory fitness, but not sedentary behavior, are associated with carotid intima-media thickness in obese adolescents. Eur J Pediatr 2016; 175(3): 391–398.
54. Huynh QL, Blizzard CL, Raitakari O, Sharman JE, Magnussen CG, Dwyer T, et al. Vigorous physical activity and carotid distensibility in young and mid-aged adults. Hypertens Res 2015; 38(5): 355. DOI:10.1038/hr.2015.9
55. Kadoglou NP, Iliadis F, Liapis CD. Exercise and carotid atherosclerosis. Eur J Vasc Endovasc Surg 2008; 35(3): 264–372. DOI:10.1016/j.ejvs.2007.08.022
56. Westerterp KR. Impacts of vigorous and non-vigorous activity on daily energy expenditure. Proc Nutr Soc 2003; 62(3): 645–650. https://doi.org/10.1079/PNS2003279
57. Bouchard C, Blair SN, Haskell WL. Physical Activity and Health, 2nd edn. Champaigne, IL: Human Kinetics, 2012.
58. Agha SY, Al Dobbagh SA. Level of physical activity among teaching and support staff in the education sector in Dohuk, Iraq. East Mediterr Health J 2010; 16(12): 1278–1284.
59. Walker TJ, Heredia NI, Lee M, Laing ST, Fisher-Hoch SP, McCormick JB, Reininger BM. The combined effect of physical activity and sedentary behavior on subclinical atherosclerosis: a cross-sectional study among Mexican Americans. BMC Public Health 2019; 19(1): 161–172. https://doi.org/10.1186/s12889-019-6439-4
60. Ried-Larsen M, Grøntved A, Froberg K, Ekelund U, Andersen LB. Physical activity intensity and subclinical atherosclerosis in Danish adolescents: The European Youth Heart Study. Scan J Med Sci Sports 2013; 23(3): 168–177. https://doi.org/10.1111/sms.12046
61. Jain A, McClelland RL, Polak JF, Shea S, Burke GL, Bild DE, et al. Cardiovascular imaging for assessing cardiovascular risk in asymptomatic men versus women: the multi-ethnic study of atherosclerosis (MESA). Circ Cardiovasc Imaging 2011; 4(1): 8–15.
62. Khalil A, Huffman MD, Prabhakaran D, Osmond C, Fall CH, Tandon N, et al. Predictors of carotid intima–media thickness and carotid plaque in young Indian adults: The New Delhi Birth Cohort. Int J Cardiol 2013; 167(4): 1322–1328. https://doi.org/10.1016/j.ijcard.2012.03.180
63. Ebrahim S, Papacosta O, Whincup P, Wannamethee G, Walker M, Nicolaides AN, et al. Carotid plaque, intima media thickness, cardiovascular risk factors, and prevalent cardiovascular disease in men and women: the British Regional Heart Study. Stroke 1999; 30(4): 841–850.
64. Mayosi BM, Flisher AJ, Lalloo UG, Sitas F, Tollman SM, Bradshaw D. The burden of non-communicable diseases in South Africa. The lancet. 2009; 374(9693):934-47.

https://doi.org/10.1016/S0140-6736(09)61087-4

65. Muluvhu TC, Monyeki MA, Strydom GL, Toriola AL. Relationship between obesity and blood pressure among employees in the Vhembe district municipality of Limpopo Province, South Africa. Cardiovasc J Afr. 2019; 30(6):1–8. DOI:10.5830/CVJA-2019-035
66. Ong KL, Allison MA, Cheung BM, Wu BJ, Barter PJ, Rye KA. Trends in C-reactive protein levels in US adults from 1999 to 2010. Am J Epidemiol. 2013; 177(12):1430-1442.

CHAPTER 4:
ARTICLE 2

The role of physical activity status in the relationship between obesity and carotid intima-media thickness in urban South African teachers: the SABPA-study

Die rol van fisieke aktiwiteit status in die verband tussen obesiteit en karotis intima-media dikte in stedelike Suid Afrikaanse onderwysers: die SABPA-studie

Tamrin Veldsman[1] (MSc)*, Mariette Swanepoel[1] (PhD), Makama A. Monyeki[1] (PhD), Johanna S. Brits[2] (PhD), Leoné Malan[2] (PhD)

[1]*Physical Activity, Sport and Recreation Research Focus Area (PhASRec), Faculty of Health Sciences, North-West University, Potchefstroom, South Africa*

[2]*Hypertension in Africa Research Team (HART), School for Physiology, Nutrition and Consumer Sciences, North-West University, Potchefstroom, South Africa*

Authors' information:

***Corresponding author**

Ms Tamrin Veldsman (Biokinetics)*
Telephone: +27 18 299 2187
Cell phone: +27 82 577 1602
Tamrin.Veldsman@nwu.ac.za
Private Bag X6001, North-West University,
Potchefstroom, South Africa, 2531

Dr Mariette Swanepoel (Biokinetics)
Telephone: +27 18 285 2282
Cell phone: +27 73 144 2242
12262404@nwu.ac.za

Prof Makama A Monyeki
(Body composition and physical activity)
Telephone: +27 18 299 1790
Cell phone: +27 82 644 4342
Andries.Monyeki@nwu.ac.za

Prof Johanna S Brits (Physiology)
Telephone: +27 18 285 2789
Cell phone: +27 84 533 4555
10069917@nwu.ac.za

Prof Leoné Malan (Physiology)
Telephone: +27 18 299 2438
Cell phone: +27 73 376 5321
Leone.Malan@nwu.ac.za

This article is prepared for submission to: *South African Journal for Research in Sport, Physical Education and Recreation (SAJRSPER).*

ABSTRACT

Globally, the prevalence of obesity and physical inactivity are on the rise, leading to increased carotid intima-media thickness (CIMT). Information on the role of physical activity (PA) in the relationship between obesity and CIMT is limited. A cross-sectional study design with a sub-sample of 216 teachers who were part of the Sympathetic Activity and Ambulatory Blood Pressure in Africans (SABPA) study was used to determine the role of PA in the relationship between obesity and CIMT. Physical activity was measured over seven consecutive days with a combined heart rate and accelerometer (ActiHeart) device. Body mass index (BMI), waist circumference (WC) and waist-to-height ratio (WHtR) were assessed. The CIMT was measured by SonoSite Micromaxx ultrasound. Other measures included blood pressure (BP), C-reactive protein (CRP), fasting blood cholesterol and glucose levels. Data were analysed using the Statistical Package for Social Science (SPSS). One-third of the teachers were physically inactive (33%) and had raised CRP (41%). Male teachers had significantly higher BP ($p < 0.001$) and CIMT ($p < 0.001$) values and were more sedentary compared to female teachers ($p < 0.001$). Positive relationships between body composition and CIMT were observed, but the inclusion of PA in the analysis did not yield any significant effect in the relationships. The cardiovascular disease risk profiles and limited PA participation of the participants may have restricted the beneficial impact of regular PA on the relationship between obesity and CIMT.

Keywords: atherosclerosis; carotid intima-media thickness; obesity; physical activity; South Africa; teachers.

INTRODUCTION

Physical inactivity is a significant public health concern (Blair, 2009) and a leading risk factor in the development of various non-communicable diseases (NCDs) (WHO, 2018). Globally, one in four adults is physically inactive (Guthold *et al.*, 2018; WHO, 2018) and the prevalence of physical inactivity is increasing in many developed and developing countries (WHO, 2010), with one-third of the South African adult population classified as sedentary (Guthold *et al.*, 2018). Teachers, in particular, spend most of their working day in sedentary or light energy-cost activities (Ainsworth *et al.*, 2011).

This increasing prevalence in physical inactivity may pose significant implications for the prevalence of NCDs such as cardiovascular disease (CVD), diabetes and cancer, as well as for modifiable risk factors such as elevated BP and raised glucose, and for increased prevalence of overweight and obesity (WHO, 2010). Between 1980 and 2008, the prevalence of global obesity, as measured by body mass index (BMI), nearly doubled (Bastien *et al.*, 2014). Of the South African adult population, 51.9% were overweight (BMI $\geq$25 kg/m^2) (WHO, 2017a) and 27% were obese (BMI $\geq$30 kg/m^2) (WHO, 2017b). Among South African teachers in Cape Town, the prevalence of overweight was 31.1%, and 53.6% were obese, and 18.7% of the teachers have been found to be at high risk of having a heart attack or stroke in the next decade (Laurence *et al.*, 2016).

Cardiovascular disease is a major cause of death in the general population (Jin *et al.*, 2018). Early detection of CVD occurrences before full manifestation can be assessed through measuring carotid intima-media thickness (CIMT) (Touboul *et al.*, 2007). Carotid intima-media thickness is a non-invasive subclinical measure to evaluate the progression of atherosclerosis and intima-media thickening (Touboul *et al.*, 2007). Obesity may worsen the progression of CIMT and, in particular, visceral/central obesity is a predictor of endothelial dysfunction and is correlated with an increased CIMT in obese individuals (Lakka *et al.*, 2001; Tankó *et al.*, 2005; Lo *et al.*, 2006; Kotsis *et al.*, 2006; Sturm *et al.*, 2009; Ortega-Loubon *et al.*, 2019).

In a study conducted by Lo *et al.* (2006) on young, healthy American females, the obese females were reported to have a higher CIMT than females who were considered to be overweight or who had a healthy BMI (<25 kg/m^2), and subcutaneous abdominal fat was more associated with increased CIMT than visceral adiposity. In middle-aged Finnish males with no known atherosclerotic disease, abdominal obesity, as measured by waist-to-hip ratio and waist circumference (WC), was associated with accelerated progression of carotid atherosclerosis (Lakka *et al.*, 2001). In a healthy middle-aged (<60 years) Chinese population, BMI was associated with an increased CIMT (Arnold *et al.*, 2019). Therefore, increased abdominal fat has been shown to be positively associated with an increased CIMT and in increased risk in developing atherosclerosis, increasing the risk of developing a cardiovascular disease.

Participation in regular PA influences CIMT, where exercise can prevent the development of atherosclerosis through weight reduction, glucose regulation, fat loss, improved endothelial function, improved glucose sensitivity and increased cardiorespiratory fitness, leading to controlled lipid values and

lowered BP values (Kadoglou *et al.*, 2008; Byrkjeland *et al.*, 2016). Higher levels of PA and decreased sedentary time are associated with a lowered risk of developing a CVD, as indicated by CIMT (Parsons *et al.*, 2016). In a study of Korean office workers, a significant positive relationship was found between central obesity and an increased CIMT among the physically inactive adults, but the relationship was not found in the office workers who were considered to be physically active (Jin *et al.*, 2018).

PURPOSE OF THE STUDY

Little is known on the role of PA in the relationship between obesity and CIMT, especially among South African teachers. Due to the nature of the occupation of teaching, levels of inactivity in teachers are high and there is a high prevalence of obesity, factors that place a burden on the South African education system (Laurence *et al.*, 2016). Thus this study focused on the role of PA in the association between obesity and CIMT in a cohort of South African teachers.

METHODOLOGY

Study design

This cross-sectional study was part of the Sympathetic Activity and Ambulatory Blood Pressure in Africans (SABPA) prospective cohort study. The baseline measurements for the SABPA-study commenced in 2008/2009, and follow-up data were collected in a similar manner to the baseline data in 2011/2012. The detailed methodology of the SABPA-study has been published elsewhere (Malan *et al.*, 2015). The Health Research Ethics Committee (HREC) of North-West University (Potchefstroom campus: NWU-0036-07-S6) approved the SABPA-study, which adhered to the Declaration of Helsinki (2014). The SABPA-study gained consent and cooperation from the North West Province Department of Education, the South African Demographic Teachers Union and the principals of the schools. All participants voluntary signed an informed consent form before data were collected.

Study population and sample

All urban-dwelling South African school teachers enrolled in the 43 schools in the Dr Kenneth Kaunda Education District residing in the North West Province of South Africa were invited to participate in the SABPA-study (N=2170). The participants were of similar socioeconomic background and were screened to meet eligibility criteria. Pregnant and lactating participants were excluded from the study, as well as participants using alpha- and beta-blockers or psychotropic substances, those who had donated blood or were vaccinated in the past 3 months and those with tympanum temperature of higher than 37.5 °C. After screening, 409 participants were eligible for data collection. The secondary data of participants who completed the follow-up measurements and who wore the ActiHeart device for a full seven consecutive days or had less than 40 minutes of daily non-contact time during awake hours (n=216) were included in this sub-study.

Anthropometric measurements

The anthropometric measurements of participants were taken by two level 2 kinanthropometrists according to the methods of the International Society for the Advancement of Kinanthropometry (ISAK) (Stewart *et al.,* 2011). Height (cm), weight (kg) and WC (cm) were measured. The height and weight of participants were used to calculate BMI (kg/m^2) and WHtR. The participants' BMI were classified according to the cut-off points of the American College of Sports Medicine (ACSM) (Riebe *et al.,* 2018) as follows: underweight = BMI <18.5 kg/m^2; normal weight = BMI between 18.5 and 24.9 kg/m^2; overweight = BMI between 25.0 and 29.9 kg/m^2; and obese = BMI ≥30 kg/m^2. WHtR of ≥0.5 was taken to indicate an increased risk of CVD (Ashwell *et al.,* 2005). Intra- and inter-observer variability were less than 5%.

Objectively measured physical activity

Participants' weekly habitual physical activity (PA) was objectively measured over seven consecutive days with a combined heart rate and accelerometer – the ActiHeart (GB0/67703, CamNtech Ltd., Cambridgeshire, UK). The resting heart rate of the participants was obtained by a registered nurse using a 12-lead electrocardiogram (NORAV Medical Ltd PC 1200, software v.5.030, Kiryat Bialik, Israel). The resting heart rate was used to calculate the sleeping heart rate (resting heart rate minus 10 beats per minute) as required to programme the ActiHeart device. Individual step test calibrations were not performed due to time constraints, the vast amount of data to be collected and the CVD risk profile of the participants; however, a biokineticist (clinical exercise physiologist) thoroughly questioned each participant about their daily and weekly PA patterns before an activity level was selected on the ActiHeart programme. Each participant's ActiHeart data were visually inspected to distinguish between sleep and awake time. Sleep and awake time of the participants were established using heart rate, metabolic equivalent of task (MET) and activity levels. Sleep time was defined as a period where there was a gradual decrease in heart rate, activity levels at zero during the evenings, and where the heart rate gradually decreased (over a period of 15 or more epochs) in the evenings to less than the average heart rate in a selected awake-time sedentary sample period (Hamer *et al*., 2017). The epoch for the full 7-day collection was set at 60-second intervals.

Awake time was indicated by an immediate increase in heart rate of more than 10–20 beats per minute, as well as increased METs and an increase in activity level. The ActiHeart software was used to derive daily time spent in various METs categories. The different MET categories were grouped according to time spent sedentary (≤1.5 METs) and time spent participating in light-intensity PA (1.5–3 METs) (Ainsworth *et al*., 2011). Activity energy expenditure (AEE), total energy expenditure (TEE) and PA level (PAL) were determined by the ActiHeart using inbuilt equations based on a branched model approach (Brage *et al*., 2004). The PAL was calculated as TEE/resting energy expenditure (REE) (Westerterp, 2017). After data analysis, only two PA groups, namely sedentary (≤1.5 METs) and light-intensity PA (1.5–3 METs) could be identified. Only one participant was classified as participating in moderate-to-high PA (>3 METs) and based on statistical power principles this individual was excluded from the analyses.

Subclinical atherosclerosis

The CIMT of participants was obtained using a SonoSite Micromaxx ultrasound system (SonoSite Inc., Bothell, WA, USA) and a 6–13 MHz linear array transducer, using previously described protocols (Touboul *et al.*, 2007). Images of at least two optimal angles of the left and right common carotid artery were obtained. The images were digitised and imported to Artery Measurement Systems automated software (AMS, Gothenburg, Sweden, v1.130) for analysing CIMT (Wendelhag *et al.*, 1997; Liang *et al.*, 2000). A maximal 10-cm segment with good quality imaging was used for analysis. The program automatically detects the borders of the intima-media of the near and far wall, as well as the inner diameter of the vessel, and calculates CIMT from around 100 discrete measurements through the 10-cm segment. This automated analysis was capable of being manually corrected if not appropriate on visual inspection. For this study, the far wall left CIMT measurements were used. Intra-observer variability was 0.04 mm between two measurements taken 4 weeks apart on the same 10 participants. CIMT of > 0.75 mm was considered indicative of moderate atherosclerotic risk and >0.9 mm was regarded as high risk (Piepoli *et al*., 2016). The images were also examined for the presence of plaque at the right and left bifurcation of the internal carotid artery. Plaque was defined as a focal structure encroaching into the arterial lumen by at least 0.5 mm or by 50% of the surrounding intima-media thickness or demonstrating a thickness >1.5 mm (Touboul *et al.*, 2007).

Lifestyle factors

Participants smoking and alcohol was indicated by answering yes/no to the questions: do you smoke? or do you consume alcohol?

Blood pressure

The resting BP of the participants was measured with a sphygmomanometer (1.3M™ Littman® II S.E. Stethoscope 2205, Reister CE 0124, No. 1010–108 Diplomat-presameter®, Germany) on the non-dominant arm with an appropriate cuff size using the Rica/Rocci Korotkoff method. The measurements were repeated after 5 minutes and the second measurement was used for the cardio-metabolic syndrome (MS) criteria for BP (Alberti *et al.*, 2009). The MS criteria for elevated blood pressure values are ≥130/85 mmHg or if the participant uses antihypertensive treatment (Alberti *et al.*, 2009).

Biochemical analysis

A registered nurse obtained fasting resting blood samples with a winged infusion set from the brachial vein branches of the dominant arm. Glucose was collected in sodium fluoride tubes, and MS markers were handled according to standardised procedures and stored at –80 °C (Malan *et al*., 2015). Blood sample analysis was performed using the Konelab™ 20i (Thermo Scientific, Vantaa, Finland). The following International Diabetes Federation (IDF) cut-points were used: high-density lipoprotein (HDL) ≤ 1.03

mmol/L, triglycerides ≥ 1.70 mmol/L and fasting glucose ≥ 5.60 mmol/L (Alberti *et al.*, 2009). High sensitive C-reactive protein (CRP) was analysed with a timed, end-point method (UniCel® DxC 800, Beckman and Coulter, Germany). CRP ≥ 3 mg/L was regarded as high risk for CVD (Ridker, 2003). Inter- and intra-variability was <5 %.

Data analysis

Statistical analyses were performed using SPSS v.26 (Inc., Chicago, IL, USA). Normality of the data was done using the Shapiro-Wilk test and Quantile-Quantile plots. Descriptive analyses (means, standard deviations and frequencies) were performed for all PA, anthropometric and CIMT measurements and risk factors for CVD. The independent t-test for normally distributed data and chi-square test for categorical variables were performed to determine significant differences by sex and groups. Analysis of variance (ANOVA) followed by a post hoc test (least significant difference test) where necessary were used to compare measured parameters between BMI and WHtR subgroups stratified by weekly PA. Spearman's *rho* correlation matrix was calculated for anthropometric measurements, AEE and CIMT between overweight and obesity in the sedentary and light PA groups. Additionally, controlled standardised regression coefficient (β) and *p*-value (95% confidence interval) were applied to the relationship between CIMT and body composition, controlling for PA. Multivariate linear regression was used to determine the predictors of CIMT. Correlation coefficient values were classified as follow; <0.10 = a weak correlation and values of 0.30 – 0.50 indicate a moderate correlation and ≥ 0.05 indicates a strong correlation. The significance level was set at $p \leq 0.05$ (Cohen, 1988).

RESULTS

Table 1 displays the basic lifestyle, anthropometric and BP characteristics of the study population according to sex and includes the *p*-value of the significant sex differences. Male teachers were significantly taller ($p < 0.001$) and heavier ($p < 0.001$) than female teachers. The findings also indicated that male teachers had a significantly larger WC than the female teachers (102.12±12.79 cm vs 91.08±16.74 cm; $p < 0.001$). Male teachers also had significantly higher systolic BP (SBP) (134.57±16.56 mmHg vs 124.04±18.42 mmHg; $p < 0.001$), diastolic BP (DBP) (90.87±10.42 mmHg vs 81.91±10.44 mmHg; $p < 0.001$) and CIMT (0.75±0.16 mm vs 0.66±0.12 mm; $p < 0.001$) than female teachers. For the entire group of teachers, 74 were overweight (34%) and 84 were obese (39%). Male teachers had a significantly higher prevalence of overweight (42%) compared with female teachers (27%). However, significantly more female teachers were obese (41%) than male teachers (37%). Furthermore, more male teachers reported smoking (20%) and alcohol usage (65%) than female teachers. The results suggest that 14% of the total participants, 20% of male and 8% of female teachers, were smokers. Overall, more than one-third of the teachers were physically inactive (33%) and had raised CRP (41%). A significant difference was observed between male and female teachers who do not have a risk for atherosclerotic disease ($p<0.001$).

Table 1: Differences in descriptive characteristics of the male and female teachers (mean ± standard deviation except where indicated)

	Total group (N=216)	Male teachers (n=104)	Female teachers (n=112)	*p*-value for sex differences
Age (years)	49.67±8.44	49.79±8.48	49.55±8.43	0.84
Height (cm)	169.12±10.18	176.6 ±7.90	162.14±6.37	<0.001*
Weight (kg)	83.65±19.62	90.75±16.51	77.06±20.04	<0.001*
BMI (kg/m^2)	29.3 ±6.49	29.06±4.77	29.64±7.76	0.51
WC (cm)	96.40±15.92	102.12±12.79	91.08±16.74	<0.001*
WHtR	0.57±0.09	0.58±0.07	0.56±0.11	0.21
SBP (mmHg)	129.11±18.29	134.57±16.56	124.04±18.42	<0.001*
DBP (mmHg)	86.22±11.33	90.87±10.42	81.91±10.44	<0.001*
CIMT (mm)	0.70±0.15	0.75±0.16	0.66±0.12	<0.001*
Underweight, n (%)	1 (1)	0 (0)	1 (1)	
Normal weight, n (%)	57 (26)	22 (21)	35 (31)	
Overweight, n (%)	74 (34)	44 (42)	30 (27)	<0.001*
Obesity, n (%)	84 (39)	38 (37)	46 (41)	
Diabetes, n (%)	22 (10)	17 (17)	5 (5)	<0.001*
Self-reported smoking, n (%); YES	30 (14)	21 (20)	9 (8)	<0.001*
NO	185 (86)	82 (80)	103 (92)	
Self-reported alcohol use, n (%); YES	104 (48)	68 (66)	36 (32)	0.51
NO	111 (52)	35(34)	76 (68)	
Hypertension medication, n (%)	67 (31)	39 (38)	28 (25)	0.36
MS, n (%)	63 (29)	48 (46)	15 (13)	0.02*
PA				
Sedentary, n (%)	71 (33)	46 (44)	25 (22)	<0.001*
Light PA, n (%)	145 (67)	58 (56)	87 (78)	
CRP, n (%)	88 (41)	36 (35)	52 (47)	0.06
Moderate atherosclerosis risk (>0.75 mm)	74 (34)	49 (47)	25 (22)	<0.001*
No atherosclerosis risk (<0.75 mm)	141 (66)	55 (53)	86 (78)	

Underweight = BMI <18.5 kg/m^2; normal weight = BMI 18.5–24.9 kg/m^2; overweight = BMI 25.0–29.9 kg/m^2; obesity = BMI ≥30 kg/m^2; sedentary = ≤1.5 METs; light physical activity = 1.5–3 METs.

BMI = Body mass index; CIMT = carotid intima-media thickness; CRP = C-reactive protein; DBP = diastolic blood pressure; MS = cardio-metabolic syndrome; PA = physical activity; SBP = systolic blood pressure; WC = waist circumference; WHtR = waist-to-height ratio.

*Level of significance was set at $p \leq 0.05$.

In Table 2, the participant's descriptive characteristics are displayed according to the BMI classification and level of PA. ANOVA was used to determine the differences between the BMI categories, but a post hoc analysis could not be performed for the light PA group due to the underweight group having only one participant. In the sedentary group of teachers, there were significant differences between the body composition variables. Obese, sedentary teachers had a significantly larger BMI (36.13±5.65 kg/m^2; $p < 0.001$), WC (115.10±13.64 cm; $p < 0.001$) and WHtR (0.67±0.09; $p < 0.001$) than teachers who were overweight or had a healthy BMI. Similarly to the sedentary teachers, teachers who participated in light PA

had significantly larger BMI (35.09±5.89 kg/m^2; $p < 0.001$), WC (106.67±12.04; $p < 0.001$) and WHtR (0.64±0.07; $p < 0.001$) than the participants who were underweight or had a healthy BMI.

Table 2: Differences in descriptive characteristics of the teachers according to body mass index classification

	BMI classification	Sedentary			Light PA		
		N	Mean±SD	*p*-value	N	Mean±SD	*p*-value
Age (years)	Normal weight	21	46.38±9.56		36	50.78 ± 6.93	
	Overweight	22	50.45±10.53	0.35	52	49.96±8.34	0.82
	Obesity	28	49.14±8.03		56	49.79±8.36	
Height (cm)	Normal weight	21	166.80±8.98		36	169.03±9.75	
	Overweight	22	171.52±10.30	0.23	52	171.39±10.27	0.05*
	Obesity	28	171.31±11.06		56	165.91±9.74	
Weight (kg)	Normal weight	21	62.53±10.17		36	65.48±9.23	
	Overweight	22	83.33±11.12	<0.001*	52	81.24±11.07	<0.001*
	Obesity	28	105.59±15.59		56	95.21±18.51	
BMI (kg/m^2)	Normal weight	21	22.35±2.01		36	22.91±1.51	
	Overweight	22	28.15±1.32	<0.001*	52	27.58±1.49	<0.001*
	Obesity	28	36.13±5.65		56	35.09±5.89	
WC (cm)	Normal weight	21	80.50±9.07		36	79.72±9.78	
	Overweight	22	97.21±7.75	<0.001*	52	93.47±7.50	<0.001*
	Obesity	28	115.10±13.64		56	106.67±12.04	
WHtR	Normal weight	21	0.48±0.47		36	0.47±0.04	
	Overweight	22	0.57±0.03	<0.001*	52	0.55±0.0	<0.001*
	Obesity	28	0.67±0.09		56	0.64±0.07	
SBP (mmHg)	Normal weight	21	127.76±19.40		36	120.28±16.35	
	Overweight	22	133.27±21.67	0.24	52	124.29±13.71	<0.001*
	Obesity	28	137.57±18.81		56	134.23±17.95	
DBP (mmHg)	Normal weight	21	85.24±13.44		36	80.78±10.42	
	Overweight	22	90.05±13.19	0.27	52	83.65±10.16	<0.001*
	Obesity	28	90.36±8.74		56	89.11±10.77	
CIMT (mm)	Normal weight	21	0.68±0.17		36	0.68±0.10	
	Overweight	22	0.73±0.18	0.50	52	0.73±0.15	0.31
	Obesity	28	0.68±0.16		56	0.70±0.15	
AEE (kcal/wk)	Normal weight	21	1011.05±918.51		36	1227.75±820.29	
	Overweight	22	668.94±501.01	0.26	52	1805.19±1337.02	0.07
	Obesity	28	736.70±692.23		56	1339.76±1029.29	
TEE (kcal/wk)	Normal weight	21	2850.17±1165.5		36	3115.53±1486.09	
	Overweight	22	2665.20±552.79	0.60	52	3844.18±1616.50	0.12
	Obesity	28	2906.01±755.57		56	3397.39±1289.10	
PAL	Underweight		–		1	2.03	
	Normal weight	12	1.49±0.15	0.82	36	2.20±0.55	0.34
	Overweight	59	1.47±0.13		51	2.31±0.56	
	Obesity	28	1.50±0.15		56	2.41±0.60	

Sedentary = ≤1.5 metabolic equivalent of task (METs); light physical activity (PA) = 1.5–3 METs; normal weight = BMI 18.5–24.9 kg/m^2; Overweight = BMI 25–29.9 kg/m^2; obesity = BMI >30 kg/m^2.

AEE = Activity energy expenditure; BMI = body mass index; CIMT = carotid intima-media thickness; DBP = diastolic blood pressure; PAL = physical activity level; SBP = systolic blood pressure; SD = standard deviation; TEE = total energy expenditure; WC = waist circumference; WHtR = waist-to-height ratio.

*Level of significance was set at $p \leq 0.05$.

Table 3 shows the independent t-test results for sedentary teachers and teachers who participated in light PA, divided into WHtR categories of greater or equal to and less than 0.5. In the sedentary group, the teachers with a WHtR ≥ 0.5 had a significantly higher SBP (143.52±19.25 mmHg vs 127.09±18.01 mmHg;

$p < 0.001$), DBP (92.48±10.67 mmHg vs 86.45±11.93 mmHg; $p = 0.03$) and PAL (1.50±0.14 vs 1.42±0.11; $p = 0.05$) compared with teachers with a WHtR < 0.5. Similarly, the teachers who participated in light PA with a WHtR ≥ 0.5 had significantly higher SBP (135.96±18.21 mmHg vs 122.51 ±14.61 mmHg; $p < 0.001$), DBP (90.16±11.17 mmHg vs 82.37±9.92 mmHg; $p < 0.001$) and PAL (2.36±0.59 vs 2.12±0.45; $p = 0.02$) when compared with teachers with a WHtR < 0.5.

Table 3: Independent t-test for participants according to waist-to-height ratio category

	WHtR category	Sedentary			Light PA		
		n	Mean±SD	*p*-value	n	Mean±SD	*p*-value
Age (years)	<0.5	44	47.32±10.21	0.08	95	49.96±7.56	0.63
	≥0.5	27	51.04±7.27		49	50.67±8.68	
Height (cm)	<0.5	44	170.17±11.33	0.89	95	169.79±10.16	0.07
	≥0.5	27	169.83±8.64		49	166.60±9.88	
Weight (kg)	<0.5	44	75.27±17.77	<0.001*	95	75.64±13.17	<0.001*
	≥0.5	27	103.37±16.29		49	96.36±19.23	
BMI (kg/m^2)	<0.5	44	25.67±3.77	<0.001*	95	26.24±3.49	<0.001*
	≥0.5	27	35.96±6.01		49	35.26±6.28	
WC (cm)	<0.5	44	89.08±12.08	<0.001*	95	87.80±10.39	<0.001*
	≥0.5	27	116.02±12.42		49	109.49±10.07	
WHtR	<0.5	44	0.52±0.05	<0.001*	95	0.52±0.05	<0.001*
	≥0.5	27	0.68±0.08		49	0.66±0.06	
SBP (mmHg)	<0.5	44	127.09±18.01	<0.001*	95	122.51±14.61	<0.001*
	≥0.5	27	143.52±19.25		49	135.96±18.21	
DBP (mmHg)	<0.5	44	86.45±11.93	0.03*	95	82.37±9.92	<0.001*
	≥0.5	27	92.48±10.67		49	90.16±11.17	
CIMT (mm)	<0.5	44	0.70±0.17	0.73	95	0.71±0.14	0.95
	≥0.5	27	0.69±0.16		49	0.71±0.16	
AEE (kcal/wk)	<0.5	12	819.09±970.19	0.93	28	1238.22±153.10	0.18
	≥0.5	59	792.33±671.42		116	1485.69±98.92	
TEE (kcal/wk)	<0.5	12	2578.99±1292.64	0.47	28	3085.28±304.02	0.19
	≥0.5	59	2862.85±725.99		116	3520.39±121.17	
PAL (kcal/wk)	<0.5	12	1.42±0.11	0.05*	28	2.12±0.45	0.02*
	≥0.5	59	1.50±0.14		116	2.36±0.59	

Sedentary = ≤1.5 metabolic equivalent of task (METs); light physical activity (PA) = 1.5–3 METs.

AEE = Activity energy expenditure; BMI= body mass index; CIMT = carotid intima-media thickness; DBP = diastolic blood pressure; PAL = physical activity level; SBP = systolic blood pressure; TEE= total energy expenditure; WC = waist circumference; WHtR, waist-to-height ratio.

*Level of significance was set at $p \leq 0.05$.

Table 4 presents the correlation coefficients for the overweight and obese participants in the sedentary and light PA groups. In the overweight, sedentary teachers, there was a moderate significant positive relationship between CIMT and WC ($r = 0.47$; $p = 0.03$). In the sedentary obese individuals, a moderate significant negative relationship between CIMT and BMI ($r = -0.46$; $p = 0.02$) was found, and a moderate inconclusive borderline significant negative relationships between CIMT and WHtR ($r = -0.36$; $p = 0.07$), and CIMT and AEE ($r = - 0.37$; $p = 0.06$) were found. In the light PA group, the results showed a weak

significant positive relationship between CIMT and age in the overweight ($r = 0.28$; $p < 0.001$) and obese ($r = 0.28$; $p = 0.003$) teachers. Also, the results indicated a weak inconclusive borderline significant positive relationship between CIMT and WC ($r = 0.17$; $p = 0.08$) in the overweight teachers who participated in light PA. In the obese participants, a weak significant positive relationship existed between CIMT and WC ($r = 0.23$; $p = 0.02$), and CIMT and AEE ($r = 0.22$; $p = 0.02$).

Table 4: Spearman's *rho* correlation matrix for anthropometric measurements, activity energy expenditure and carotid intima-media thickness among overweight and obese participants in the sedentary and light-intensity physical activity groups

		Sedentary											
		Overweight (n=22)						**Obese (n=28)**					
		Age (years)	**BMI (kg/m^2)**	**WC (cm)**	**CIMT (mm)**	**WHtR**	**AEE (kcal/wk)**	**Age (years)**	**BMI (kg/m^2)**	**WC (cm)**	**CIMT (mm)**	**WHtR**	**AEE (kcal/wk)**
Age	*r*	–	-0.12	0.01	0.05	0.03	-0.01	–	-0.03	0.29	0.27	0.16	-0.45*
(years)	*p*	–	0.60	0.98	0.83	0.90	0.96	–	0.89	0.14	0.17	0.41	0.02
BMI	*r*	-0.12	–	0.36	0.02	0.28	0.10	-0.03	–	0.62**	-0.46*	0.81**	0.25
(kg/m^2)	*p*	0.60	–	0.10	0.94	0.21	0.66	0.89	–	<0.001	0.02	<0.001	0.20
WC (cm)	*r*	0.01	0.36	–	0.47*	0.69**	-0.16	0.29	0.62**	–	-0.11	0.78**	0.02
	p	0.98	0.10	–	0.03	<0.001	0.47	0.14	<0.001	–	0.57	<0.001	0.90
CIMT	*r*	0.05	0.02	0.47*	–	0.24	-0.25	0.27	-0.46*	-0.11	–	-0.36	-0.37
(mm)	*p*	0.83	0.94	0.03	–	0.28	0.26	0.17	0.02	0.57	–	0.07	0.06
WHtR	*r*	0.03	0.28	0.69**	0.24	–	0.11	0.16	0.81**	0.78**	-0.36	–	0.18
	p	0.90	0.21	<0.001	0.28	–	0.63	0.41	<0.001	<0.001	0.07	–	0.36
AEE	*r*	-0.01	0.10	-0.16	-0.25	0.11	–	-0.45*	0.25	0.02	-0.37	0.18	–
(kcal/wk)	*p*	0.96	0.66	0.47	0.26	0.63	–	0.02	0.20	0.90	0.06	0.36	–
		Light PA											
		Overweight (n=104)						**Obese (n=112)**					
Age	*r*	–	0.12	0.08	0.28**	0.27**	0.04	–	-0.00	0.37**	0.28**	0.27**	0.03
(years)	*p*	–	0.23	0.45	0.001	0.01	0.72	–	0.97	<0.001	0.003	<0.001	0.76
BMI	*r*	0.12	–	0.56**	0.10	0.56**	-0.04	-0.00	–	0.37**	0.05	0.65**	0.11
(kg/m^2)	*p*	0.23	–	<0.001	0.30	<0.001	0.73	0.97	–	<0.001	0.64	<0.001	0.25
WC (cm)	*r*	0.08	0.56**	–	0.17	0.62**	0.17	0.37**	0.37**	–	0.23*	0.76**	0.26**
	p	0.45	<0.001	–	0.08	<0.001	0.08	<0.001	<0.001	–	0.02	<0.001	0.01
CIMT	*r*	0.28**	0.10	0.17	–	0.11	-0.05	0.28**	0.05	0.23*	–	0.06	0.22*
(mm)	*p*	<0.001	0.30	0.08	–	0.26	0.64	0.003	0.64	0.02	–	0.51	0.02
WHtR	*r*	0.27**	0.56**	0.62**	0.11	–	-0.23*	0.27**	0.65**	0.76**	0.06	–	0.11
	p	0.01	<0.001	<0.001	0.26	–	0.02	<0.001	<0.001	<0.001	0.51	–	0.27
AEE	*r*	0.04	-0.04	0.17	-0.05	-0.23*	–	0.03	0.11	0.26**	0.22*	0.11	–
(kcal/wk)	*p*	0.72	0.73	0.08	0.64	0.02	–	0.76	0.25	0.01	0.02	0.27	–

Sedentary = ≤1.5 metabolic equivalent of task (METs), light activity = 1.5–3 METs, moderate-to-high activity = ≥3 METs; normal weight = BMI 18.5–24.9 kg/m^2; overweight = BMI 25–29.9 kg/m^2; obese = BMI >30 kg/m^2.

AEE = Activity energy expenditure; BMI = body mass index; CIMT = carotid intima-media thickness; PA = physical activity; WC = waist circumference; WHtR = waist-to-height ratio.

*Level of significance was set at $p \leq 0.05$.

**Correlation was significant at the 0.01 level (two-tailed).

In the measures of body composition, WC (p = 0.027) and WHtR (p = 0.533) were positively related to CIMT (Table 5). A significant positive relationship was observed between WC and CIMT. The observed correlation was explained by 2.3% (R^2; 0.023) WC in the model, and it was an inconclusive borderline statistically significant ($F(2; 211) = 2.489$; p = 0.085) result. The addition of PA into the regression models did not change the magnitude of the regression coefficients for any of the body composition variables and CIMT.

Table 5: Controlled standardised regression coefficients (β) and p-values (95% confidence interval) for the relationship between carotid intima-media thickness and body composition, controlling for physical activity

	'Crude'			**'Crude' + PA**		
	β	***p*-value**	**95% CI**	***β***	***p*-value**	**95% CI**
BMI (kg/m^2)	-0.023	0.741	-0.004; 0.003	-0.022	0.747	-0.004; 0.003
WC (cm)	0.151	0.027*	0.000; 0.003	0.152	0.027*	0.000; 0.003
WHtR	0.043	0.533	-0.150; 0.289	0.043	0.535	-0.151; 0.289

β = Standardised regression coefficient; BMI = body mass index; CI = confidence interval; PA = physical activity; WC = waist circumference; WHtR = waist-to-height ratio.

*Level of significance is set at $p \leq 0.05$.

An inspection of individual predictors revealed that age (β = 0.227; p = 0.001) and sex (β = -0.183; p = 0.033) were significant predictors, and WC (β = 0.382; p = 0.061) and total cholesterol (β = 0.125; p = 0.066) were inconclusive borderline significant predictors (Table 6). An increase in age was associated with an increase in CIMT. All three independent variables (BMI, WC and WHtR) had a significant combined effect on CIMT ($F(10, 349) = 7.163$; $p < 0.001$).

Table 6: Multivariate linear regression for predicting carotid intima-media thickness

Variables	**Standardised *β***	**95% CI**	**p-value**
Age (years)	0.227	0.002; 0.006	**0.001***
Sex	-0.183	-0.103; -0.004	**0.033***
BMI (kg/m^2)	0.033	-0.005; 0.006	0.777
WC (cm)	0.382	0.000; 0.007	**0.061#**
Total cholesterol (mmol/L)	0.125	-0.001; 0.038	**0.066#**
CRP (mg/dl)	-0.072	-0.006; 0.002	0.311
PAL	-0.014	-0.025; 0.019	0.785
SBP (mmHg)	0.051	-0.001; 0.002	0.595
DBP (mmHg)	0.032	-0.002; 0.003	0.736
Smoking	0.067	-0.019; 0.100	0.186
Self-reported alcohol use	0.018	-0.025; 0.036	0.728

β = Standardised regression coefficient; BMI = body mass index; CI = confidence interval; CRP = C-reactive protein; DBP = diastolic blood pressure; PAL = physical activity level; smoking = 1 or more cigarettes per day; SBP = systolic blood pressure; WC = waist circumference.

*Level of significance is set as $p \leq 0.05$; # indicates borderline significance.

DISCUSSION

The purpose of this study was to investigate the role of PA in the relationship between obesity and CIMT in teachers in the North West Province of South Africa. The results of the study showed significant positive relationships between CIMT and WC, however the relationship diminished when PA was included in the model. Also, the current findings showed that more than one-third of the teachers were overweight or obese, sedentary, and had elevated CRP values. Male teachers had significantly higher BP, CIMT, CRP and sedentary levels when compared with female teachers. The results of this study are congruent with the results of Jin and colleagues (2018) among Korean office workers.

In the observed significant positive relationships between CIMT and WC, adding PA into this relationship did not yield any significant effect in this relationship. Jin *et al.* (2018) indicated that physical inactivity in sedentary Korean office workers may lead to a higher risk of abdominal obesity and an elevated CIMT that was not seen in physically active persons. In performing the multivariate linear regression analyses, age, sex, WC and total cholesterol were essential determinants for predicting CIMT. Physical activity status was not a predictor of CIMT in our study. PA was a predictor of abnormally increased CIMT in the study of Jin *et al.* (2018), but this was not the case in this study. This may be due to 33% of the participants being sedentary and overweight and the remaining 67% of the participants only participating in light-intensity PA, indicating that the intensity of PA may have been too low to influence the relationship between obesity and CIMT. Teachers spend most of their working time seated, standing and walking, which are all low energy-cost activities (Ainsworth *et al.*, 2011).

Another reason for our findings that PA did not predict CIMT may be the high prevalence of overweight (34%) and obesity (39%) in this population. The prevalence of overweight and obesity was consistent with a recent South African study among municipal workers in South Africa (Muluvhu *et al.*, 2019) and with the South African statistics noted in the recent World Health Organization Overweight and Obesity report (WHO, 2017c).

A moderate significant positive association was observed between WC and CIMT among the teachers who were overweight and sedentary; and in the obese teachers participating in light PA. This result was in agreement with previous results whereby strong associations between abdominal obesity and the risk of developing CVD were reported (Yusuf *et al.*, 2005; Balkau *et al.*, 2007; Casanueva *et al.*, 2010), and congruent with information in articles on middle-aged adults from Finland, USA, Korea and China (Lakka *et al.*, 2001; Lo *et al.*, 2006; Park *et al.*, 2015; Arnold *et al.*, 2019). In our study, however, we did find a significant positive association between CIMT and BMI in the sedentary obese participants. These results were similar to the study of Arnold *et al.* (2019), in which a weak positive association between CIMT and BMI in middle-aged Chinese adults was found.

The results of our study also indicated a weak significant positive relationship between CIMT and AEE in light PA obese individuals. One can speculate that the high prevalence of overweight and obesity might

have contributed to the weak positive correlation, due to the large mean body size of the participants (BMI 29.36 kg/m^2), as energy expenditure increases with increased body size (Westerterp, 2017). Larger body sizes, regardless of the level of PA, might have struggled to achieve a 5- to 20-fold increase in metabolic rate compared with non-obese individuals (Westerterp, 2017). The moderate negative association between CIMT and BMI in the obese sedentary participants may also be explained by the use of BMI, which does not differentiate between fat mass and lean body mass but only considers a person's weight and height; therefore WC may be a stronger predictor of increased CIMT than BMI (Lakka *et al.*, 2001; Tankó *et al.*, 2005; Lo *et al.*, 2006; Kotsis *et al.*, 2006; Sturm *et al.*, 2009; Ortega-Loubon *et al.*, 2019).

In our study, more than one-third (41%) of the participants had elevated CRP >3 mg/L, which is considered to be high when compared to the middle-aged adults (40–79 years) from the EPIC-Norfolk study, which also revealed that more than a third of their participants had elevated CRP (Ahmadi-Abhari *et al.*, 2013). The high prevalence of CRP >3mg/L may be explained by the high prevalence of overweight and obesity in our study population, as CRP (an inflammatory marker) is often increased in persons with increased abdominal obesity (Bastien *et al.*, 2014). Thus, this study indicates the importance of assessing cardio-metabolic risk in South African teachers regardless of their PA status. Teaching is a physically inactive occupation and future research should focus on providing PA interventions to teachers to reduce cardio-metabolic risk factors, especially physical inactivity and overweight/obesity.

Potential limitations to this study may include the cross-sectional design of the study, which prohibited possible detection of longitudinal changes in CIMT; future studies should focus on a longitudinal design to investigate changes in CIMT and PA over time. The study population is not representative of all South African teachers; as teachers were only sampled in one province of South Africa it may not be possible to generalise the results to the whole South African population. The strict adherence to the wearing time of the ActiHeart device limited the study sample. Individual step test calibration of the ActiHeart device was not performed due to the vast amount of participants, limited time and the high-risk profiles of the participants; however, participants were thoroughly interviewed about their habitual PA patterns.

CONCLUSION

Significant positive relationships between CIMT and WC were observed in this study; however, including PA in the analysis did not yield any significant observable effect on the relationships between CIMT and body composition variables. The study reported a high prevalence of physical inactivity, high CRP and overweight/obesity in the sampled population and these factors may have diminished the protective role of PA in the relationship between CIMT and obesity. Given the risk profile of the teachers, effective PA intervention and education programmes should be implemented to reduce their CVD risk.

FUNDING INFORMATION

The SABPA-study is funded by the Hypertension in Africa Research Team (HART; North-West University), the North West Education Department, the Medical Research Council (MRC) of South Africa, the National Research Foundation (NRF) of South Africa, Roche Diagnostics, South Africa and the Metabolic Syndrome Institute, France. The funding institutions played no role in the design and conduct of the study; collection, management, analysis and interpretation of the data; or preparation of the manuscript. The views expressed in this article are those of the authors and not necessarily the funding bodies.

DISCLAIMER

The views and opinions, findings and conclusions or recommendations expressed in this article are those of the authors and do not reflect any official policy or position of any affiliated agency and therefore the NRF and MRC do not accept any liability in this regard.

REFERENCES

AHMADI-ABHARI, S., LUBEN, R.N., WAREHAM, N.J. & KHAW, K.T. (2013). Seventeen year risk of all-cause and cause-specific mortality associated with C-reactive protein, fibrinogen and leukocyte count in men and women: The EPIC-Norfolk study. *European Journal of Epidemiology*, 28(7):541–550. DOI:10.1007/s10654-013-9819-6

AINSWORTH, B.E., HASKELL, W.L., HERRMAN, S.D., MECKES, N., BASSETT, D.R., TUDOR-LOCKE, C., GREER, J.L., VEZINA, J., WHITT-GLOVER, M.C. & LEON, A.S. (2011). Compendium of physical activities: a second update of codes and MET values. *Medicine and Science in Sports and Exercise*, 43(8):1575–1581.

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. & SMITH, 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. DOI:10.1161/CIRCULATIONAHA.109.192644

ARNOLD, M., LINDEN, A., CLARKE, R., GUO, Y., DU, H., BIAN, Z., WAN, E., YANG, M., WANG, L., CHEN, Y., CHEN, J., LONG, H., GU, Q., COLLINS, R., LI, L., CHEN, Z. & PARISH, S. (2019). Carotid intima-media thickness but not carotid artery plaque in healthy individuals is linked to lean body mass. *Journal of American Heart Association*, 8(15):1–13. DOI:10.1161/ JAHA.118.011919

ASHWELL, M. & HSIEH, S.D. (2005). Six reasons why the waist-to-height ratio is a rapid and effective global indicator for health risks of obesity and how its use could simplify the international public health message on obesity. *International Journal of Food Science and Nutrition*, 56(5):303–307. DOI:10.1080/09637480500195066

BALKAU, B., DEANFIELD, J.E., DESPRÉS, J.P., BASSAND, J.P., FOX, K.A.A., SMITH, S.C., BARTER, P., TAN, C.E., VAN GAAL, L., WITTCHEN, H.U., MASSIEN, C. & HAFFNER, S.M. (2007). International day for the evaluation of abdominal obesity (IDEA): A study of waist circumference, cardiovascular disease, and diabetes mellitus in 168 000 primary care patients in 63 countries. *Circulation*, 116(17):1942–1951. DOI:10.1161/CIRCULATIONAHA.106.676379

BASTIEN, M., POIRIER, P., LEMIEUX, I. & DESPRÉS, J.-P. (2014). Overview of Epidemiology and Contribution of Obesity to Cardiovascular Disease. *Progress in Cardiovascular Disease*, 56(4):369–381. DOI:http://dx.doi.org/10.1016/j.pcad.2013.10.016

BLAIR, S.N. (2009). Physical inactivity: the biggest public health problem of the 21st century. *British Journal of Sports Medicine*, 43(1):1–2. DOI:10.1016/j.annepidem.2009.01.019

BRAGE, S., BRAGE, N., FRANKS, P.W., EKELUND, U., WONG, M.Y., ANDERSEN, L.B., FROBERG, K. & WAREHAM, N.J. (2004). Branched equation modeling of simultaneous accelerometry and heart rate monitoring improves estimate of directly measured physical activity energy expenditure. *Journal of applied physiology, 96*(1), pp.343-351. DOI: 10.1152/japplphysiol.00703.2003.

BYRKJELAND, R., STENSAETH, K.-H., ANDERSSEN, S., NJERVE, I.U., ARNESEN, H., SELJEFLOT, I. & SOLHEIM, S. (2016). Effects of exercise training on carotid intima-media thickness in patients with type 2 diabetes and coronary artery disease. *Cardiovascular Diabetology,* 15(1):1–13. DOI:10.1186/s12933-016-0336-2

CASANUEVA, F.F., MORENO, B., RODRÍGUEZ-AZEREDO, R., MASSIEN, C., CONTHE, P., FORMIGUERA, X., BARRIOS, V. & BALKAU, B. (2010). Relationship of abdominal obesity with cardiovascular disease, diabetes and hyperlipidaemia in Spain. *Clinical Endocrinology,* 73(1):35–40. DOI:10.1111/j.1365-2265.2009.03727.x

COHEN, J.W. 1988. Statistical power analysis for behavioural sciences. 2nd edn. Hillsdale, NJ:Lawrence Erlbaum Associates.

GUTHOLD, R., STEVENS, G.A., RILEY, L.M. & BULL, F.C. (2018). Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys. *Lancet Global Health,* 6(10):1077–1086. DOI:http://dx.doi.org/10.1016/ S2214-109X(18)30357-7

HAMER, M., BRUWER, E.J., DE RIDDER, J.H., SWANEPOEL, M., KENGNE, A.P., COCKERAN, M. & MALAN, L. (2017). The association between seven-day objectively measured habitual physical activity and 24 h ambulatory blood pressure: the SABPA study. *Journal of Human Hypertension*; 31:409–414. DOI:10.1038/jhh.2016.93

JIN, Y., KIM, D., CHO, J., LEE, I., CHOI, K. & KANG, H. (2018). Association between obesity and carotid intima-media thickness in Korean office workers: The mediating effect of physical activity. *Biomed Research International*, 2018:1–10. DOI:https://doi.org/10.1155/2018/4285038

KADOGLOU, N.P.E., ILIADIS, F. & LIAPIS, C.D. (2008). Exercise and Carotid Atherosclerosis. *European Journal for Vascular and Endovascular Surgery,* 35(3):264–272. DOI:10.1016/j.ejvs.2007.08.022

KOTSIS, V.T., STABOULI, S. V., PAPAMICHAEL, C.M. & ZAKOPOULOS, N.A. (2006). Impact of obesity in intima-media thickness of carotid arteries. *Obesity,* 14(10):1708–1715.

LAKKA, T.A., LAKKA, H.M., SALONEN, R., KAPLAN, G.A. & SALONEN, J.T. (2001). Abdominal obesity is associated with accelerated progression of carotid atherosclerosis in men. *Atherosclerosis*, 154(2):497–504.

LAURENCE, E.C., VOLMINK, J., ESTERHUIZEN, T.M., DALAL, S. & HOLMES, M.D. (2016). Risk of cardiovascular disease among teachers in Cape Town: Findings of the South African PaCT pilot study. *South African Medical Journal,* 106(10):996–1001. DOI:10.7196/SAMJ.2016.v106i10.10869

LIANG, Q., WENDELHAG, I., WIKSTRAND, J. & GUSTAVSSON, T. (2000). A multiscale dynamic programming procedure for boundary detection in ultrasonic artery images. *IEEE Transactions on Medical Imaging,* 19(2):127–142.

LO, J., DOLAN, S.E., KANTER, J.R., HEMPHILL, L.C., CONNELLY, J.M., LEES, R.S. & GRINSPOON, S.K. (2006). Effects of obesity, body composition, and adiponectin on carotid intima-media thickness in healthy women. *Journal of Clinical Endocrinology and Metabolism,* 91(5):1677–1682. DOI:10.1210/jc.2005-2775

MALAN, L., HAMER, M., FRASURE-SMITH, N., STEYN, H.S. & MALAN, N.T. (2015). Cohort profile: Sympathetic activity and ambulatory blood pressure in Africans (SABPA) prospective cohort study. *International Journal of Epidemiology,* 44(6):1814–1822. DOI:https://doi.org/10.1093/ije/dyu199

MULUVHU, T.C., MONYEKI, M.A., STRYDOM, G.L. & TORIOLA, A.L. (2019). Cardiovascular topics – Relationship between obesity and blood pressure among employees in the Vhembe district municipality of Limpopo Province, South Africa. *Cardiovascular Journal of Africa,* 30(6):1–8. DOI:10.5830/CVJA-2019-035

ORTEGA-LOUBON, C., FERNÁNDEZ-MOLINA, M., SINGH, G. & CORREA, R. (2019). Obesity and its cardiovascular effects. *Diabetes/Metabolism Research and Reviews,* 35(4):1–11. DOI:10.1002/dmrr.3135

PARK, J.K., PARK, H. & KIM, K.B. (2015). The relationship between distribution of body fat mass and carotid artery intima-media thickness in Korean older adults, *Journal of Physical Therapy Science,* 27(10):3141–3146.

PARSONS, T.J., SARTINI, C., ELLINS, E.A., HALCOX, J.P.J., SMITH, K.E., ASH, S., LENNON, L.T., WANNAMETHEE, S.G., LEE, I.-M., WHINCUP, P.H. & JEFFERIS, B.J. (2016). Objectively measured physical activity, sedentary time and subclinical vascular disease: a cross-sectional study in older British men. *Preventive Medicine,* 89:194–199. DOI:http://dx.doi.org/10.1016/j.ypmed.2016.05.031

PIEPOLI, M.F., HOES, A.W., AGEWALL, S., ALBUS, C., BROTONS, C., CATAPANO, A.L., COONEY, M-T., CORRÀ, U., COSYNS, B., DEATON, C., GRAHAM, I., HALL, M.S., HOBBS, F.D.R., LØCHEN, M-L., LÖLLGEN, H., MATQUES-VIDAL, P., PERK, J., PRESCOTT, E., REDON, J., RICHTER, D.J., SATTAR, N., SMULDERS, Y., TIBERI, M., VAN DER WORP, H.B., VAN DIS, I. & VERSCHUREN, W.M.M. (2016) European Guidelines on cardiovascular disease prevention in clinical practice: The Sixth Joint Task Force of the European Society of Cardiology and Other Societies on

Cardiovascular Disease Prevention in Clinical Practice. *European Journal of Preventive Cardiology*, 23(11):NP1–96. DOI:10.1177/2047487316653709

RIDKER, P.M. (2003). Cardiology Patient Page. C-reactive protein: a simple test to help predict risk of heart attack and stroke. *Circulation*, 108(12):1–5.

RIEBE, D., EHRMAN, J.K., LIGUORI, G., MAGAL, M., *Eds*. (2018). ACSM's guidelines for exercise testing and prescription (10th ed.). Philadelphia: Wolhuters Kluwer.

STEWART, A., MARFELL-JONES, M., OLDS, T. & DE RIDDER, J.H. (2011). International standard for anthropometric assessment. (3rd ed.). New Zealand: ISAK.

STURM, W., SANDHOFER, A., ENGL, J., LAIMER, M., MOLNAR, C., KASER, S., WEISS, H., TILG, H., EBENBICHLER, C.F. & PATSCH, J.R. (2009). Influence of visceral obesity and liver fat on vascular structure and function in obese subjects. *Obesity*, 17(9):1783–1788. DOI:10.1038/oby.2009.81

TANKÓ, L.B., BAGGER, Y.Z., QIN, G., ALEXANDERSEN, P., LARSEN, P.J. & CHRISTIANSEN, C. (2005). Enlarged waist combined with elevated triglycerides is a strong predictor of accelerated atherogenesis and related cardiovascular mortality in postmenopausal women. *Circulation*, 111(15):1883–1890. DOI:10.1161/01.CIR.0000161801.65408.8D

TOUBOUL, P.-J., HENNERICI, M.G., MEAIRS, S., ADAMS, H., AMARENCO, P., BORNSTEIN, N., CSIBA, L., DESVARIEUX, M., EBRAHIM, S., FATAR, M., HERNANDEZ HERNANDEZ, R., JAFF, M., KOWNATOR, S., PRATI, P., RUNDEK, T., SITZER, M., SCHMINKE, U., TARDIF, J.-C., TAYLOR, A., VICAUT, E., WOO, K.S., ZANNAD, F. & ZUREIK, M. (2007). Mannheim carotid intima-media thickness consensus (2004–2006). *Cerebrovascular Disease*, 23(1):75–80. DOI:10.1159/000097034

WENDELHAG, I., LIANG, Q., GUSTAVSSON, T. & WIKSTRAND, J. (1997). A new automated computerized analyzing system simplifies readings and reduces the variability in ultrasound measurement of intima-media thickness. *Stroke*, 28(11):2195–2200. DOI:https://www.ahajournals.org/doi/10.1161/01.STR.28.11.2195

WESTERTERP, K.R. (2017). Control of energy expenditure in humans. *European Journal of Clinical Nutrition*, 71(3):340–344. DOI:10.1038/ejcn.2016.237

WHO (WORLD HEALTH ORGANISATION). (2010). Global recommendations on physical activity for health. [https://apps.who.int/iris/bitstream/handle/10665/44399/9789241599979_eng.pdf;jsessionid=04C423D4CAE804D52D889A6E370BA2ED?sequence=1]. (Retrieved on 16 July 2019.)

WHO (WORLD HEALTH ORGANIZATION). (2017a). Global health observatory data repository: Prevalence of overweight among adults, BMI ≥ 25. Hyperlink: [http://apps.who.int/gho/data/view.main.BMI25Cv?lang=en]. (Retrieved on 17 September 2019.)

WHO (WORLD HEALTH ORGANIZATION). (2017b). Global health observatory data repository: Prevalence of obesity among adults, BMI ≥ 30. Hyperlink: [http://apps.who.int/gho/data/view.main.BMI30Cv?lang=en]. (Retrieved on 17 September 2019.)

WHO (WORLD HEALTH ORGANIZATION). (2017c). Overweight and Obesity. Geneva. Hyperlink: [https://www.who.int/gho/ncd/risk_factors/overweight/en/]. (Retrieved on 22 August 2019.)

WHO (WORLD HEALTH ORGANIZATION). (2018). Prevalence of insufficient physical activity among adults. Hyperlink: [http://apps.who.int/gho/data/view.main.2463?lang=en]. (Retrieved on 16 July 2019.)

YUSUF, S., HAWKEN, S., ÔUNPUU, S., BAUTISTA, L., FRANZOSI, M.G., COMMERFORD, P., LANG, C.C., RUMBOLDT, Z., ONEN, C.L., LISHENG, L., TANOMSUP, S., WANGAI, P., RAZAK, F., SHARMA, A.M. & ANAND, S.S. (2005). Obesity and the risk of myocardial infarction in 27 000 participants from 52 countries: A case-control study. *Lancet*, 366(9497):1640–1649.

CHAPTER 5:

ARTICLE 3

The relationship between physical activity status, body fatness and cardio-metabolic syndrome in a cohort of urban South African teachers: the SABPA-study

Tamrin Veldsman[1] (MSc), Mariette Swanepoel[1] (PhD), Makama A Monyeki[1] (PhD), Johanna S Brits[2] (PhD), Leoné Malan[2] (RN, PhD)

[1]*Physical Activity, Sport and Recreation Research Focus Area (PhASRec), Faculty of Health Sciences, North-West University, Potchefstroom, South Africa*

[2]*Hypertension in Africa Research Team (HART), North-West University, Potchefstroom, South Africa*

Corresponding author's address:

Ms Tamrin Veldsman

Private Bag X6001, North-West University, Potchefstroom, South Africa, 2531

Email: Tamrin.Veldsman@nwu.ac.za

Telephone: +27 18 299 2187 Fax: +27 87 231 5480

Manuscript word count: 5962 words (excluding abstract and references)

Abstract word count: 276 words

This article is prepared for submission to: *African Journal of Primary Health Care and Family Medicine (PHCFM).*

ABSTRACT

Background: The global prevalence of cardio-metabolic syndrome (MS) is increasing due to increased levels of physical inactivity and obesity. In South Africa, information about teachers' physical activity (PA) status, body fatness and MS is limited.

Aim: To assess the relationship between PA status, body fatness (i.e. body mass index, waist circumference and waist-to-height ratio) and MS in a cohort of urban South African teachers.

Setting: The study setting was Dr Kenneth Kaunda District, North West Province, South Africa.

Methods: A cross-sectional study on a secondary data of 216 teachers aged 25–65 years was conducted. Anthropometry and biochemical measurements were taken, PA was objectively measured and lifestyle behaviours were examined. The Statistical Package for Social Science (SPSS v.26) was used to analyse the data. Correlation coefficients and partial correlations were calculated in the analysis of participants with and without MS. Statistical significance was set as $p \leq 0.05$.

Results: In this study, 29% of the participants (46% male; 13% female) were classified with MS; 33% of total participants were sedentary and 67% participated in light activity. A weak significant negative relationship was found between mean 7-day awake METs and triglycerides (r = -0.29; p = 0.02), and weak inconclusive borderline negative associations found between gamma-glutamyl transferase and mean 7-day awake metabolic equivalent of task (METs) (r = -0.25; p = 0.06), activity energy expenditure (r = -0.24; p = 0.06) and physical activity level (r = -0.23; p = 0.07). After adjustments for age group, self-reported smoking and alcohol use, a weak significant negative relationship between mean 7-day awake METs and triglycerides (r = -0.28; $p < 0.01$) remained with small changes.

Conclusion: In the teachers with MS, only one MS marker, triglycerides showed an inconclusive negative association with PA. Physical activity could therefore be beneficial in the regulation of triglycerides. Physical activity intervention studies and education on the benefits of PA and healthy lifestyle choices are recommended.

Keywords: body fatness, cardio-metabolic syndrome, physical activity status, SABPA-study, teacher

BACKGROUND

The global prevalence of cardio-metabolic syndrome (MS) is increasing, becoming both a clinical and public health concern.[1-2] The number of people diagnosed with MS and therefore at risk for developing cardiovascular disease (CVD) in the next 5–10 years is set to double in persons with MS and will have 1.5 times increased risk of all-cause mortality compared with apparently healthy individuals. [1,3] Cardio-metabolic syndrome refers to a complex cluster of metabolic risk factors in the development of CVD and diabetes, which include elevated blood pressure (BP), triglyceride and total cholesterol levels; low high-density lipoprotein (HDL) levels; and central obesity.[1,4-5]

The global prevalence of MS is estimated to be between 17% and 25%. [6] In urban South Africa, MS varies between 0% and 50 % or higher depending on the definition of MS used and the population studied.[6] In a study conducted in an urban community in Free State Province, South Africa, 39.7% of participants had three or more risk factors for MS [7], and in Gauteng Province, South Africa, 29% of Africans were diagnosed with MS.[8] The variance in the prevalence may be explained by differences in the MS diagnostic criteria.[9] Regarding the different diagnostic criteria for MS,[10] the most commonly used criteria include those of the World Health Organization (WHO), International Diabetes Federation (IDF) and the National Cholesterol Education Program Adult Treatment Panel (NCEP ATP III). However, in 2009, the Joint Interim Statement (JIS) by the IDF, National Heart, Lung and Blood Institute, American Heart Association, World Heart Federation, International Atherosclerosis Society and International Association for the Study of Obesity proposed a harmonised definition of MS that takes into account the different waist circumferences (WCs) of different ethnic groups.[1]

Physical inactivity is a major risk factor in the development of MS and increases the odds of developing MS by 73%.[11-12] The increasing prevalence of physical inactivity and obesity may lead to an increased global prevalence of MS.[1,9] Physical inactivity is inversely associated with health outcomes.[13] Additionally, in both self-reported[14-15] and objective data[13,16], low levels of PA are reported to be associated with MS. Abdominal obesity is a common sign in a person presenting with MS.[1] Moderate and high levels of PA are associated with reduced odds of developing MS.[17] Due to the increasing global prevalence of MS and the health consequences thereof, the risk factors for MS across the population need to be well understood.[13]

Teachers are considered to be physically inactive and spent most of their working time in sedentary or light energy-cost activities.[18] In a South African study, 18.7% of teachers in Cape Town were at risk of having a heart attack or stroke within the next 10 years, and more than half of the teachers were overweight or obese.[19] Due to the working conditions of teachers, which foster high levels of inactivity, the high prevalence of overweight and obesity in teachers, and their high risk of developing a CVD, studies are needed to investigate the prevalence of MS and the relationships among MS, PA status and body fatness. The aim of this study was therefore to assess the relationships between PA status, body fatness and MS in a cohort of urban South African teachers.

METHODS

Study design

This cross-sectional study made use of secondary data from the Sympathetic Activity and Ambulatory Blood Pressure in Africans (SABPA) prospective cohort study (N=409).[20]

Study population and sampling

The study sample comprised of urbanised African teachers in Dr Kenneth Kaunda District in North West Province, South Africa. The reason this target population was chosen; was to obtain a homogenous sample from a similar socioeconomic class. Participants between 25 and 65 years were included, but were excluded from the SABPA-study if they were pregnant, lactating, using α- or β-blockers, had psychotropic substance dependence, were blood donors or had been vaccinated in the previous 3 months, or had an ear temperature higher than 37° C. Only participants who wore the ActiHeart for a full 7 days with less than 40 minutes improper ActiHeart contact time (N=216) were included. Detailed methodology of the cohort profile of the SABPA-study has been published elsewhere.[20] Power analyses were performed for the SABPA cohort study using previous studies. Ambulatory dysfunction[21] and cortisol data[22-23] were used to obtain relative effect sizes based on differences in biological profiles and genotyping hypothalamic-pituitary-adrenal axis variation. This resulted in sample sizes of 50–416 to explain biological differences and to detect single nucleotide polymorphisms with a statistical power of 0.8 and a level of significance of 0.05.[21-23] Since the current study is part of the SABPA prospective cohort study by virtue, the group size of selected participants that met the inclusion criteria was within the range of 50–416 participants.

Data collection

Anthropometric measurements

A level 2 kinanthropometrist measured participants' height (cm), weight (kg) and WC (cm). Participants wore minimal clothing, according to the recommendations of the International Society for the Advancement of Kinanthropometry (ISAK). [24] The body mass index (BMI) of participants was calculated by dividing body weight in kilograms by height in metres squared.[24] Waist-to-height ratio (WHtR) was calculated by dividing WC by height in cm. [25] Intra- and inter-observer variability were less than 10%.

Biochemical measurements

A sterile winged infusion set was used to obtain blood samples from the antebrachial vein branches of the right arm by a registered nurse, handled according to standardised procedures, and stored at –80° C until blood analyses were performed. Sodium fluoride (NaF), HDL, gamma-glutamyl transferase (GGT) and triglycerides were measured and analysed using the Konelab 20i sequential multiple analyser computer

(SMAC) (Thermo Scientific, Vantaa, Finland) and Unicel DXC 800 (Beckman and Coulter, Germany) at accredited independent laboratories. Inter- and intra-variability were less than 5%.

Lifestyle behaviour

A closed ended (yes/no) indication was used to determine the participants' smoking habits and alcohol usage. Objectively measured GGT was also used as a measure of alcohol usage.

Blood pressure

Resting BP was measured with a sphygmomanometer (1.3M^{TM} Littman® II S.E. Stethoscope 2205, Reister CE 0124, No. 1010–108 Diplomat-presameter®, Germany) on the non-dominant arm using the Rica/Rocci Korotkoff method. After 5 minutes, the measurement was repeated, and the second measurement was used for the MS criteria for BP.[1]

Cardio-metabolic syndrome

Participants were classified with MS when three or more of the risk factors for MS were present, according to the JIS.[1] Waist circumference was classified as a risk at ≥94 cm and ≥80 cm for Caucasian males and females, respectively[1], and WC for Africans was classified as a risk at ≥90 cm for males and ≥98 cm for females.[26] Other risk factors for MS included HDL in males ≤1.0 mmol/L and in females ≤1.3 mmol/L; triglycerides ≥1.70 mmol/L; fasting glucose ≥5.60 mmol/L; systolic BP (SBP) ≥130 mmHg; and diastolic BP (DBP) ≥85 mmHg and persons who were on hypertensive treatment.[1]

Physical activity

The PA of participants was measured over seven consecutive days with an ActiHeart (GNO/67703, CamNtech Ltd., Cambridgeshire, UK) combined heart rate and accelerometer device. Participants' resting heart rate was obtained from a resting 12-lead electrocardiogram (NORAV Medical Ltd PC 1200, software version 5.030, Kiryat Bialik, Israel) performed by a registered nurse. The resting heart rate was used to calculate the sleep heart rate (resting heart rate minus 10 beats per minute) required by the ActiHeart programme when the device was fitted to the participants. Individual step test calibration was not performed due to the high cardiovascular risk profile of the participants and time constraints during data collection because of the large number of participants; however, a biokineticist (clinical exercise physiologist) thoroughly questioned the participants about their weekly PA behaviour, to choose a PA level to programme the ActiHeart. Heart rate, the metabolic equivalent of task (MET, 1 MET regarded as being asleep) and activity level were used to differentiate sleeping time from awake time. When a gradual decrease in heart rate was measured during the evenings (with 15 or more epochs) to below average heart rate in a sedentary awake-time sample period, and the activity level was equal to zero, the participant was considered asleep. The end of sleeping time could be seen by an immediate increase in the participant's heart rate of more than 10–20 beats per minute relative to the above sleeping heart rate together with an increased MET and activity

level. The distribution of PA intensity was expressed as sedentary (>1.5 METs), time spent in light PA (1.5–3 METs) and time spent in moderate-to-vigorous PA (>3 METs).[27] The total energy expenditure (TEE) of an individual was expressed in kilocalories (kcal) and was composed of the resting energy expenditure (REE), diet-induced energy expenditure (DEE) and activity-induced energy expenditure (AEE). Physical activity level (PAL) was calculated as TEE/REE.[28]

Data analysis

Data were analysed using the Statistical Package for Social Sciences (SPSS) version 26 (Inc., Chicago, IL, USA). The data distribution was evaluated using histograms Quantile-Quantile plots. Descriptive statistics (means, standard deviations) were calculated for PA status, body fatness (i.e. BMI, WC and WHtR) and MS. Frequencies for percentages were calculated. The independent T-test for normally distributed data was used to determine the differences among groups. Chi-square was used to determine significant differences between the expected frequencies and the observed frequencies in one or more categories. For data that was not normally distributed, Mann-Whitney U test was used to compare significant differences between two independent groups when the dependent variable was either ordinal or continuous. To study the relationship between PA status, body fatness (i.e. BMI, WC and WHtR) and MS, correlation coefficients were calculated, and partial correlation controlled for age, sex and lifestyle behaviour (smoking and alcohol drinking [GGT]) for the entire group and for those with MS and without MS. Correlation coefficient values were classified as follows: <0.10 indicates a weak correlation, 0.30 – 0.5 indicates a moderate correlation and ≥0.50 indicates a large correlation. Statistical significance was set at $p \leq 0.05$. [29]

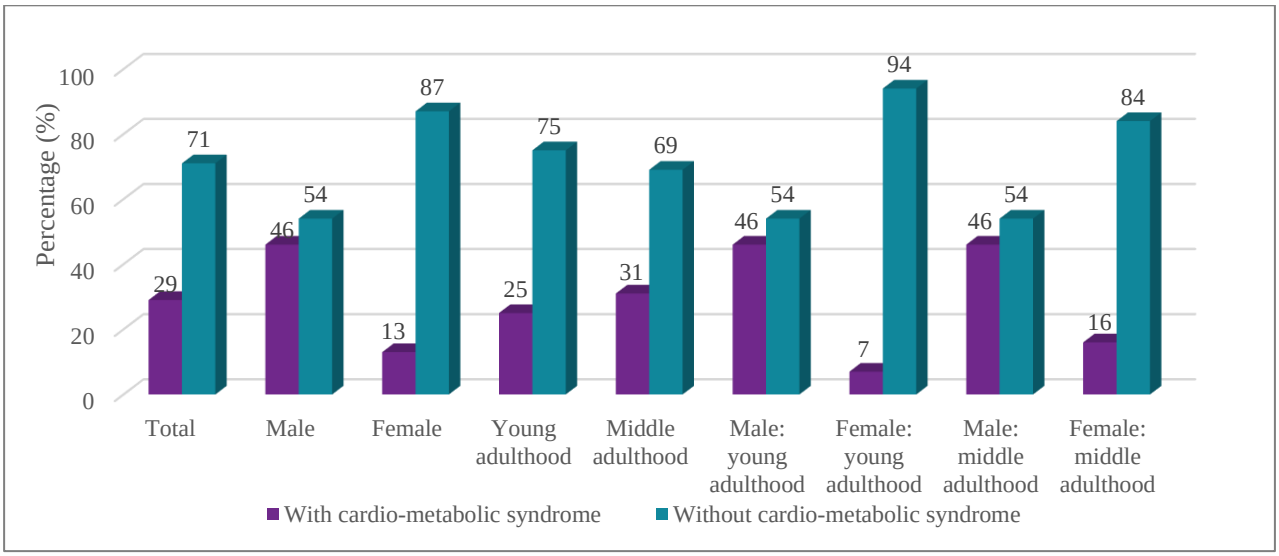
Ethical considerations

Ethical clearance was obtained from the Health Research Ethics Committee (HREC) of North-West University (00036-07-S6), and the study conformed to the ethical principles outlined in the Declaration of Helsinki (revised 2004). Permission for this study was obtained from the North West Department of Education, as well as the South African Democratic Teachers' Union. Before recruitment, participants were informed about the study and assistance was available to participants who preferred to receive the information in their home language. Participants were allowed to refuse data collection, and were not contacted again. The anonymity and confidentiality of participants were assured throughout the study, by allocating a coded number to each participant.

RESULTS

From a total of 216 teachers, 29% were classified with MS, with almost half of the male teachers (46%) classified with MS (Fig. 1). After dividing the participants into age groups according to the guidelines suggested by Statistics: Provisional Guidelines on Standard International Age Classification of 1982 (UNDESA, 1982)[30], more middle adulthood (45–64 years) teachers (31%) than young adulthood (25–44

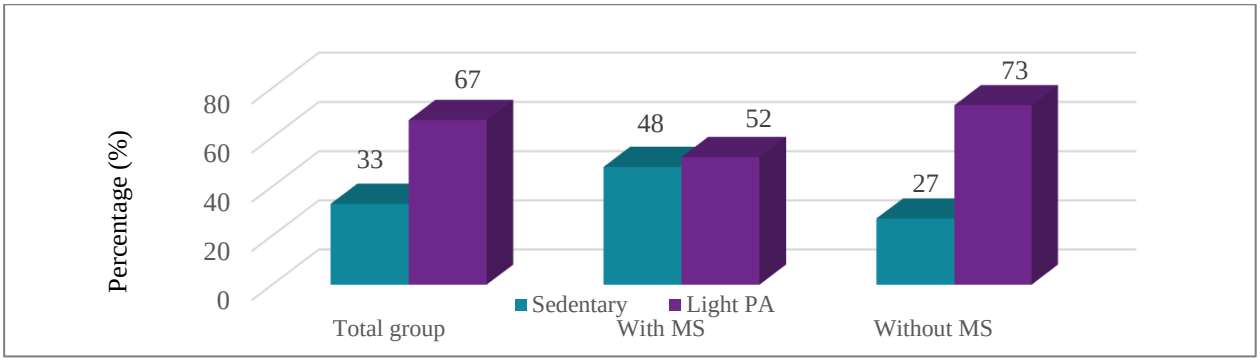
years) teachers (25%) were found to present with MS. Almost half of the males in both age groups (46%) presented with MS.



Young adulthood = 25–44 years, middle adulthood = 45–64 years.

Figure 1: The prevalence of cardio-metabolic syndrome among teachers

Figure 2 depicts the PA status among the entire group of teachers and according to classification as presenting with or without MS. In the entire group of teachers, 33% were sedentary and 67% were classified as lightly active. In the teachers with MS, almost half (48%) were classified as sedentary and 52% were classified as participating in light PA. In persons who did not present with MS, 73% of the participants were considered to be lightly active.

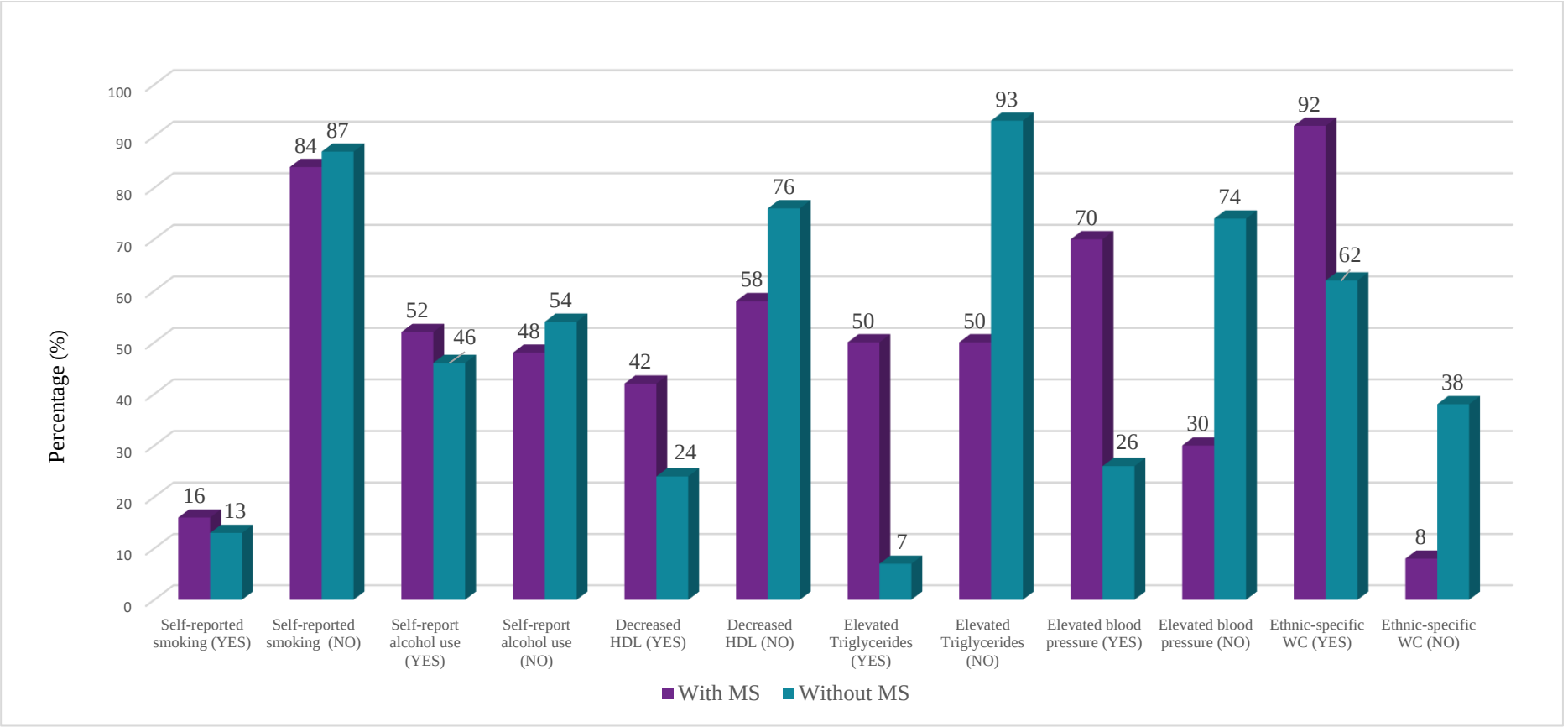


MS = cardio-metabolic syndrome

Figure 2: The prevalence of sedentary and light physical activity among teachers with and without cardio-metabolic syndrome

Figure 3 indicates the prevalence of cardio-metabolic risk factors and lifestyle behaviours among teachers presenting with MS and without MS. Among the teachers presenting with MS, the highest prevalence risk factor (92%, 58/63) was having a WC larger than the ethnic-specific cut-points developed by Prinsloo and

colleagues (2011). [26] The second highest prevalence cardio-metabolic risk factor was having BP equal to or higher than 130/85 mmHg (70%). [1] More than half (52%) of the participants reported drinking alcohol. Elevated triglyceride levels were present in half of the teachers (50%), and decreased HDL was present in almost half (42%) of the teachers. The prevalence of self-reported smoking was 16%. Furthermore, the results showed that HDL concentrations in teachers presenting with MS were significantly lower (Mann-Whitney *U*: 3852.00, $p = 0.008$) than in those without MS. Also, elevated triglycerides and BP were both significantly higher in teachers presenting with MS (Mann-Whitney *U*: 2681.50 and 2349.00, $p < 0.001$) than in those without MS. The teachers classified in the MS category (n=58) had significantly higher WC (Mann-Whitney *U*, 3375.33, $p < 0.001$) than those without MS (n=5).



MS = cardio-metabolic syndrome; Yes = risk factor; No = no risk

Figure 3: Distribution of prevalence of cardio-metabolic risk factors and lifestyle behaviours among teachers presenting with and without cardio-metabolic syndrome

Table 1 depicts the characteristics of the teachers according to diagnosis of MS. Teachers with MS were significantly taller ($p < 0.002$; 172.48±9.89 cm vs 167.73±10.00 cm) and heavier ($p < 0.001$; 93.91±19.43 kg vs 79.42±18.13 kg) than those without MS, and had significantly greater BMI ($p = 0.001$; 31.71±6.92 kg/m^2 vs 28.39±6.06 kg/m^2), WC (106.59±15.28 cm vs 92.20±14.23 cm) and WHtR ($p < 0.001$; 0.62±0.10 vs 0.55±0.08). GGT in teachers with MS (71.83±87.40 U/L) was more than double that of the teachers without MS (32.50±34.36 U/L). Total cholesterol ($p < 0.001$; 4.92±1.14 mmol/L vs 4.27±0.91 mmol/L), triglyceride ($p < 0.001$; 1.80±1.10 mmol/L vs 1.02±0.50 mmol/L) and glucose values (6.34±2.92 mmol/L vs 4.48±0.74 mmol/L) were significantly higher in teachers with MS than those without MS. SBP ($p < 0.001$; 141.98±15.14 mmHg vs 123.80±16.80 mmHg) and DBP ($p < 0.001$; 93.95±8.73 vs 83.04±10.74 mmHg) were also significantly higher in teachers with MS.

Table 1: Descriptive characteristics of participants presenting with cardio-metabolic syndrome and participants without cardio-metabolic syndrome

	MS	N	Mean±SD	*t*	*df*	*p*-value
Age (years)	YES	63	51.25±8.11	1.783	214	0.07
	NO	153	49.01±8.50			
Mean 7-day awake METs	YES	63	1.85±0.70	-1.403	214	0.16
	NO	153	2.00±0.68			
AEE (kcal/wk)	YES	63	1183.89±998.66	-0.619	214	0.53
	NO	153	1282.03±1083.19			
TEE (kcal/wk)	YES	63	3291.41±1188.29	0.201	214	0.84
	NO	153	3250.99±1400.56			
PAL	YES	63	1.99±0.68	-0.878	214	0.38
	NO	153	2.08±0.63			
Height (cm)	YES	63	172.48±9.89	3.181	214	0.002*
	NO	153	167.73±10.00			
Weight (kg)	YES	63	93.91±19.43	5.224	214	<0.001*
	NO	153	79.42±18.13			
BMI (kg/m^2)	YES	63	31.71±6.92	3.496	214	0.001*
	NO	153	28.39±6.06			
WC (cm)	YES	63	106.59±15.28	6.608	214	<0.001*
	NO	153	92.20±14.23			
GGT (U/L)	YES	61	71.83±87.40	4.724	213	<0.001*
	NO	152	32.50±34.36			
TC (mmol/L)	YES	62	4.92±1.14	4.724	213	<0.001*
	NO	153	4.27±0.91			
HDL (mmol/L)	YES	62	0.99±0.34	-1.36	212	0.17
	NO	152	1.06±0.33			
Glucose (mmol/L)	YES	62	6.34±2.92	7.32	212	<0.001*
	NO	152	4.48±0.74			
TG (mmol/L)	YES	62	1.80±1.10	7.083	213	<0.001*
	NO	153	1.02±0.50			
SBP (mmHg)	YES	63	141.98±15.14	7.432	214	<0.001*
	NO	153	123.80±16.80			
DBP (mmHg)	YES	63	93.95±8.73	7.144	214	<0.001*
	NO	153	83.04±10.74			
WHtR	YES	63	0.62±0.10	5.332	214	<0.001*
	NO	153	0.55±0.08			

YES = participants with cardio-metabolic syndrome (MS); NO = participants without cardio-metabolic syndrome
AEE = activity energy expenditure; BMI = body mass index; DBP = diastolic blood pressure; GGT = gamma-glutamyl transferase; HDL = high-density lipoprotein; METs = metabolic equivalent of task; MS = cardio-metabolic syndrome; PAL = physical activity level; SBP = systolic blood pressure; TC = total cholesterol; TEE = total energy expenditure; TG = triglycerides; WC = waist circumference; WHtR = waist-to-height ratio.
* The level of significance is set as $p \leq 0.05$.

Table 2 depicts the relationship between PA status, body fatness (i.e. BMI, WC and WHtR) and cardio-metabolic risk factors in the total group of teachers. In the relationship between PA and the anthropometric variables (BMI, WC and WHtR), a weak significant positive relationship was found between TEE and WC (r = 0.17; p = 0.02). Regarding the relationship between PA and the cardio-metabolic risk factors, AEE (r = -0.19; p = 0.01) and PAL (r = -0.16; p = 0.02) showed a weak significant negative relationship with GGT. Furthermore, an inconclusive weak borderline negative relationship was found between PAL and triglycerides (r = - 0.13; p = 0.06). Regarding the relationship between the anthropometric variables and the cardio-metabolic risk factors, weak and moderate significant positive relationships were found between BMI and GGT (r = 0.28, p < 0.001); glucose (r = 0.35; p < 0.001); triglycerides (r = 0.25; p < 0.001); SBP (r = 0.33; p < 0.001); and DBP (r = 0.29; p < 0.001). Moderate significant positive relationships were observed between WC and GGT (r = 0.38; p < 0.001); glucose (r = 0.44; p < 0.001); triglycerides (r = 0.40; p < 0.001); SBP (r = 0.43; p <0.001) and DBP (r = 0.41; p < 0.001). Between WHtR and the cardio-metabolic risk factors, moderate significant positive relationships were observed with GGT (r = 0.36; p < 0.001); glucose (r = 0.43; p < 0.001); triglycerides (r = 0.33; p < 0.001); SBP (r = 0.40; p < 0.001) and DBP (r = 0.35; p < 0.001).

Table 2: The relationship between physical activity status, body fatness and cardio-metabolic risk factors in a cohort of urban South African teachers

		BMI (kg/m^2)	WC (cm)	Smoking	Alcohol use	GGT (U/L)	Glucose (mmol/L)	TC (mmol/L)	TG (mmol/L)	SBP (mmHg)	DBP (mmHg)	WHtR
AEE (kcal/wk)	*r*	-0.04	-0.02	0.01	0.06	-0.19**	-0.10	0.07	-0.11	-0.07	-0.08	-0.08
	p	0.53	0.73	0.89	0.38	0.01	0.12	0.31	0.12	0.33	0.24	0.26
TEE (kcal/wk)	*r*	0.09	0.17*	-0.05	-0.01	-0.07	-0.003	0.07	0.03	0.03	0.04	0.06
	p	0.21	0.02	0.44	0.89	0.31	0.96	0.29	0.72	0.71	0.60	0.40
PAL	*r*	0.10	0.001	-0.04	0.02	-0.16*	-0.09	-0.05	-0.13$^{\#}$	-0.07	-0.07	0.05
	p	0.13	0.98	0.60	0.75	0.02	0.49	0.51	0.06	0.34	0.34	0.51
BMI (kg/m^2)	*r*	–	0.84**	0.02	-0.03	0.28**	0.35**	0.08	0.25**	0.33**	0.29**	0.91**
	p	–	<0.001	0.77	0.70	<0.001	<0.001	0.27	<0.001	<0.001	<0.001	<0.001
WC (cm)	*r*	0.84**	–	-0.06	-0.11	0.38**	0.44**	0.11	0.40**	0.43**	0.41**	0.92**
	p	<0.001	–	0.40	0.10	<0.001	<0.001	0.11	<0.001	<0.001	<0.001	<0.001
Smoking	*r*	0.02	-0.06	–	0.18**	-0.18**	-0.04	-0.19**	-0.24**	-0.06	-0.08	-0.01
	p	0.77	0.40	–	0.01	0.01	0.54	<0.001	<0.001	0.42	0.22	0.88
Alcohol use	*r*	-0.03	-0.11	0.02**	–	-0.29**	-0.14*	0.01	-0.21**	-0.10	-0.12	-0.03
	p	0.70	0.10	0.01	–	<0.001	0.05	0.89	<0.001	0.15	0.09	0.62
GGT (U/L)	*r*	0.28**	0.38**	-0.18**	-0.29**	–	0.54**	0.21**	0.53**	0.38**	0.40**	0.36**
	p	<0.001	<0.001	0.01	<0.001	–	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Glucose (mmol/L)	*r*	0.35**	0.44**	-0.04	-0.14*	0.54**	–	0.21**	0.46**	0.40**	0.38**	0.43**
	p	<0.001	<0.001	0.54	0.05	<0.001	–	<0.001	<0.001	<0.001	<0.001	<0.001
TC (mmol/L)	*r*	0.08	0.11	-0.19**	0.01	0.21**	0.21**	–	0.37**	0.20**	0.18**	0.13*
	p	0.27	0.11	<0.001	0.89	<0.001	<0.001	–	<0.001	<0.001	0.01	0.05
TG (mmol/L)	*r*	0.25**	0.40**	-0.24**	-0.21**	0.53**	0.46**	0.37**	–	0.28**	0.25**	0.33**
	p	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	–	<0.001	<0.001	<0.001
SBP (mmHg)	*r*	0.33**	0.43**	-0.06	-0.10	0.38**	0.40**	0.20**	0.28**	–	0.84**	0.40**
	p	<0.001	<0.001	0.42	0.15	<0.001	<0.001	<0.001	<0.001	–	<0.001	<0.001
DBP (mmHg)	*r*	0.29**	0.41**	-0.08	-0.12	0.00**	0.38**	0.02**	0.25**	0.84**	–	0.35**
	p	<0.001	<0.001	0.22	0.09	<0.001	<0.001	0.01	<0.001	<0.001	–	<0.001
WHtR	*r*	0.91**	0.92**	-0.01	-0.03	0.36**	0.43**	0.13*	0.33**	0.40**	0.35**	–
	p	<0.001	<0.001	0.88	0.62	<0.001	<0.001	0.05	<0.001	<0.001	<0.001	–

AEE = activity energy expenditure; BMI = body mass index; DBP – diastolic blood pressure; GGT = gamma-glutamyl transferase; PAL = physical activity level; SBP = systolic blood pressure; TC = total cholesterol; TEE = total energy expenditure; TG = triglycerides; WC = waist circumference; WHtR = waist-to-height ratio.
**Correlation is significant at 0.01; *Correlation is significant at 0.001.

Table 3 depicts the Spearman correlation matrix (*rho*) for anthropometric variables and cardio-metabolic risk factors according to teachers presenting with MS and teachers without MS. Regarding the relationship between PA and the cardio-metabolic risk factors in teachers with MS, a weak significant negative relationship between mean 7-day awake METs and triglycerides (r = -0.29; p = 0.02) was found which was not present in those without MS. An inconclusive weak borderline significant negative relationship was found between GGT and mean 7-day awake METs (r = -0.24; p = 0.06); AEE (r = -0.24; p = 0.06) and TEE (r = -0.23; p = 0.07). However, in teachers without MS, only a weak significant negative relationship between mean 7-day awake METs and GGT (r = -20; p = 0.02) was observed. An inconclusive weak borderline significant positive association between AEE and self-reported smoking (r = 0.23; p = 0.07) was found in teachers with MS which was not present in those without MS.

Table 3: Spearman correlation *rho* for anthropometric variables and cardio-metabolic syndrome variables according to teachers presenting with cardio-metabolic syndrome and without cardio-metabolic syndrome

		MS participants (n=62)									
		BMI (kg/m^2)	**WC (cm)**	**Smoking**	**Alcohol use**	**TC (mmol/L)**	**TG (mmol/L)**	**GGT (U/L)**	**SBP (mmHg)**	**DBP (mmHg)**	**WHtR**
Age group	*r*	-0.16	-0.07	0.19	0.13	-0.02	-0.16	-0.23	0.28*	0.01	-0.04
	p	0.20	0.61	0.15	0.32	0.87	0.20	0.07	0.03	0.95	0.77
Mean 7-day awake METS	*r*	0.10	-0.01	0.10	0.14	-0.19	-0.29*	-0.25#	-0.07	0.02	0.05
	p	0.44	0.96	0.43	0.27	0.13	0.02	0.06	0.57	0.86	0.70
AEE (kcal/wk)	*r*	0.07	0.01	0.23#	0.13	0.07	-0.21	-0.24#	0.05	-0.09	0.05
	p	0.59	0.92	0.07	0.31	0.59	0.10	0.06	0.71	0.50	0.72
TEE (kcal/wk)	*r*	0.16	0.13	0.17	0.11	-0.01	-0.19	-0.23#	-0.04	-0.16	0.08
	p	0.23	0.33	0.17	0.41	0.95	0.14	0.07	0.74	0.20	0.55
PAL	*r*	0.16	0.05	0.05	0.06	-0.12	-0.20	-0.18	0.04	0.11	0.15
	p	0.22	0.67	0.69	0.65	0.35	0.12	0.17	0.78	0.40	0.23
		Non-MS participants (n=153)									
Age group	*r*	-0.09	0.000	0.06	0.09	0.22**	0.04	-0.07	0.09	0.02	-0.03
	p	0.30	0.99	0.47	0.28	0.01	0.59	0.43	0.27	0.86	0.70
Mean 7-day awake METS	*r*	0.03	0.01	-0.10	-0.01	-0.02	-0.04	-0.20*	-0.15#	-0.13	-0.03
	p	0.67	0.88	0.21	0.91	0.86	0.61	0.02	0.07	0.11	0.75
AEE (kcal/wk)	*r*	-0.05	0.02	-0.11	0.01	0.08	-0.02	-0.14	-0.04	-0.03	-0.09
	p	0.51	0.79	0.18	0.87	0.31	0.82	0.09	0.61	0.74	0.29
TEE (kcal/wk)	*r*	0.08	0.22**	-0.16	-0.07	0.09	0.12	-0.01	0.06	0.11	0.07
	p	0.33	0.01	0.06	0.42	0.27	0.14	0.94	0.44	0.17	0.42
PAL	*r*	0.13	0.05	-0.09	-0.02	-0.001	-0.03	-0.08	-0.04	-0.04	0.07
	p	0.12	0.53	0.28	0.85	0.99	0.74	0.35	0.59	0.62	0.43

Age groups: Young adulthood = 25–44 years, middle adulthood = 45–64 years.

AEE = activity energy expenditure; BMI = body mass index; DBP = diastolic blood pressure; GGT = gamma-glutamyl transferase; PAL = physical activity level; SBP = systolic blood pressure; TC = total cholesterol; TEE = total energy expenditure; TG = triglycerides; WC = waist circumference; WHtR = waist-to-height ratio.

# indicates borderline significance.

*The level of significance is set as $p \leq 0.05$.

**The level of significance is set as $p \leq 0.01$.

Table 4 depicts the correlation coefficients, adjusted for age group, sex, self-reported smoking and alcohol usage, of the entire group of participants. Regarding the relationship between PA measurements and the cardio-metabolic risk factors, weak significant negative associations were found between mean 7-day awake METs and GGT (r = -0.19; p = 0.01) and triglycerides (r = -0.19; p = 0.01). Additionally, TEE was weakly and negatively related with GGT (r = -0.17; p = 0.02) and triglycerides (r = -0.18; p = 0.01). Also, PAL was weakly negatively associated with triglycerides (r = -0.15; p = 0.03). An inconclusive weak borderline significant relationship was found between mean 7-day awake METs and total cholesterol (r = -0.13; p = 0.06). A weak significant negative relationship was found between GGT and AEE (r = -0.18; p = 0.01); and AEE and triglycerides (r = -0.20; p = 0.01). Weak significant relationships were found between TEE and GGT (r = -0.17; p = 0.02); and TEE and triglycerides (r = -0.18; p = 0.01). Regarding the relationship between the anthropometric variables and the cardio-metabolic risk factors, a weak significant positive relationship between WC and triglycerides (r = 0.16; p = 0.02) was found. Among the relationships with WHtR, a weak significant positive relationship with cholesterol (r = 0.17; p = 0.01) and triglycerides (r = 0.21; p < 0.001) was found. An inconclusive weak borderline significant association was also found between WHtR and GGT (r =0.13; p = 0.06). Furthermore, inconclusive weak borderline significant relationships were found between BMI and triglycerides (r = 0.13; p = 0.07), as well as cholesterol (r = 0.13; p = 0.06).

Table 4: Correlation coefficients adjusted for age group, sex, self-reported smoking and alcohol usage of the total group of teachers

		Mean 7-day awake METs	AEE (kcal/wk)	TEE (kcal/wk)	PAL	BMI (kg/m^2)	WC (cm)	GGT (U/L)	Chol (mmol/L)	TG (mmol/L)	WHtR
Mean 7-day awake METs	*r*	–	0.65*	0.58*	0.55*	0.04	0.01	-0.19*	-0.13#	-0.19*	-0.03
	p	–	<0.001	<0.001	<0.001	0.63	0.91	0.01	0.06	0.01	0.63
AEE (kcal/wk)	*r*	0.65*	–	0.96*	0.60*	0.004	-0.01	-0.18*	0.01	-0.20*	-0.04
	p	<0.001	–	<0.001	<0.001	0.96	0.94	0.01	0.87	0.01	0.59
TEE (kcal/wk)	*r*	0.58*	0.96*	–	0.53*	0.07	0.06	-0.17*	0.02	-0.18*	0.02
	p	<0.001	<0.001	–	<0.001	0.29	0.39	0.02	0.74	0.01	0.71
PAL	*r*	0.55*	0.60*	0.53*	–	0.11	0.06	-0.12	-0.09	-0.15*	0.06
	p	<0.001	<0.001	<0.001	–	0.12	0.37	0.08#	0.20	0.03	0.40
BMI (kg/m^2)	*r*	0.04	0.004	0.07	0.11	–	0.89*	0.06	0.13#	0.13#	0.90*
	p	0.63	0.96	0.29	0.12	–	<0.001	0.43	0.06	0.07	<0.001
WC (cm)	*r*	0.01	-0.01	0.06	0.06	0.89*	–	0.04	0.12	0.16*	0.96*
	p	0.91	0.94	0.39	0.37	<0.001	–	0.61	0.08	0.02	<0.001
GGT (U/L)	*r*	-0.19*	-0.18*	-0.17*	-0.12#	0.06	0.04	–	0.18*	0.22*	0.13#
	p	0.01	0.01	0.02	0.08	0.43	0.61	–	0.01	0.001	0.06
Chol (mmol/L)	*r*	-0.13#	0.01	0.02	-0.09	0.13#	0.12	0.18*	–	0.36*	0.17*
	p	0.06	0.87	0.74	0.20	0.06	0.08	0.01	–	<0.001	0.01
TG (mmol/L)	*r*	-0.19*	-0.20*	-0.18*	-0.15*	0.13#	0.16*	0.22*	0.36*	–	0.21*
	p	0.01	0.01	0.01	0.03	0.07	0.02	0.001	<0.001	–	<0.001
WHtR	*r*	-0.03	-0.04	0.02	0.06	0.90*	0.96*	0.13#	0.17*	0.21*	–
	p	0.63	0.59	0.71	0.40	<0.001	<0.001	0.06	0.01	<0.001	–

AEE = activity energy expenditure; Chol = serum cholesterol; GGT = gamma-glutamyl transferase; PAL = physical activity level; TEE = total energy expenditure; TG = triglycerides; WC = waist circumference; WHtR = waist-to-height ratio.

* The level of significance is set as $p \leq 0.05$.

Borderline significance.

Table 5 depicts the correlation coefficients adjusted for age group, sex, self-reported smoking and alcohol usage according to teachers with MS and without MS. Regarding the relationship between PA and cardio-metabolic risk factors among teachers with MS, a weak significant negative association was found between mean 7-day awake METs and triglycerides (r = -0.28; p = 0.03), which was not present in teachers without MS. Additionally, a weak significant negative relationship was found between TEE and triglycerides (r = - 0.26; p = 0.05), whilst an inconclusive weak borderline significant negative association was found between PAL and triglycerides (r = -0.24; p = 0.07). No statistically significant relationships were found between anthropometric variables and cardio-metabolic risk factors in teachers with MS. However, in teachers without MS, an inconclusive weak borderline significant negative association was found between GGT and mean 7-day awake METs (r = -0.16; p = 0.06). Triglycerides was moderately and positively associated with WC (r = 0.35; p < 0.001) and WHtR (r = 0.36; p < 0.001) in teachers without MS.

Table 5: Correlation coefficients adjusted for age group, sex, self-reported smoking and alcohol usage stratified by cardio-metabolic syndrome status

		MS participants										Non-MS participants									
		Mean 7-day METs	**AEE (kcal/ wk)**	**TEE (kcal/ wk)**	**PAL**	**BMI (kg/ m^2)**	**WC (cm)**	**GGT (U/L)**	**TC (mmol /L)**	**TG (mmol/ L)**	**WHtR**	**Mean 7-day METs**	**AEE (kcal/ wk)**	**TEE (kcal/ wk)**	**PAL**	**BMI (kg/ m^2)**	**WC (cm)**	**GGT (U/L)**	**TC (mmol/ L)**	**TG (mmol/ L)**	**WHtR**
Mean 7-day METs	*r*	–	0.68*	0.97*	0.61*	-0.02	-0.01	-0.21	-0.21	-0.28*	-0.07	–	0.63*	0.57*	0.94*	0.09	0.05	-0.16#	-0.07	-0.06	0.01
	p	–	<0.001	<0.001	<0.001	0.89	0.92	0.13	0.12	0.03	0.63	–	<0.001	<0.001	<0.001	0.29	0.54	0.06	0.38	0.47	0.90
AEE (kcal/ wk)	*r*	0.68*	–	0.97*	0.61*	0.01	0.02	-0.20	-0.02	-0.22	0.01	0.63*	–	0.95*	0.60*	0.002	-0.02	-0.15	0.04	-0.11	-0.06
	p	<0.001	–	<0.001	<0.001	0.93	0.89	0.14	0.89	0.10	0.93	<0.001	–	<0.001	<0.001	0.98	0.84	0.08	0.67	0.18	0.45
WC (cm)	*r*	-0.01	0.02	0.12	0.01	0.93*	–	-0.09	-0.12	-0.18	0.95*	0.05	-0.02	0.03	0.11	0.87*	–	0.03	0.10	0.35*	0.96*
	p	0.92	0.89	0.37	0.92	<0.001	–	0.52	0.36	0.17	<0.001	0.54	0.84	0.71	0.19	<0.001	–	0.72	0.22	<0.001	<0.001
GGT (U/L)	*r*	-0.21	-0.20	-0.21	-0.16	-0.02	-0.09	–	0.17	0.13	0.05	-0.16	-0.15	-0.12	-0.05	0.02	0.03	–	0.09	0.19*	0.12
	p	0.13	0.14	0.12	0.22	0.91	0.52	–	0.21	0.32	0.72	0.06#	0.08	0.13	0.54	0.78	0.72	–	0.27	0.02	0.15
Chol (mmol / L)	*r*	-0.21	-0.02	-0.06	-0.14	-0.03	-0.12	0.17	–	0.33*	-0.02	-0.07	0.04	0.06	-0.05	0.10	0.10	0.09	–	0.28*	0.12
	p	0.12	0.89	0.58	0.21	0.79	0.36	0.21	–	0.01	0.88	0.38	0.67	0.50	0.55	0.23	0.22	0.27	–	<0.001	0.15
TG (mmol / L)	*r*	-0.28*	-0.22	-0.26*	-0.24#	-0.11	-0.18	0.13	0.33*	–	-0.09	-0.06	-0.11	-0.08	-0.04	0.23*	0.34*	0.19*	0.28*	–	0.36*
	p	0.03	0.10	0.05	0.07	0.39	0.17	0.32	0.01	–	0.49	0.47	0.18	0.31	0.63	0.01	<0.001	0.02	<0.001	–	<0.001
WHtR	*r*	-0.07	0.01	0.08	0.01	0.91*	0.95*	0.05	-0.02	-0.09	–	0.01	-0.06	-0.01	0.11	0.89*	0.96*	0.12	0.12	0.36*	–
	p	0.63	0.93	0.54	0.97	<0.001	<0.001	0.72	0.88	0.49	–	0.90	0.45	0.93	0.19	<0.001	<0.001	0.15	0.15	<0.001	–

AEE = activity energy expenditure; Chol = serum cholesterol; GGT = gamma-glutamyl transferase; MS = cardio-metabolic syndrome; PAL = physical activity level; TEE = total energy expenditure; TC = total cholesterol; TG = serum triglycerides; WC = waist circumference; WHtR = waist-to-height ratio.

* The level of significance is set as $p \leq 0.05$.

DISCUSSION

The study aimed to determine the relationship between PA status, body fatness (i.e. WC, BMI and WHtR) and MS in a cohort of South African teachers. In these relationships, WC was moderately and positively correlated with triglycerides in all the participants. Furthermore, our results showed a weak significant negative relationship between TEE and triglycerides among teachers classified with MS, and an inconclusive weak borderline negative association between PAL and triglycerides. Also, a weak significant negative association between mean 7-day awake METs and triglycerides among the teachers classified with MS after adjustment for age group, sex, self-reported smoking and alcohol use was found.

The observed weak relationship between WC and triglycerides in this study is congruent with findings from the Family-Based Intervention Trial for Heart Health (FIT Heart) by Christian and coworkers (2009)[31] where it was reported that participants with increased WC were significantly more likely to have increased triglycerides. Furthermore, the observed relationship between WC and triglycerides confirms the well-known notion that visceral adipose tissue (VAT) is a key mediator, influencing glucose metabolism, BP, lipid profile and inflammatory profile.[32] According to Tchernof (1996)[33], patients with increased VAT typically present with an increased concentration of low-density lipoprotein (LDL) particles, which are found to be associated with an elevated fasting triglyceride concentration.[33]

In this study, the prevalence of MS was 29% in the total population, 46% in male teachers and 13% in female teachers according to the JIS for diagnosis of MS.[1] Contradictory results have been reported in the USA using data from the National Health and Nutrition Examination Survey (NHANES), indicating that nearly 35% of all adults and 50% of adults above the age of 60 years have MS.[35] The observed prevalence of MS in our study is similar to 29% reported in urban participants from Gauteng Province[8], but when compared to the findings from an urban population in KwaZulu-Natal (26.5%), the prevalence of MS in the two former studies is noted to be high.[5] The differences in the prevalence of MS may be due to varying criteria for the diagnosis of MS and the ethnic specificity of the WC cut-points used.[6]

The high prevalence of MS in this study may be due to the age of the participants (mean age in teachers with MS 51.25±8.11 years vs without MS 49.01 ±8.50 years), as the prevalence of MS increases linearly with age. [4] Another reason may be that all participants were classified as either sedentary (33%) or participated in light-intensity PA (67%), with 48% of the participants with MS were sedentary and 52% were classified as lightly active. The risk of being diagnosed with MS increases to 73% when a person is regarded as physically inactive.[11-12] In this study, an extremely high prevalence (92%) of abdominal obesity in persons with MS was observed, as indicated by the ethnic-specific WC cut-point developed by Prinsloo and colleagues (2011).[26] Our findings though inconclusive suggests that the teachers with high abdominal fat could have influenced the high prevalence of MS.

In this study, a weak significant negative relationship between the PA variables (mean 7-day awake METs, TEE and AEE) and GGT in the total participants were found, indicating that participants who expend more energy have lower GGT levels. This result is in contradiction to a systematic review on PA and alcohol consumption that stated that higher rates of alcohol consumption were associated with higher levels of PA.[36] A systematic review by Piazza-Gardner and Barry (2012)[37] revealed that participants who were regular drinkers (self-reported alcohol consumption) were more physically active than light or former drinkers. The contradictory results may be because four self-reported classifications (abstainers, former drinkers, light drinkers and drinkers) were used in the other study, and in this study the exact number of drinks were not indicated to determine this association.[37] Another reason for the results may be the significantly higher serum GGT in the teachers with MS than their non-MS counterparts in the current study. The high prevalence of alcohol consumption may influence the incidence of MS, as heavy alcohol consumption is associated with an increased risk in developing MS and very light alcohol consumption is associated with reduced risk of MS.[38] However, after adjusting for age group, sex, self-reported smoking and alcohol consumption, this relationship in persons with MS was diminished but still existed in non-MS participants.

A weak significant negative relationship was found between triglycerides and mean 7-day awake METs, TEE and PAL; this is in contradiction with other studies on PA and dyslipidaemia that found no significant correlation between triglycerides and PA.[39-40] Reasons for the disparity may be that in this study, the participants' triglyceride levels were not classified as dyslipidaemia; however, a high prevalence of elevated triglycerides could have contributed to this result, indicating that participating in PA may be beneficial to triglyceride levels in people with MS. This relationship, however, was not present in the teachers who were not diagnosed with MS; the low prevalence of elevated triglycerides may be a possible explanation.

The strengths of the study were the inclusion of a unique cohort of teachers and highly standardised, objectively measured experimental protocols. Possible limitations to this sub-study were the cross-sectional design, which may infer causality. The study is limited by its sample size, because of the strict adherence to the wearing time of the ActiHeart device. Therefore the results cannot be generalised to the teachers of North West Province or the entire population of South African teachers. Larger sample sizes and the inclusion of teachers from other provinces of South Africa would enable clinical comparisons. Another limitation of the study was that individual step test calibration was not performed due to a large number of participants in the larger SABPA-study, the cardio-metabolic risk profiles of the participants and time constraints; however, a biokineticist (clinical exercise physiologist) thoroughly interviewed the participants about their weekly PA patterns before programming the ActiHeart device.

CONCLUSION

The prevalence of MS is alarmingly high among teachers in North West Province, South Africa, as reflected by the prevalence of cardio-metabolic risk factors in the study participants. Most of the participants were classified as inactive or participating in light PA. The significant, though weak, relationship between mean

7-day awake METs and triglycerides in teachers with MS could indicate that PA may be beneficial in lowering triglyceride levels. Future studies should focus on developing adequate PA interventions for teachers to participate in, and educating teachers about the risk factors that contribute to MS. Teachers should be made aware of the benefits of participating in regular PA.

ACKNOWLEDGEMENTS

The authors' acknowledge the assistance of all members of the SABPA research team.

COMPETING INTERESTS

The authors declare that they have no financial or personal relationships that may influence the authors in the write up of this article.

AUTHORS CONTRIBUTIONS

T.V. wrote the manuscript. T.V. and M.A.M. were involved in the data analyses, interpretation of the data, drafting the manuscript and editing the final version of the article. M.S. made a contribution to data collection, interpretation of data and critical editing of the manuscript. J.S.B. was involved in the critical revision of the manuscript and data interpretation. L.M. is the principal investigator of the SABPA-study, assisted in data collection, data entry and interpretation of the data and assisted in critical revision of the manuscript. All authors read and approved the final version of the manuscript.

FUNDING INFORMATION

The SABPA-study is funded by HART (North-West University); North West Province Education Department; the Medical Research Council of South Africa; the National Research Foundation, South Africa; Roche Diagnostics, South Africa; and the Metabolic Syndrome Institute, France. The funding institutions played no role in the design and conduct of the study; collection, management, analysis and interpretation of the data; or preparation of the manuscript. The views expressed in this article are those of the authors and not necessarily the funding bodies.

REFERENCES

1. Alberti KG, Eckel RH, Grundy SM, Zimmet PZ, Cleeman JI, Donato KA, et al. 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. 2009;120(16):1640–1645. https://doi.org/10.1161/CIRCULATIONAHA.109.192644

2. He D, Xi B, Xue J, Huai P, Zhang M, Li J. Association between leisure time physical activity and metabolic syndrome: a meta-analysis of prospective cohort studies. Endocrine. 2013;46:231–240. DOI:10.1007/s12020-013-0110-0

3. Mottillo S, Filion KB, Genest J, Joseph L, Pilote L, Poirier P, et al. The metabolic syndrome and cardiovascular risk: a systematic review and meta-analysis. JACC. 2010;56(14):1113–1132. DOI:10.1016/j.jacc.2010.05.034

4. Kirk EP, Klein S. Pathogenesis and pathophysiology of the cardiometabolic syndrome. J Clin Hypertens. 2009;11(12):761–765. DOI:10.1111/j.1559-4572.2009.00054.x

5. Motala AA, Mbanya JC, Ramaiya KL. Metabolic syndrome in sub-Saharan Africa. Ethn Dis. 2009; 19:S2-8.

6. Okafor C. 2012. The metabolic syndrome in Africa: Current trends. Indian J Endocrinol Metab. 16(1):56–66. DOI:10.4103/2230-8210.91191

7. Van Zyl S, Van der Merwe LJ, Walsh CM, Groenewald AJ, Van Rooyen FC. Risk-factor profiles for chronic diseases of lifestyle and metabolic syndrome in an urban and rural setting in South Africa. Afr J Prim Health Care Fam Med. 2012; 4(1): 1–10. DOI:10.4102/phcfm.v4i1.346

8. George JA, Norris SA, van Deventer HE, Crowther NJ. The association of 25 hydroxyvitamin D and parathyroid hormone with metabolic syndrome in two ethnic groups in South Africa. PLoS One. 2013;8(4):e61282. DOI:10.1371/journal.pone.0061282

9. Grundy SM. Metabolic syndrome pandemic. Arterioscler Throm Vas. 2008;28(4):629–636. https://doi.org/10.1161/ATVBAHA.107.151092

10. Camarillo-Romero E, Dominguez-Garcia MV, Amaya-Chavez A, Camarillo-Romero MD, Talavera-Pina J, et al. Effects of a physical activity program on markers of endothelial dysfunction, oxidative stress, and metabolic status in adolescents with metabolic syndrome. ISRN Endocrin. 2012. Article ID 970629. DOI:10.5402/2012/970629

11. Edwardson CL, Gorely T, Davies MJ, Gray LJ, Khunti K, Wilmot EG, Yates T, Biddle SJ. Association of sedentary behaviour with metabolic syndrome: a meta-analysis. PloS One. 2012;7(4): e34916. DOI:10.1371/journal.pone.0034916

12. Strasser B. Physical activity in obesity and metabolic syndrome. Ann N Y Acad Sci. 2013;1281(1):141–159. DOI:10.1111/j.1749-6632.2012.06785.x

13. Bankoski A, Harris TB, McClain JJ, Brychta RJ, Caserotti P, Chen KY, et al. Sedentary activity associated with metabolic syndrome independent of physical activity. Diabetes Care. 2011;34(2):497–503. https://doi.org/10.2337/dc10-0987

14. Baceviciene M, Luksiene D, Cesnaitiene V, Raubaite S, Peasey A, Tamosiunas A. Dose-response association between physical activity and metabolic syndrome. Open Med. 2013;8(2):273–282. https://doi.org/10.2478/s11536-012-0123-8

15. Turi BC, Codogno JS, Fernandes RA, Monteiro HL. Low levels of physical activity and metabolic syndrome: cross-sectional study in the Brazilian public health system. Cienc Saude Coletiva. 2016:1043–1050. DOI:10.1590/1413-81232015214.23042015

16. Scheers T, Philippaerts R, Lefevre J. SenseWear-determined physical activity and sedentary behavior and metabolic syndrome. Med Sci Sports Exerc. 2013;45(3):481–489. DOI:10.1249/MSS.0b013e31827563ba

17. Chu AH, Moy FM. Association between physical activity and metabolic syndrome among Malay adults in a developing country, Malaysia. J Sci Med Sport. 20141;17(2):195–200. https://doi.org/10.1016/j.jsams.2013.04.003

18. Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR, Tudor-Locke C, et al. 2011 compendium of physical activities: A second update of codes and MET values. Med Sci Sports Exerc. 2011;43(8):1575–1581. DOI:10.1249/MSS.0b013e31821ece12

19. Laurence EC, Volmink J, Esterhuizen TM, Dalal S, Holmes MD. Risk of cardiovascular disease among teachers in Cape Town: Findings of the South African PaCT pilot study. South African Med J 2016;106(10):996–1001. DOI:10.7196/SAMJ.2016.v106i10.10869

20. Malan L, Hamer M, Frasure-Smith N, Steyn HS, Malan NT. Cohort Profile: Sympathetic activity and Ambulatory Blood Pressure in Africans (SABPA) prospective cohort study. Int J Epidemiol. 2015;44(6):1814–1822. https://doi.org/10.1093/ije/dyu199

21. Kohara K, Nishida W, Maguchi M, Hiwada K. Autonomic nervous function in non-dipper essential hypertensive subjects. Evaluation by power spectral analysis of heart rate variability. Hypertension (Dallas, Tex.: 1979). 1995;26(5):808–814.

22. Rogausch A, Kochen MM, Meineke C, Hennig J. Association between the BclI glucocorticoid receptor polymorphism and smoking in a sample of patients with obstructive airway disease. Addict Biol. 2007;12(1):93–99. https://doi.org/10.1111/j.1369-1600.2006.00045.x

23. Sato N, Suzuki N, Sasaki A, Aizawa E Obayashi T, Kanazawa M, et al. Corticotropin-Releasing Hormone Receptor 1 Gene Variants in Irritable Bowel Syndrome. PloS One. 2012;7(9):e42450. DOI:10.1371/journal.pone.0042450

24. Stewart A, Marfell-Jones M, Olds, T, De Ridder JH. International standard for anthropometric assessment,3rd edn. New Zealand: ISAK. 2011:137

25. Ashwell, M & hsieh, SD. Six reasons why the waist-to-height ratio is a rapid and effective global indicator for health risks of obesity and how its use could simplify the international public health message on obesity. *International Journal of Food Science and Nutrition,* 2005;56(5):303–307. DOI:10.1080/09637480500195066

26. Prinsloo J, Malan L, De Ridder JH, Potgieter JC, Steyn HS. Determining the waist circumference cut off which best predicts the metabolic syndrome components in urban Africans: the SABPA study. Exp Clin Endocrinol Diabetes. 2011;119(10):599–603. http://dx.doi.org/ 10.1055/s-0031-1280801

27. Assah FK, Ekelund U, Brage S, Wright A, Mbanya JC, Wareham NJ. Accuracy and validity of a combined heart rate and motion sensor for the measurement of free-living physical activity energy expenditure in adults in Cameroon. Int J Epidemiol. 2011;40(1):112–120. https://doi.org/10.1093/ije/dyq098

28. Westerterp KR. Control of energy expenditure in humans. Eur J Clin Nutr. 2017;71(3):340–344. DOI:10.1038/ejcn.2016.237

29. Cohen, J.W. 1988. Statistical power analysis for behavioural sciences. 2nd edn. Hillsdale, NJ:Lawrence Erlbaum Associates.

30. UNDESA (United Nations Department of International Economic and Social Affairs). Statistics: provisional guidelines on standard international age classification of 1982. Statistics Papers Series M No 74. New York: Publishing Service United Nations, 1982:28.

31. Christian AH, Mochari H, Mosca LJ. Waist circumference, body mass index, and their association with cardiometabolic and global risk. J Cardiometab Syndr. 2009;4(1):12–19. DOI:10.1111/j.1559-4572.2008.00029.x

32. Despres JP, Lemieux I. Abdominal obesity and metabolic syndrome. Nature, 2006;444(7121):881–887.

33. Tchernof A, Lamarche B, Prud 'Homme D, Nadeau A, Moorjani S, Labrie F, Lupien PJ, Despres JP. The dense LDL phenotype: association with plasma lipoprotein levels, visceral obesity, and hyperinsulinemia in men. Diabetes Care, 1996;19(6):629–637

34. McNamara JR, Jenner JL, Li Z, Wilson PW, Schaefer EJ. Change in LDL particle size is associated with change in plasma triglyceride concentration. Arterioscler Thromb. 1992;12(11):1284–1290

35. Aguila M, Bhuket T, Torres S, Liu B, Wong RJ. Prevalence of the metabolic syndrome in the United States, 2003-2012. JAMA. 2015;313(19):1973–1974.

36. Dodge T, Clarke P, Dwan R. The relationship between physical activity and alcohol use among adults in the United States: A systematic review of the literature. Am J Heal Promot. 2017;31(2):97–108.

37. Piazza-Gardner AK, Barry AE. Examining physical activity levels and alcohol consumption: Are people who drink more active? Am J Heal Promot. 2012;26(3):95–105.

38. Sun K, Ren M. Liu D, Wang C, Yang C, Yan L. Alcohol consumption and risk of metabolic syndrome: A meta-analysis of prospective studies. Clin Nutr Elsevier Ltd. 2014;33(4):596–602.

39. Chu AHY, Moy FM. Associations of occupational, transportation, household and leisure-time physical activity patterns with metabolic risk factors among middle-aged adults in a middle-income country. Prev Med (Baltim). 2013; 57(SUPPL):14–17.

40. Mohan V, Gokulakrishnan K, Deepa R, Shanthirani CS, Datta M. Association of physical inactivity with components of metabolic syndrome and coronary artery disease – The Chennai Urban Population Study (CUPS no. 15). Diabet Med. 2005;22(9):1206–1211.

CHAPTER 6:

SUMMARY, CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

6.1 SUMMARY

The main purpose of the research presented in this thesis was to investigate the relationships between physical activity (PA) status, cardio-metabolic risk factors and carotid intima-media thickness (CIMT) in a cohort of teachers. In this chapter, a summary of this thesis is presented and the main research findings of the research are discussed, and summarised in the conclusion. At the end of the chapter, study limitations and recommendations for future studies are presented.

In Chapter 1, the background, problem statement, study objectives and proposed hypotheses of the study were stated. A paucity in the literature regarding the relationship between PA status, cardio-metabolic risk factors and, especially, CIMT was emphasised. Chapters 1 and 2 (literature review) were written using the North-West University (NWU) referencing guidelines. In those chapters, physical inactivity was revealed to be one of the major modifiable risk factors for non-communicable diseases (NCDs). Physical inactivity was shown to lead to the development of oxidative stress, linking physical inactivity to the development of cardio-metabolic diseases. Oxidative stress and low HDL cholesterol play a key role in the development of atherosclerosis. The increasing prevalence of physical inactivity, NCDs and cardio-metabolic syndrome in this century are major public and clinical health concerns. One of the major causes of global mortality due to NCDs is cardiovascular disease (CVD). The studied literature suggested that to detect future CVD events, a non-invasive measure of end-organ damage, CIMT, can be used for tracking the progression of atherosclerosis in the human population, as a preventative measure. Atherosclerosis therefore indicates the risk of a future CVD event, such as stroke or myocardial infarction.

Although substantial evidence exists emphasising the importance of regular PA, a large proportion of the population remains physically inactive. Physical inactivity is a major modifiable risk factor in the development of NCDs, especially CVD, and contributes to the development of other risk factors for CVD such as overweight and obesity, hypertension, dyslipidaemia and hyperglycaemia.

A narrative literature review on PA, NCDs and CIMT was presented in Chapter 2 with a thorough description of PA and the measuring instruments. The literature highlighted that a third of the South African population do not meet the PA guidelines for health promotion. The health benefits of regular PA were elaborated on, with an explanation of how regular PA may be beneficial in the management of oxidative stress. Several methods of measuring PA subjectively are possible, using questionnaires and interviews; however, a lack of understanding and the under-reporting of PA intensities by participants may influence

the accuracy of results. The use of objective measuring instruments to establish PA behaviour is becoming more common in order to compare PA behaviour across countries.

Studies objectively measuring PA, CIMT and cardio-metabolic risk factors are scarce, especially in developing countries such as South Africa. Rapid urbanisation and a westernised lifestyle, to which South Africa is not exempted from, have led too much of the global population not meeting the recommended PA guidelines. This exacerbates physical inactivity prevalence as well as the development of cardio-metabolic risk factors for developing NCDs. A cluster of these risk factors is known as cardio-metabolic syndrome.

In answering the research questions outlined in Chapter 1 in this thesis, objective measures for PA staus, CIMT, and cardio-metabolic risk factors and alcohol (using gamma-glutamyl transferase [GGT]), and the subjective variables of self-reported smoking and alcohol use were used. A cross-sectional study design was employed using a secondary data from a sampled teachers with similar socioeconomic backgrounds who participated in the prospective Sympathetic Activity and Ambulatory Blood Pressure (SABPA) study from Dr Kenneth Kaunda District in North West Province, South Africa. The thesis comprises of three research articles (Chapters 3–5) based on the set research questions in Chapter 1. The three research articles can be read independently, and are written using the guidelines prescribed by the chosen journals, in compliance with NWU guidelines; clause 5.10.5 which states that a thesis written in article format must be presented for examination purposes as an integrated unit, supplemented with a problem statement, an introduction and a synoptic conclusion as prescribed by faculty rules (NWU, 2017:29).

Chapter 3 (Article 1) assessed the relationship between 7 days of objectively measured PA and CIMT in a cohort of urban South African teachers. This publication is unique as only participants with a full 7 days of objectively measured PA data, measured by the use of the ActiHeart device, were included in the study, in which true awake time in a 24-hour cycle was used to calculate the metabolic equivalent of task (MET) categories for PA status. Activity energy expenditure (AEE), total energy expenditure (TEE) and physical activity level (PAL) were used to determine the associations between PA and CIMT.

The objective of Chapter 4 (Article 2) was to determine the role of objectively measured PA in the relationship between obesity and CIMT in a cohort of urban South African teachers. The uniqueness of this article, especially in the South African context, is that it includes objectively measured health parameters.

In the last article (Article 3, Chapter 5) presented in this thesis, the relationships between PA status, body fatness and cardio-metabolic syndrome in the cohort of South African teachers were examined. The Joint Interim Statement (JIS) criteria were used to indicate the prevalence of teachers presenting with cardio-metabolic syndrome. The waist circumference (WC) value for Africans, as developed by Prinsloo *et al.* (2011:4) was used in the analysis of the data. The next section of this chapter will focus on the conclusions drawn from the three research articles.

6.2 CONCLUSION

Through the three related articles, this thesis set out to determine the relationship between PA status, CIMT and cardio-metabolic risk factors in a cohort of teachers. The conclusions drawn are based on the hypotheses posed in Chapter 1.

Hypothesis 1: *There will be a significant negative relationship between PA status and CIMT in a cohort of urban South African teachers.*

A moderate statistically significant negative relationship was found between CIMT and PAL (r = -0.30; p = 0.01) in the sedentary participants. When adjusting for age, sex, total cholesterol, 24-hour ambulatory blood pressure, WC and C-reactive protein (CRP), a moderate significant negative relationship was found between CIMT and total energy expenditure (TEE) (r = -0.31; p = 0.05), and an inconclusive weak borderline negative relationship was found between CIMT and AEE (r = -0.28; p = 0.07) in the sedentary male teachers. An inconclusive weak borderline significant negative relationship between CIMT and mean 7-day metabolic equivalent of tasks (r = -0.19; p = 0.08) existed. When CRP was added to the control variables, the inconclusive borderline significant correlation diminished; therefore, CRP was excluded in the analyses. No significant relationships were observed between CIMT and PA for female teachers in the sedentary group; however, the results indicated an inconclusive weak borderline negative association between CIMT and mean 7-day METs (r = - 0.19; p = 0.08) in the female teachers who were classified as lightly active. Therefore, the set hypothesis is partially accepted, since only light participation in PA indicated an inconclusive borderline weak significant negative association between CIMT and mean 7-day METs.

Hypothesis 2: *Physical activity will have a positive and significant role in the relationship between obesity and CIMT in a cohort of urban South Africa teachers.*

Our results indicated that WC (p = 0.027) was positively and significantly associated with CIMT. A significant positive relationship was found between WC and CIMT. The observed correlation is explained by 2.3% (R^2; 0.023) WC in the model, and it was an inconclusive borderline statistically significant (F(2; 211) = 2.489, p = 0.085) result. When PA was added into the regression models, the magnitude of the regression coefficients for any of the body composition variables and CIMT did not differ. Therefore, hypothesis 2 is rejected, since the addition of PA into the regression models did not yield significant changes in the relationships between the body composition variables and CIMT.

Hypothesis 3: *Positive and significant associations will be observed between PA and body fatness (i.e. body mass index, WC and WHtR) and cardio-metabolic syndrome in a cohort of urban South African teachers.*

In this study, the results indicated a weak significant positive relationship between WC and triglycerides in the total group of teachers (r = 0.16; p = 0.02). In the MS participants, a weak significant negative relationship was found between mean 7-day awake METs and triglycerides (r = -0.29; p = 0.02), and an inconclusive weak borderline negative relationship between GGT and mean 7-day awake METs (r = -0.25; p = 0.06); AEE (r = -0.24; p = 0.06); and PAL (r = -0.23; p = 0.07). After adjusting for age group, self-reported smoking and alcohol use, a weak significant negative relationship between mean 7-day awake METs and triglycerides (r = -0.28; p < 0.01) remained with small changes. Therefore, hypothesis 3 is partially accepted, as WC was weak and positively associated with triglycerides in the total group of teachers after adjustments. In addition, in the teachers classified with cardio-metabolic syndrome, a weak negative relationship between PA and triglycerides was found.

6.3 CONTRIBUTION OF THE STUDY

The conclusions of this study has led to contributions to the scientific body of knowledge, methodology and public health. This thesis is unique because PA status, CIMT and cardio-metabolic risk factors were objectively measured in a cohort of urban teachers in North West Province, South Africa, where available data on teachers are limited. Furthermore, the relationship between objectively measured PA and CIMT in teachers has been sparsely investigated. The available literature on young and middle-aged adults' PA status and CIMT is limited, and the results are not congruent. In this thesis, participation in light activity was significantly beneficial in capping the development of CIMT and it decreased triglyceride levels in the sampled teacher population. The thesis also contributes knowledge on teachers' cardio-metabolic risk factors for the development of NCDs in North West Province – one of the previous studies on teachers and their risk factors for the development of NCDs in South Africa was conducted in Cape Town (Laurence *et al.*, 2016:996), and did not include the measurement of CIMT. Another important feature of this thesis was the strict adherence to the participants wearing the ActiHeart device for a full 7 day period and that it only included participants who complied with wearing the ActiHeart or had less than 40 minutes of non-contact time during their awake hours, thus indicating true measures of activity. The study also used specific awake-time data for TEE, AEE, METs and PAL, to describe PA and thereafter objectively classifying the teachers into PA categories. This thesis formed part of a larger prospective cohort study, the SABPA-study, which was well planned and conducted under strictly controlled conditions in fully equipped research facilities. The SABPA-study participants were a homogeneous group, so that the results could not to be influenced. The use of objective measures, such as blood analysis and the use of the ActiHeart device, has added valuable information to the body of science.

The findings of this study also might contribute to important implications for policy in the public health sector and in education. Physical inactivity is a major public health concern in the 21st century, and a major modifiable risk factor in the development of NCDs. The World Health Organization (WHO) global action plan has several objectives, including a 10% decrease in physical inactivity and a 25% decrease in the mortality rate due to NCDs (WHO, 2018:13). The global action plan also elaborates the need for people to be more active when travelling and moving around in their environment and during work (WHO, 2018:7). Furthermore, in South Africa in adhering to the WHO global action, published a document on Strategy for the Prevention and Control of Obesity in South Africa in 2016 (Department of Health, 2016:5) with an ambitious target of decreasing the prevalence of obesity by 10% by 2020. However, the thesis findings have reported high levels of physical inactivity, overweight and obesity, and high prevalence of cardio-metabolic risk factors for NCDs among the study population at hand. Therefore, the Department of Basic Education should take into cognisance that an increased PA status is beneficial in capping the development of atherosclerosis, an underlying cause of CVD, and that increased triglyceride levels are a risk factor for cardio-metabolic disease. Increasing PA may enhance the work capacity and general health of teachers, and may have a significantly beneficial effect in reducing the economic burden of disease in the teaching community.

6.4 LIMITATIONS

Although objective measures of PA, CIMT and cardio-metabolic risk factors were used in determining the relationships in this study, the results should be interpreted with the following limitations in mind:

- The cross-sectional study design limited data collection to measurements at one time point. Therefore, the progression of CIMT and the risk factors for cardio-metabolic syndrome could not be examined.
- The study population was from North West Province, South Africa only and thus the results cannot be generalised to the entire South African population.
- The exclusion of participants who did not wear the ActiHeart device for seven full days with less than 40 minutes non-wearing time influenced the number of participants who could be included and the PA categories. From the 359 participants in SABPA 2, only 216 adhered to the inclusion criteria of wearing the ActiHeart for 7 full days, as some participants experienced allergic reactions and discomfort. This could have masked the true relationships between PA and the other variables of interest.
- Individual step test calibration of each participant wearing the ActiHeart was not performed, due to the vast number of participants, the high cardiovascular risk of the participants and time constrictions during data collection. Instead, after thorough historical health profile questioning, which included physical activity participation, by amongst others a biokineticist (clinical exercise

physiologist), the PA level of the participants was programmed. This lack of ActiHeart calibration might have affected the comparability of data to that of other developed countries.

- The low levels of PA from this study could be due to the set equations for determining PA in the ActiHeart that are based on laboratory activities mostly developed in studies in the UK where the climate condition is characterised by cool, wet winters and warm, wet summers. Hot temperatures are rarely featured, and this is different to South African climate conditions, which are characterised by heat and humidity. There are also differences in the free-living settings between the UK and South Africa.
- Clear population specific cut-points for PA need to be developed, as there is inconsistency in the existing PA cut-points, as well as in the specific cut-points for CIMT in relation to the development of atherosclerosis.

6.5 RECOMMENDATIONS AND FUTURE RESEARCH

The following recommendations are tendered with a view to future research:

- A longitudinal study design may enable the researcher to establish the true influence of a physically active lifestyle on the progression of CIMT and the development of atherosclerosis, obesity and cardio-metabolic syndrome over time. In addition, the inclusion of teachers from the other provinces of South Africa could provide more reliable data on the relationships among PA status, CIMT and cardio-metabolic risk factors in South African teachers.
- Recruitment of more participants (±1000) in future epidemiological studies may help to increase the statistical power to the high level needed to determine the relationships among the variables of interest. Additionally, motivation strategies for participant compliance should be included.
- Performing an individual step test calibration prior to data collection is advised in order to calibrate the devices individually and to ensure accuracy of the results. However, using a standardised PA questionnaire together with objectively measured PA could strengthen the results and enable researchers to validate the ActiHeart device in South African conditions.
- In addition to objective measures such as the ActiHeart device, the International Physical Activity Questionnaire (IPAQ), which has been validated against objective measures of PA, could be used to enable international comparisons of PA status.
- Further research could focus on developing ethnic- and country-specific cut-points for PA patterns and on the development and progression of atherosclerosis as measured by CIMT.
- Studies should be initiated to determine the effect of interventions to increase PA on the development of CIMT, using a randomised controlled study design with obese participants. These would strengthen the evidence base of the beneficial impact of PA on progression of atherosclerosis, and determine the risk of CVD in people who are obese.

REFERENCES

Department of Health (South Africa). 2016. Strategy for the prevention and control of obesity in South Africa 2015–2020. http://www.health.gov.za/index.php/2014-03-17-09-09-38/policies-and-guidelines/category/327-2017po?download=1832:strategy-for-the-prevention-and-control-of-obesity-in-south-africa Date of access: 20 Feb. 2020.

Laurence, E.C., Volmink, J., Esterhuizen, T.M., Dalal, S. & Holmes, M.D. 2016. Risk of cardiovascular disease among teachers in Cape Town: Findings of the South African PaCT pilot study. *South African Medical Journal,* 106(10):996–1001. doi:10.7196/SAMJ.2016.v106i10.10869

NWU (North-West University). 2017. General Academic rules – approved by council on 21 September 2017. http://www.nwu.ac.za/sites/www.nwu.ac.za/files/files/i-governance-management/policy/2019.06.20_A-Rules_e.pdf Date of access: 20 Feb. 2020.

Prinsloo, J., Malan, L., De Ridder, J.H., Potgieter, J.C. & Steyn, H.S. 2011. Determining the waist circumference cut off which best predicts the metabolic syndrome components in urban Africans: the SABPA study. *Experimental and Clinical Endocrinology and Diabetes,* 119(10):599–603. http://dx.doi.org/ 10.1055/s-0031-1280801

WHO (World Health Organization). 2018. *Global action plan on physical activity 2018–2030: more active people for a healthier world.* Geneva: World Health Organization

APPENDIX A:

ETHICS DOCUMENTATION

Private Bag X1290, Potchefstroom
South Africa 2520

Tel: 018 299-1111/2222
Fax: 018 299-4910
Web: http://www.nwu.ac.za

Research Ethics Regulatory Committee
Tel: 018 299-4849
Email: nkosinathi.machine@nwu.ac.za

ETHICS APPROVAL LETTER OF STUDY

Based on approval by the North West University Health Research Ethics Committee (NWU-HREC) on 07/11/2018, the NWU Health Research Ethics Committee hereby approves your study as indicated below. This implies that the North-West University Research Ethics Regulatory Committee (NWU-RERC) grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title: The relationship between physical activity status, coping styles and selected cardio metabolic risk factors in a cohort teachers: the SABPA study.
Study Leader/Supervisor (Principal Investigator)/Researcher: Dr M Swanepoel
Student: T Veldsman

Ethics number:

N	W	U	-	0	0	0	7	9	-	1	8	-	A	1
Institution				Study Number						Year			Status	

Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation

Application Type: Single Study
Commencement date: **2018/11/07** **Risk:** **Minimal**
Expiry date: 2019/11/30
Approval of the study is initially provided for a year, after which continuation of the study is dependent on receipt and review of an annual (or as otherwise stipulated) monitoring report and the concomitant issuing of a letter of continuation.

Special in process conditions of the research for approval (if applicable):

- Please provide the HREC with copies of the goodwill permission letters from all the entities to be included in this study, indicating access to potential participants in the study.
- Please provide the HREC with copies of the signed confidentiality agreements with the co-coder, the mediators and the independent person when they become available.

General conditions:
While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, the following general terms and conditions will apply:

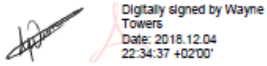
- *The study leader/supervisor (principle investigator)/researcher must report in the prescribed format to the NWU-HREC:*
  - *annually (or as otherwise requested) on the monitoring of the study, whereby a letter of continuation will be provided, and upon completion of the study; and*

- *without any delay in case of any adverse event or incident (or any matter that interrupts sound ethical principles) during the course of the study.*

- *The approval applies strictly to the proposal as stipulated in the application form. Should any amendments to the proposal be deemed necessary during the course of the study, the study leader/researcher must apply for approval of these amendments at the NWU-HREC, prior to implementation. Should there be any deviations from the study proposal without the necessary approval of such amendments, the ethics approval is immediately and automatically forfeited.*
- *Annually a number of studies may be randomly selected for an external audit.*
- *The date of approval indicates the first date that the study may be started.*
- *In the interest of ethical responsibility the NWU-RERC and NWU-HREC reserves the right to:*
  - *request access to any information or data at any time during the course or after completion of the study;*
  - *to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process;*
  - *withdraw or postpone approval if:*
    - *any unethical principles or practices of the study are revealed or suspected;*
    - *it becomes apparent that any relevant information was withheld from the NWU-HREC or that information has been false or misrepresented;*
    - *submission of the annual (or otherwise stipulated) monitoring report, the required amendments, or reporting of adverse events or incidents was not done in a timely manner and accurately; and / or*
    - *new institutional rules, national legislation or international conventions deem it necessary.*
- *NWU-HREC can be contacted for further information or any report templates via Ethics-HRECApply@nwu.ac.za or 018 299 1206.*

The NWU-HREC would like to remain at your service as scientist and researcher, and wishes you well with your study. Please do not hesitate to contact the NWU-HREC or the NWU-RERC for any further enquiries or requests for assistance.

Yours sincerely



Prof Wayne Towers
Chair NWU Health Research Ethics Committee

Current details: (22351930) M:\DSS1\8533\Monitoring and Reporting Cluster\Ethics\Certificates\Templates\Research Ethics Approval Letters\9.1.5.4.2 HREC Ethical Approval Letter.docm
3 December 2018

File reference: 9.1.5.4.2

Private Bag X6001, Potchefstroom
South Africa 2520

Tel: 018 299-1111/2222
Web: http://www.nwu.ac.za

Health Sciences Ethics Office for Research, Training and Support

North-West University Health Research Ethics Committee (NWU-HREC)
Tel: 018-285 2291
Email: Wayne.Towers@nwu.ac.za

Dr M Swanepoel
Human Movement Science
PhASRec

10 October 2019

Dear Dr Swanepoel

APPROVAL OF YOUR AMENDMENT REQUEST BY THE NORTH-WEST UNIVERSITY HEALTH RESEARCH ETHICS COMMITTEE (NWU-HREC) OF THE FACULTY OF HEALTH SCIENCES

Ethics number: NWU-00079-18-A1

Kindly use the ethics reference number provided above in all future correspondence or documents submitted to the administrative assistant of the North-West University Health Research Ethics Committee (NWU-HREC) secretariat.

Study title: The relationship between physical activity status, coping styles and selected cardio metabolic risk factors in a cohort teachers: the SABPA study

Study leader/Researcher: Dr M Swanepoel

Student: T Veldsman-21684537

You are kindly informed that your amendment request (removal of variable from analysis) to the aforementioned project has been approved. Any future amendments to the proposal or other associated documentation must be submitted to the NWU-HREC, Faculty of Health Sciences, North-West University, prior to implementing these changes. These requests should be electronically submitted to Ethics-HRECApply@nwu.ac.za, for review BEFORE approval can be provided, with a cover letter with a specific subject title indicating, "Amendment request: NWU-XXXXX-XX-XX". The letter should include the title of the approved study, the names of the researchers involved, the nature of the amendment/s being made (indicating what changes have been made as well as where they have been made), which documents have been attached and any further explanation to clarify the amendment request being submitted. The amendments made should be indicated in yellow highlight in the amended documents. The *e-mail*, to which you attach the documents that you send, should have a *specific subject line* indicating that it is an amendment request e.g. "Amendment request: NWU-XXXXX-XX-XX". This e-mail should indicate the nature of the amendment. This submission will be handled via the expedited process.

We wish you the best as you conduct your research. If you have any questions or need further assistance, please contact the Faculty of Health Sciences Ethics Office for Research, Training and Support at Ethics-HRECApply@nwu.ac.za.

Yours sincerely

Digitally signed by Wayne Towers
Date: 2019.10.10 10:40:40 +02'00'

Prof Wayne Towers
Chairperson: NWU-HREC

Prof Minrie Greeff
Head of Health Sciences Ethics Office for Research, Training and Support

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT

Private Bag X6001, Potchefstroom
South Africa 2520

Tel: (018) 299-4900
Faks: (018) 299-4910
Web: http://www.nwu.ac.za

Ethics Committee
Tel +27 18 299 2542
Fax +27 18 297 5308
Email Ethics@nwu.ac.za

Dr L Malan

Dear Dr Malan

6 February 2008

ETHICS APPROVAL OF PROJECT

The North-West University Ethics Committee (NWU-EC) hereby approves your project as indicated below. This implies that the NWU-EC grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the project may be initiated, using the ethics number below.

Project title:.SABPA (Sympathetic activity and Ambulatory Blood Pressure in Africans)

***Ethics* number**: N W U - 0 0 0 3 8 - 0 7 - S 6

Approval date: 12 November 2007 **Expiry date**: 11 November 2012

Special conditions of the approval (if any): None

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:

- *The project leader (principle investigator) must report in the prescribed format to the NWU-EC:*
  - *annually (or as otherwise requested) on the progress of the project,*
  - *without any delay in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.*
- *The approval applies strictly to the protocol as stipulated in the application form. Would any changes to the protocol be deemed necessary during the course of the project, the project leader must apply for approval of these changes at the NWU-EC. Would there be deviated from the project protocol without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.*
- *The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date, a new application must be made to the NWU-EC and new approval received before or on the expiry date.*
- *In the interest of ethical responsibility the NWU-EC retains the right to:*
  - *request access to any information or data at any time during the course or after completion of the project;*
  - *withdraw or postpone approval if:*
    - *any unethical principles or practices of the project are revealed or suspected,*
    - *it becomes apparent that any relevant information was withheld from the NWU-EC or that information has been false or misrepresented,*
    - *the required annual report and reporting of adverse events was not done timely and accurately,*
    - *new institutional rules, national legislation or international conventions deem it necessary.*

The Ethics Committee would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the Ethics Committee for any further enquiries or requests for assistance.

Yours sincerely

Prof M M J Lowes
(chair NWU Ethics Committee)

APPENDIX B:

INFORMED CONSENT FORM (SABPAII)

- **PARTICIPANT INFORMATION AND CONSENT FORM**

NORTH-WEST UNIVERSITY POTCHEFSTROOM CAMPUS

SCHOOL FOR PHYSIOLOGY, NUTRITION AND CONSUMER SCIENCES

PARTICIPANT INFORMATION AND CONSENT FORM

PART 1

PRINCIPAL RESEARCHER: Prof Leoné Malan, Subject Group Physiology
PROJECT LEADER: Prof Leoné Malan

Associate Researcher(s): The postdoctoral fellows involved in this trial are Dr. P Szabolcs, Mr M Glynn. Other persons assisting in the study are Proff Nico T Malan, Alta E Schutte, Hugo W. Huisman, Johannes M. van Rooyen, Rudolph Schutte, Drs. Carla M.T. Fourie, Wayne Smith, Carina Mels, Mrs. Tina Scholtz, Lisa Uys, Mr Ruan Kruger (Hypertension in Africa Researc Team), Proff. Hans de Ridder (Anthropometry, Physical activity), Johan Potgieter, Dr Tumi Khumalo (Psychology), Proff Linda Brand & Brian Harvey (Pharmacology), Kobus Mentz (Education), Francois van der Westhuizen (Biochemistry), Ronel Pretorius (Nursing), Yackoob Seedat (Kwazulu Natal), Paul Rheeder (Pretoria University), Proff Nancy Frasure- Smith & Francois Lespérance (Canada), Drs Alaa Alkerwi (Luxembourg), M Hamer (UK), Manja Reimann, Proff Tjalf Ziemssen, C Kirschbaum (Germany), Eco JCN de Geus (Netherlands); Markus Schlaich & Dr G Lambert (Australia), Prof Morten Rostrup (Norway).

This Participant Information and Consent Form are **8** pages long. Please make sure you have all the pages.

- ***Your Consent***

You are invited to take part voluntarily in this research project.

This participant information document contains detailed information about the research project which has been explained to you verbally. Its purpose is to explain to you as openly and clearly as possible all the procedures involved in this project before you decide whether or not to take part.

Please read this *Participant Information Form* carefully. Feel free to ask questions about any information in the document. You may also wish to discuss the project with a relative or friend or your local health worker. Feel free to do this.

Once you understand what the project is about and if you agree to take part in it, you will be asked to sign the Consent Form. By signing the Consent Form, you indicate that you understand the information and that you give your consent to participate in the research project.

You will be given a copy of the Participant Information and Consent Form to keep as a record.

- ***What is the study about?***

The aim of this project is to have an impact on the eventual prevention and treatment of lifestyle

diseases in Africans from South Africa. New knowledge regarding the relationship between higher nervous system activity implicating cardiovascular, metabolic and psychological well-being will improve understanding and change strategies at the roots of treatment and prevention of lifestyle diseases.

Our research has shown that lifestyle diseases in urban Africans present higher obesity levels, high blood pressure or hypertension prevalence rates and the experiencing of more stress. This pattern is enhanced during psychosocial stress/urbanisation in participants with a specific coping style. Hence, the planned SABPA project, which is the first study in South Africa where coping and direct markers of in Africans will be measured.

- ***Purpose of study***

The purpose of this study is to ***repeat most of our previous measurements*** although not the stressor exposure measures. We will investigate biological markers associated with higher nervous system activity in urban teachers with a specific coping style.

To investigate the relationship between blood pressure, inflammation, obesity, stress and coping in more detail we are going to perform this study in 409 men and women from the North-West province, aged 25-65 years. A comprehensive assessment of the cardiovascular and nervous systems by means of non-invasive painless techniques will be performed and blood and saliva samples will be taken by an experienced research nurse to determine your blood sugar, cardiovascular, inflammation and stress hormone levels amongst other health markers.

- ***Procedures***

All measurements are performed in the Metabolic Unit (lipid clinic) of the University. A researcher has explained the entire procedure in detail and while you are reading this information document you have time to ask questions and to have clarified matters. If you are fine with the explained procedure you are requested to sign a
*consent form (at the end of this document). Remember all personal data will be handled with care and remain confidential.

**By consenting to participate in this study, you consent to the storage and later analysis and testing of your stored blood samples for the purposes noted above. Your blood will also be tested for preliminary results on HIV status, since your HIV status may directly influence the main purposes of this study. If you would like to know what your HIV-status is, we will provide it. If tested positive we will refer you to your doctor and he/she will perform the necessary tests which will allow you to apply for chronic medication benefits. Also, the blood cells from your donated blood sample will be used to investigate the molecular genetics of higher nervous system activity and Type 2 diabetes in order to enable pre-symptomatic diagnosis of hypertension and diabetes in the long term.*

Why was I chosen? Educators are exposed to changing curricula and disciplinary problems whilst living in an urban environment adding to higher stress experiencing and nervous system activity.

- ***How was I chosen?***

Inclusion criteria*:*
All SABPA I (2008/2009) black (Phase I) and Caucasian (Phase II) teachers (male and female)

Exclusion criteria: *pregnancy, lactation, temperature >37°C.* ***You can not be included if you have donated blood or been vaccinated in the previous 3 months****.*

- ***What will be expected of me?***

You, as participant will be screened once by a registered nurse to be eligible complying with the inclusion criteria. The following procedures will be followed:

- Recruitment and informed sessions with all participants will be done two months prior to

the study (October - November 2010, Phase I, and **November, 2011, Phase II**) and informed consent forms will be signed.

- After selection of all participants, the details of the project will be discussed with you in English or your home language, i.e. what the exact objectives of the study are, what procedures will be taken and what will be expected from each of you (e.g. overnight stay, resting blood pressure procedures and fasting urine and blood samples are required, importance of complying with the correct sampling methods, incentives). You will be given the opportunity to ask questions.
- Data collection for each participant will involve two days (15 min in the morning and 2½ hours in the evening) on Day I; and 2 hours on Day II):

- **DAY I**
  - On day I between 07:00-08:00, the blood pressure apparatus, which will measure your blood pressure and heart function will be applied to your arm and waist at your school and you can then resume your normal daily activities.
  - Urine sampling (24h) and 24h diets will commence.
  - At the end of Day I (**15:00**) you have to visit us or be transported from your schools to the Physiology F12 building (NWU) and will overnight in the Metabolic Unit Research Facility of the North-West University. This unit is a research unit for human studies and equipped with 10 well furnished bedrooms, a kitchen, two bathrooms and a television room. Each of you will be subjected to the following procedures:
    - At 15:00 you will be welcomed at F12 at the HART clinic and eye measurements including saliva sampling pertaining to cardiometabolic health will commence.
    - Hair sampling and pre-counselling for HIV/AIDS will be done.
    - You will go then go the Metabolic Unit Research Facility of the North-West University (G17) to receive your own bedroom. All other apparatus will be shown and the procedures, which will be done, will be explained again and you will receive dinner.
    - After dinner, the psychosocial questionnaires will be completed under supervision of registered clinical psychologists/postgraduate students. Completion of questionnaires will take approximately 40 min, From 22:00 you will be fasting, therefore, this will be you last meal for Day I as you must be fasting on Day II for obtaining good results.
    - Thereafter, you can relax and watch television or socialize with your co-participants. It will be wise to go to bed not later than 22:00 as the blood pressure apparatus will take measurements every hour during the night and it can be tiring.

- **DAY II**
  - At 06:45 on Day II in the anthropometric station your weight, height and body circumferences will be measured.
  - Urine sampling will be completed before 07:30 whereafter the blood pressure apparatus will be removed (07:30 after last measurement).
  - Next the cardiovascular measurements will follow consisting of three separate procedures:
    - Firstly, after being in semi-recumbent position for 10 minutes your blood pressure will be taken in duplicate with the sphygmomanometer (the same as used at clinics) with a resting period of 5 minutes in between.
    - Secondly, our registered research nurse will measure the ECG which measures heart function, with 12 leads, which will be placed into position on your rib cage/front part of the body.

- Thirdly, the assessment of pulse wave velocity will follow, i.e. giving an indication of how stiff your vessel walls are. The stiffer your vessel wall is the faster the blood travels from one point of your body to another. These painless measurements will require two technicians using blunt probes (tonometer) putting light pressure on the neck and on the foot to measure the velocity of the pulse waves. This takes only a few minutes.
- A once-off blood sample of 48 ml will be obtained between 08:30 - 09:00 from a vein in your dominant arm.
- Lastly, an ultrasound device will be taken of your arteries in the neck with a blunt probe to indicate the intrinsic thickness of your arteries which contributes to high blood pressure.
- You have reached the end of the sampling phase.

➢ Immediate feedback on your HIV/AIDS status, obesity levels, blood pressure and blood glucose/sugar values will be given. *HIV/AIDS post-test counselling will be arranged if you are tested positive.*

➢ **Thank you for your participation! You now will have the opportunity to shower and a take away breakfast will be given**.

➢ You will now be transported back to your school and after one week you will receive your 24-hour blood pressure, 12 lead ECG and eye reports as well as sleeping disturbances/sleep apnea risk.

○ ***Possible Risks***

The measurements performed in our study will include only non-invasive techniques that are not expected to reveal any risks but might cause little discomfort. The taking of blood samples is an invasive procedure with a minimal risk of bleeding. Thus the procedure may cause only a few seconds of light discomfort. All tests will be performed by experienced research nurses of our department. There may be additional unforeseen or unknown risks.

○ ***Precautions to protect the participant***

The Metabolic Unit facility of the NWU is fully equipped, and in case of an emergency which could not be handled by the registered nurse, the supervising medical doctor P de K Geldenhuys will be contacted. Dr. Geldenhhuys was notified before the study commenced that this study will be taking place, and that there is a slight possibility

that he may be contacted. Supporting medical treatment care facilities will be at hand anytime if needed.

○ ***Other Treatments Whilst on Study***

It is important to tell the research staff about any treatments or medications you may be taking, including non-prescription medications, vitamins or herbal remedies during your participation in the study.

- ***Incentives***

1. All teachers will receive feedback on their health profile and if necessary references will be given to physicians/clinics/hospitals.

2. Blood pressure, kidney functioning, eye measures and ECG monitoring (normally costing R8000.00). Your benefit of participation is a comprehensive assessment of the cardiovascular and metabolic condition including investigation of blood pressure, inflammatory status and psychological well- being. These examinations will help us to assess the degree of vascular impairment of the arteries and to predict your risk of possible cardiovascular events such as heart attacks and stroke. The results may assist your doctor in decision making for further treatment or for instituting preventive measures. Our study will also contribute to the identification of possible factors leading to high blood pressure. As 24 hour ambulatory blood pressure monitoring is required for the diagnosis of hypertension, medical aids insist on this method of diagnosis to qualify for chronic medication. Additional testing could also reveal illnesses of a chronic nature and would serve as a motivation to qualify for chronic medication, such as metabolic syndrome, anti-inflammatory and cholesterol-lowering drugs.

   Monetary incentive as compensation for discomfort and token of appreciation of R100.00 / US$±14))

   Diet for 24 hours (R150.00 / Two breakfasts, lunch and dinner

Privacy, Confidentiality and Disclosure of Information

By consenting to participate in this study, you consent to the storage and later analysis and testing of your stored blood samples for purposes noted above. Your blood samples will be discarded immediately after analysis. All information provided by you and the results of tests will be treated in the strictest confidence, and will only be used for the purpose of this research project. It will only be disclosed with your permission, except as required by law. The results of your medical tests will be labeled only with a code number, and will be stored separately from any identifying information. When the results are analyzed we will be looking for differences between groups of people, not at the results of individuals. No information that could identify any person taking part in the study will be revealed when the results are reported.

- ***Participation is Voluntary***

Participation in any research project is voluntary. If you do not wish to take part you are not obliged to. If you decide to take part and later change your mind, you are free to withdraw from the project at any stage.

Your decision whether to take part or not to take part, or to take part and then withdraw, will not affect your routine treatment, your relationship with those treating you or your relationship with the North-West University.

Before you make your decision, a member of the research team will be available so that you can ask any questions you have about the research project. You can ask for

any information you want. Sign the Consent Form only after you have had a chance to ask your questions and have received satisfactory answers.

If you decide to withdraw from this project, please notify a member of the research team before you withdraw.

- ***Ethical Guidelines***

This project will be carried out according to Ethical Guidelines of the Helsinki declaration from 2008, with additional notes in 2002. This statement has been developed to protect the interests of people who agree to participate in human research studies.

The ethical aspects of this research project have been approved by the Human Research Ethics Committee of ***North-West University Potchefstroom: (NEW-EC): 0003603S6***

- ***Further Information or Any Problems***

If you require further information or if you have any problems concerning this project, you can contact the principal researcher or *the other* researchers responsible for this project.

Project Leader Prof Leoné Malan (018-299 2438); Cell 0733765321



Signature

PART 2

To the subject signing the consent as in part 3 of this document

You are invited to participate in a research project as described in paragraph 2 of Part 1 of this document. It is important that you read/listen to and understand the following general principles, which apply to all participants in our research project:

1. **Participation in this project is voluntary.**

2. **It is possible that you personally will not derive any benefit from participation in this project, although the knowledge obtained from the results may be beneficial to other people.**

3. **You will be free to withdraw from the project at any stage without having to explain the reasons for your withdrawal. However, we would like to request that you would rather not withdraw without a thorough consideration of your decision, since it may have an effect on the statistical reliability of the results of the project.**

4. **The nature of the project, possible risk factors, factors which may cause discomfort, the expected benefits to the subjects and the known and the most probable permanent consequences which may follow from your participation in this project, are discussed in Part 1 of this document.**

5. **We encourage you to ask questions at any stage about the project and procedures to the project leader or the personnel, who will readily give more information. They will discuss all procedures with you.**

PART 3

Consent

Title of the project: "**THE SABPA STUDY** (**S**ympathetic activity and
- **A**mbulatory **B**lood **P**ressure in **A**fricans)".

I, the undersigned…… (full names) read / listened to the information on the project in PART 1 and PART 2 of this document and I declare that I understand the information. I had the opportunity to discuss aspects of the project with the project leader and I declare that I participate in the project as a volunteer. I hereby give my consent to be a subject in this project.

(Signature of the subject)

Signed at..... on ……2011/12

Witnesses

1.....

2.....

Signed at..... on ……20011/12

APPENDIX C:

PROOF OF LANGUAGE EDITING

STATEMENT ON EDITORIAL ASSISTANCE

I hereby confirm that I, Helen Elizabeth ROBINSON, edited the doctoral thesis written by Tamrin Veldsman, titled ' Relationships between physical activity status, intima–media thickness and cardio-metabolic risk factors in a cohort of teachers: The SABPA study.'

Corrections were made in respect of grammar, punctuation, spelling, syntax, tense and language use. The content remains the work of the author.

My edit may not be identical to that submitted. At their discretion the author has the prerogative to accept, delete or change, before submission, amendments made by the editor.



Helen Robinson
ID: 7001051824085
Member: Professional Editors' Guild of South Africa

PO Box 482
Mahikeng
North West Province
Tel: 082 714 3003
msinsi@mweb.co.za

06/03/2020

APPENDIX D:

GUIDELINES FOR AUTHORS

GUIDELINES FOR AUTHORS:
CARDIOVASCULAR JOURNAL OF AFRICA

INFORMATION FOR AUTHORS: THE CARDIOVASCULAR JOURNAL OF AFRICA

The Cardiovascular Journal of Africa is pleased to consider original articles, reviews, discussions on topical issues, case studies, meeting reports and other contributions relevant to the understanding, treatment and care of vascular disease.

Original articles and reviews are sent for independent peer-review. Material is accepted for publication on the understanding that it has not been published elsewhere. Authors will be asked to confirm this in writing and transfer copyright to the Journal.

Authors submitting papers to CVJA should also register as a reviewer as a quid pro quo for authors for reviewers reviewing your submission. If authors do not register as reviewers it may be taken in consideration when deciding on acceptance and rejection, and the time of publication. We do try not to call on a reviewer more than once a year but in rare circumstances it may be twice.

IMPORTANT NOTICE TO ALL AUTHORS:

Manuscript Submission Fee & Article Processing Charge (effective 13 December 2016)

It has become necessary for the Cardiovascular Journal of Africa to charge a manuscripts submission fees for all articles submitted for publication. On acceptance of a manuscript an additional Article Processing Fee will apply before publishing.

Manuscript Submission Fee: South African and International Authors: ZAR 1000.

Paid on Submission of Manuscript.

Article Processing/Publishing Fee: South African and International Authors: ZAR 6000.

Paid on Article Acceptance for Publication in the CVJA.

This is normal for most, if not all, journals. We so far have been able to survive without charging authors for submissions and processing but can no longer do so. We regret that we have to implement this as from the 13 of December 2016. Payment will need to be made online and once payment has been received, the manuscript will be further processed for possible publication.

The payment of the manuscript submission fee and does not guarantee publication of the article. The manuscript submission fee is not refundable in the event of rejection as processing cost will have been incurred. (Payment can be made online with a valid credit card)

GUIDELINES FOR AUTHORS AND READERS OF THE CVJA

The Cardiovascular Journal of Africa (CVJA), which incorporates the Cardiovascular Journal of South Africa, is particularly concerned with publication of scientific articles related to Cardiac and Vascular conditions and situations, concerning adults and children, in Sub Saharan Africa. But will accept articles from all parts of the world.

Basic Science publications related to clinical aspects either for elucidation, in-depth understanding or therapeutic approaches are accommodated. The Journal functions as official medium for other related societies which do not as yet have own Journals such as, Hypertension, Stroke, Nuclear Medicine and Magnetic Resonance in Cardiology, Paediatrics, Molecular and Cellular Cardiology, and Vascular disease in Diabetes and Obesity.

Index Medicus / PubMed Central / Medline and Sabinet lists the Journal for indexing and electronic citation. A printed version and an electronic version for citation and publication of abstracts are produced. The abstracts of articles published appear on PubMed with a link out to Sabinet to give access to full text retrieval of published material. In order to improve visibility for our authors, the CVJAfrica is now also able to index articles for PubMed Central.

ARTICLE SUBMISSION

All categories of manuscripts for the Cardiovascular Journal of Africa must be submitted on-line to Editorial Manager. You will be assigned your own password and user name. This will allow complete interaction between the editor and authors. Internally, reviewers will be approached to review material in their field of expertise and assigned with similar interaction. All information will be entirely protected and confidential.

All submissions should be written in a clear and succinct manner, following the style of the Journal. Title page should include a descriptive title; authors' surname and forename, address of each author and full address, telephone, fax and e-mail contacts for the corresponding author. In text: tables and figures are either inserted as part of sentence, for example Table 1, or in parentheses, for example (Fig. 1). Each table should carry a descriptive heading.

Editorial Manager will clearly indicate which aspects of the submission must be supplied off-line (download off-line document). This must be provided to the Journal by mail (PO Box 1013, Durbanville, South Africa, 7551) or e-mail to info@clinicscardive.com

All images MUST be at or above intended display size, with the following image resolutions: Line Art 800 dpi, Combination (Line Art + Halftone) 600 dpi, Halftone 300 dpi Image files also must be cropped as close to the actual image as possible.

Preferred Image Format Alternative Image Format

Image Format .tif

Image Width Greater than or equal to

intended display size

Colorspace RGB

DPI 500+

Alpha Channels None

Layers Flattened

Image Format .jpg

Image Width Greater than or equal to intended display size

Colorspace RGB

DPI 500+

Compression Quality Maximum

References numbered in the order of appearance in the text, according to Vancouver style. For articles: Author AB, Author C, Author M. The title of the article. Abbreviated journal title 1999; 14: 172–183. For book chapters: Author AB, Author CD. The title of the chapter. In: Editor A, Editor BC, ed. Title of the book, 2nd edn. Location: Publisher, 1999: 133 –139. DOI Numbers / PMID (Pubmed ID / PMC ID) must be added to all references to facilitate tagging for PubMed Central.

ORIGINAL ARTICLES:

Title page as above. Abstract (150 words) a short inclusive statement suitable for direct electronic abstracting, identifying the purpose of the study, key methods, the main results and the main conclusion. Keywords: maximum of six keywords for indexing. Introduction: concise description of background, sufficient for the non-specialist to appreciate the context of the work. Clear statement of the purpose of the study. Methods: a brief description of study design, procedures, analytical techniques and statistical evaluation. Results: a clear account of the study findings using quantitative language where possible and cross-referenced to tables and figures. Discussion: an

interpretation of the study placed within the context of current knowledge, leading to specific conclusions where possible. Acknowledgements. References, figures and tables as above.

REVIEWS:

Title page as above. Abstract (150 words) setting out the scope, key messages and conclusions of the review. Body of text liberally partitioned with headings and subheadings leading to a synopsis with conclusions at the end. Key messages in a separate box itemising two to five short principal statements. Acknowledgements, references, tables and figures as above.

Other articles should adopt a concise style consistent with similar articles previously published in the journal. Manuscripts should include a title page, and appropriate subheadings for text. Style of tables, figures and references as above.

Figures be sent to us in a high resolution JPEG format, but they MUST be sent separately from the Word document. If not in high resolution JPEG, then PowerPoint will do.

Editorial Manager will clearly indicate which aspects of the submission must be supplied off-line (download off-line document). This must be provided to the Journal by mail (PO Box 1013, Durbanville, South Africa, 7551) or e-mail to info@clinicscardive.com

The status of progression of the peer-review system will be directly accessible by authors. The Editorial Manager system is particularly useful to authors and reviewers as there is a direct link to PubMed for viewing all related articles on the subject matter.

Submitted manuscripts must be supplied with a covering letter with any additional information that may be helpful to the editor, such as the type or format of article that the manuscript represents. If the manuscript has been submitted previously to another journal, it is helpful to include the previous editor's and reviewers' comments with the submitted manuscript, along with the authors' responses to those comments. Copies of any permission to reproduce published material, to use illustrations or report information about identifiable people, or to name people for their contributions must accompany the manuscript.

EDITORIAL POLICY:

Statements and opinions expressed in articles and communications in CVJA are those of the authors and not those of the Editor or publisher. The Editor and publisher disclaims any responsibility or liability for such views. Neither the Editor nor the publisher guarantees, warrants or endorses any product or service advertised in this publication; neither do they guarantee any claim made by the manufactures of such product or service.

Material submitted for publication in the Cardiovascular Journal of Africa is accepted on condition that it has not been published elsewhere. The management reserves the copyright of the articles published. Aspects of cardiovascular medicine related to Sub-Saharan Africa will be encouraged.

Authors submitting papers to CVJA should also register as a reviewer as a quid pro quo for authors for reviewers reviewing your submission. If authors do not register as reviewers it may be taken in consideration when deciding on acceptance and rejection, and the time of publication. We do try not to call on a reviewer more that once a year but in rare circumstances it may be twice.

ONLINE FIRST: ADVANCED ONLINE PUBLICATION AHEAD OF PRINT

The Cardiovascular Journal of Africa is launching an online First Advance Online Publication (ePublication ahead of print) with full text availability via PubMed and this website which is accessible via Google and other search engines.

This facility is also known internationally as E-publication, ahead of print and offers authors the opportunity to publish their research articles sooner for an international audience.

Articles published online with CVJA will be published with unique DOI numbers, which ensures that the article can be cited using the date of the manuscript's first online posting and its DOI number. DOI's provide a persistent, permanent way to identify manuscripts in an electronic environment and are generated via our Editorial Management system and in accordance with the policy of the DOI foundation.

An example, of how articles are cited first online and then in print version is provided below:

Webster I et al. AMP Kinase activation and glut4 translocation in isolated cardiomyocytes. Cardiovasc J Afr. Prepublished month, day, year. DOI: 10.5830/CVJA-2011-042

The initial PubMed citation will be updated after the print version appears.

Cost of First Advance Online Publication (Payment can be made online with a valid credit card)

ZAR 4000 for Authors outside of Africa

ZAR 1500 for African Authors (including South Africa)

Please note that the Online First option is only available once your article has been accepted for publication. Also note there will be no refunds, any payment made before an article is accepted / rejected will be forfeited.

GUIDELINES FOR AUTHORS:

SOUTH AFRICAN JOURNAL FOR RESEARCH IN SPORT, PHYSICAL EDUCATION AND RECREATION

INFORMATION FOR AUTHORS

The *South African Journal for Research in Sport, Physical Education and Recreation* is published by the North-West University, Potchefstroom. Contributions from the fields of Sport Science, Physical Education, Recreation/Leisure Studies, Exercise Science and Dance Studies will be considered for publication. The articles submitted will be administered by the appropriate Subject Review Editor and evaluated by two or more referees. The decision as to whether a particular article is to be published or not, rests with the Editorial Board.

SUBMISSION

Manuscripts that do not comply with the following requirements regarding process, style and format will not be handled.

Manuscripts should be typed with ***SINGLE spacing*** in 10-point Times New Roman letter size for the text. All the text in *tables* and *figures* should be in 10-point Times New Roman font size and single spacing. Please do not use *Calibri*. The original manuscript can be submitted by Email. The length may not exceed 20 pages (tables, figures, references, etc. included). The **page setup** (cm) must be in the following format:

MARGINS		**PAPER SIZE**
Top:	3.56 cm	*Width*: 17.5 cm
Bottom:	1.78 cm	*Height*: 24.5 cm
Left:	2.11 cm	
Right:	2.11 cm	
Gutter:	0.00 cm	
Header:	2.03 cm	
Footer:	0.89 cm	

Original manuscripts may be submitted in English and should be sent to:

The Editor (Prof. Hanlie Moss)
South African Journal for Research in Sport, Physical Education and Recreation
Physical Activity, Sport and Recreation Research Unit
North-West University, POTCHEFSTROOM
Republic of South Africa

Editorial Office
Tel.: +27 (0)18-299 1821

E-mail: sajrsper@nwu.ac.za

CONDITIONS:

Each manuscript must be accompanied by a ***covering letter*** in which the following is declared: (1) that the manuscript contains original research; (2) that the manuscript or parts of the manuscript has not been published elsewhere previously; (3) that the manuscript is not currently being presented elsewhere for publication; and (4) that all the authors have read and approved the manuscript. This signed declaration regarding the originality must accompany each manuscript.

Authors are also requested to name three/3 potential referees, of which one/1 must be an *international* referee (the Journal is not bound to use these referees). Complete information regarding the referees (name, surname, e-mail address and telephone numbers) must be provided in the cover letter.

We discourage the practice of parts of the same study submitted for other issues of this Journal. Authors who submit a manuscript from a study of which some data have been or will be published elsewhere, must provide a strong justification in the accompanying letter to the Editor. The justification for not publishing all the data together in one paper must also be motivated in the covering letter.

The author should also ensure that the ***language*** of the manuscript has been ***edited*** thoroughly (English [UK]) by the time of submission. The name, address and telephone number of the person who did the language editing must be provided. Any expenses incurred by the Journal dealing with language editing will be added to the author's page fees.

The manuscript must have an ***ethical clearance number*** that was supplied by the authentic ethical committee of a specific institution. The process that was followed to obtain ethical clearance must be described in the manuscript under the heading, 'Ethical clearance'. No manuscript can be published without this declaration. Review, theoretic or philosophical articles do not require ethical clearance.

Any uncertainty regarding the ***statistical procedures*** that arise during the assessment of the manuscript will be referred to a local statistician. Any expenses incurred by the Journal dealing with statistical procedures will be added to the author's page fees.

PREPARATION OF MANUSCRIPT:

Manuscripts must be presented in a format that is compatible with *Microsoft Word for Windows* (PC). Tables, all figures (illustrations, diagrams, etc.) and graphs are regarded as text and must be presented in a format that is compatible with ***Word*** and figures should be ***accessible*** to make any text corrections. Photographs must be presented in *jpg* format.

Original manuscripts must contain the following sections in the following sequence: Title page, Abstract, Introduction, Purpose of Research, Methodology, Results, Discussion, Practical application/Recommendations, Conclusions, Acknowledgements (if applicable) and References (not all applicable to review/theoretical/philosophical articles). Appendices are acceptable but must be succinct.

Title page:

The first page of each manuscript should indicate the *title* in English and Afrikaans (will be translated for foreign authors), the *names* (title, first name in full and other initials, surname) of the author(s), the *telephone* numbers (work & home [& *mobile* for local authors]), *facsimile* number, *Email* address and the *field of study*. The ***complete mailing address*** and ***telephone numbers*** of the corresponding author and the institution (department, faculty, university, city, country) where the work was conducted should be provided in full. When more than one author and/or authors from various departments and institutions are involved, the **[1]*author*(s)** must be numbered according to their **[1]*department*(s)**. If any of the above-mentioned information should change during the review process, please inform the Subject Editor. A ***short title*** of not more than ***45 characters*** (including spaces), should be provided for use as a running heading.

Abstract:

Each manuscript must be accompanied by an abstract of approximately 150-200 words in *English* and should be set on a *separate page* as a SINGLE paragraph (single spacing). A list of three to seven ***keywords*** in *English* is required for indexing purposes and should be typed below the abstract in alphabetical order.

Text:

Start the text on a new page with the title of the article (centred and *without* the names of the authors). Follow the style of the most recent issue of the Journal regarding the use of headings and subheadings. Use only ***one line space*** after a paragraph. Only make use of ***section breaks*** and not ***page breaks***. The text, as well as the tables and figures, may not be in any other format than ***normal***. Thus, ***no style sheets*** may be used, also in the case of the list of references.

Tables and figures:

Tables and figures should be numbered with *Arabic* numerals (1, 2, etc.). Tables require the heading at the *top*, while figures have the legend *below* and both must **not** be included in the cells of the table/figure. ***Note:*** Use the decimal POINT (**not** the decimal comma). The site where the table or figure should be placed in the text must be indicated clearly in the manuscript. All tables and figures are to be placed *after the reference list* with each on a ***separate page***, always ending with a ***section break***. Any preference for the use of *colour* in the case of figures or photographs must be noted and will be at an *additional cost* to the page tariff.

It is essential that tables/figures should be *contained/fit within the page setup* described earlier for this Journal. Portrait layout is preferred for all tables/figures. Tables must use separate rows/columns (do not merge cells) for each item. Figures must be in ***Word*** and *accessible to make corrections* or changes within the figure where deemed necessary. Please ensure that especially the figures are of high quality for printing purposes. Any preference for the use of *colour* in the case of figures or photographs must be noted and will be at an *additional cost* to the page tariff.

References:

In the *text*, the Harvard method must be adopted by providing the author's surname and the date placed in parentheses. *For example:* Daly (1970); King and Loathes (1985); (Botha & Sonn, 2002); McGuines *et al.* (1986) or (Daly, 1970:80) where Daly is not part of the sentence and page number is added for a direct quotation. More than one reference must be arranged ***chronologically*** (Daly, 1970; King & Loathes, 1985). Note that *et al.* (italics) is used in the body of the text from the beginning when there are ***more than two authors***, but never in the list of references, where all authors must be provided.

List of references:

Only the references cited in the text should be listed alphabetically according to surname (last name) of authors (uppercase) after the body of text under the heading, **REFERENCES** (uppercase) starting on a new page. In the case where the TITLE of an article, book, etc., is in any other language than English, the author must also provide an ***English translation*** of the title in parentheses (this applies to Afrikaans titles as well).

In the case of articles published in ***JOURNALS***, references listed should include the surnames and initials (upper case and with full-stop and without spaces between initials) of ***all*** authors, the date of the publication in parentheses, the full title of the article, the full title of the journal (italics and no abbreviations), the volume number, the series/issue number in parentheses (if the said journal does not use issue numbers, the month of publication should be used), followed by a colon and a space with the first and last page numbers separated by a hyphen. In the case of online journals, use “online” if page numbers are not provided. The use of the correct punctuation is of importance.

If the reference is a ***BOOK***, the surname (last name, upper case) and initials (with full-stop and without spaces) of the author or editor (Ed.) must be provided, followed by the date of publication in parentheses followed by a full-stop, the title of the book (italics) as given on the title page, the number of the edition (ed.) in parentheses, the city (and abbreviation for the state in the case of the USA OR the country) where published, followed by a colon, a space and the name of the publisher.

For a ***CHAPTER*** in a book, the page numbers of the chapter cited must be provided in parentheses (not italics) after the title of the book (pp. 20-29). For further details, authors should consult the most recent publication of this Journal for other examples.

If the reference is a ***THESIS*** (master's level) or ***DISSERTATION*** (doctoral level), italics is **not** used in the title as it is an unpublished work. Provide the name of the city, state/country, colon, university and department/faculty.

For ***ELECTRONIC SOURCES,*** all references start with the same information that would be provided for a printed source (if available). The web page information follows the reference style. It will usually contain the name of the author(s) (if known), year of publication or last revision, title of complete work in *inverted commas*, title of web page, Uniform Resource Locater (URL) or access path in square text brackets (do not end the path statement with a full stop), full stop after the closing bracket and date of access (Retrieved on 10 December 2015]. See "How to cite information from the Internet and the Worldwide Web" at [http://www.apa.org/journals/webref.html] for specific examples. When citing a Web site in the text, merely give the author and date. When reference is made to a specific statement (quotation) in the article/document and no page number can be provided, the word 'online' is used for citing in the text (Van der Merwe, 2010:online).

When referencing an article in a ***NEWSPAPER,*** the key word of the newspaper is typed in capitals, as this is how it will appear in the ***alphabetical listing*** of references, namely ~~*The*~~ *CAPE ARGUS* (*The*) will appear under "C" or *BURGER* (*Die*) will appear under "B".

In the case of a paper presented in conference ***PROCEEDINGS***, the editors and the title of the proceedings, the page numbers of the article being referred to and the details of the congress (when and where it was held) and by whom (city, state, publisher) the proceedings was published should be provided.

Examples of style of formulations for different references:

Journal

ZHENG, N.; BARRENTINE, S.W.; FLEISIG, G.S. & ANDREWS, J.R. (2008). Kinematic analysis of swing in pro and amateur golfer. *International Journal of Sports Medicine*, 29(6): 487-493.

Book

WEINBERG, R.S. & GOULD, D. (2011). *Foundations of sport and exercise psychology* (5th ed.). Champaign, IL: Human Kinetics.

Chapter in book

SCHNECK, C.M. (2010). Visual perception. In J. Case-Smith & J.C. O'Brian (Eds.), *Occupational therapy for children* (6th ed.) (pp. 373-403). Maryland Heights, MO: Mosby.

Thesis/Dissertation

SURUJLAL, J. (2004). Human resources management of professional sports coaches in South Africa. Unpublished doctoral dissertation. Johannesburg, South Africa: Rand Afrikaans University.

Proceedings of a conference

HARDMAN, K. & MARSHALL, J. (2001). Worldwide survey on the state and status of physical education in schools. In G. Doll-Tepper & D. Scoretz (Eds.), *World summit on physical education* (pp. 15-37). Proceedings of the "World Summit on Physical Education", 3-5 November 1999. Berlin, Germany: International Council of Sport Science and Physical Education (ICSSPE).

Personal communication/correspondence/interview

BOUKES, P.B. (2015). Personal communication from the Acting Director of Sport at the Nelson Mandela Metropolitan University, Port Elizabeth on 27 February 2015.

JACOBS, L. (2015). Personal interview with the Spokesperson of UNICEF, 25 August, Pretoria.

Newspaper

CAPE ARGUS (*The*) (1997). 25 March, p. 5.

Electronic source

DINOFFER, J. (2011). "Activities to build balance". *Prevent child obesity 101*. Hyperlink: [http:// www.preventchildobesity101.com/Activities/BalanceActivities.php]. Retrieved on 20 November 2012.

ADMINISTRATION

If authors honour the rules and specifications for the submission of manuscripts, unnecessary delays would be avoided. Requesting ‘copy right’, concerning figures or photographs, is the responsibility of the authors and should be indicated. A manuscript that does not meet the requirements, as set out above, will be returned to the author without being evaluated. A subject specialist Editor administers and coordinates the assessment of the referees and provides the final recommendation.

The corresponding author will receive a complimentary copy of the Journal and five reprints of the article that could be shared with the co-authors. The original manuscripts and illustrations will be discarded one month after publication unless a request is received to return the original to the corresponding author. A page fee of South African **R300** per page is payable on receipt of a statement issued by the Editor.

GUIDELINES FOR AUTHORS:

AFRICAN JOURNAL OF PRIMARY HEALTH CARE AND FAMILY MEDICINE

AUTHOR GUIDELINES: AFRICAN JOURNAL OF PRIMARY HEALTH CARE AND FAMILY MEDICINE

OVERVIEW

INTRODUCTION

Authors are encouraged to submit original manuscripts online, which are not presently under consideration at another journal, in a format defined by the author guidelines. Submitted manuscripts are pre-screened by plagiarism detection software both before and after blind peer review, prior to acceptance. The journal allows the author to track and participate in all activities related to the processing of the manuscript, such as the review process, copy editing, layout editing and proofing of manuscripts, which are all managed online.

PUBLICATION PROCEDURE

Upon acceptance of a manuscript for publication by the Editor-in-Chief, the editorial staff will work towards preparing the manuscript for online publication. The first stage involves language editing, after which the manuscript is returned to the corresponding author for review. This is the author's final opportunity to make text changes to the manuscript and submit a revised version. At a final stage the editorial staff will send the author one set of galley proofs, and the author will have two working days to mark any typographical errors. It may not be possible to incorporate author corrections in the printed version of the manuscript if the author fails to respond to proofreading requests. Authors should visit their personalised homepage frequently to assess the location or stage of the manuscript.

New Submission

The manuscripts are uploaded and processed online, so you need to register and login into the journal website. Start the 5-step submission process by either:

In your **My User Home**, select **New Submission** next to Author.

In your **My User Home**, select **Author**, and underneath the heading **Start a New Submission** select **CLICK HERE**.

Make sure you have your cover letter and manuscript body in one document and any supplementary information (e.g. illustrations, legal documents, etc.) in separate documents saved on your computer, ready for upload. Refer to the **Submissions Guidelines** for more details.

HOW TO SUBMIT A NEW SUBMISSION

Each step is on a separate page. The submission process can be interrupted at any time; when you return to the site you can continue from where you left off. You can scroll down and click on the **Next** button to save your work and advance to the next page:

STEP 1: Select the journal section, complete the submission checklist and agree to our **copyright and licensing policy**. Save and continue.

STEP 2: Upload the submission file. Click on the **Choose file** button and locate the file on your computer. When you have selected the file you wish to upload, click the **Upload** button. Save and continue.

STEP 3: Insert the manuscript metadata, author(s) details, manuscript title, manuscript abstract and keywords as it is in the manuscript. Save and continue.

STEP 4: Upload supplementary files e.g. legal documents and any supplementary information such as large tables and photographs. You can only upload one supplementary file at a time and have a limit of 15MB per single file. Click on the **Choose file** button and locate the file on your computer. When you have selected the file that you wish to upload, click the **Upload** button. Repeat the process until all supplementary files have been uploaded. Save and continue.

STEP 5: Confirm the files for submission. Select the **Finish Submission** button. After completing the manuscript submission you will receive a submission confirmation via email. You can also log into the journal website at any time to check the status of your manuscript.

OVERVIEW

The author guidelines include information about the types of articles received for publication and preparing a manuscript for submission. Other relevant information about the journal's policies and the reviewing process can be found under the about section. The **compulsory cover letter** forms part of a submission and must be submitted together with all the required **forms.** All forms need to be completed in English.

EDITORIALS

Editorials are by invitation only and are intended to provide expert comment on relevant topics within the focus and scope of the journal.

Word limit	800 words
References	10 or less

COUNTRY PROFILES

Country Profiles are by invitation only and are intended to provide expert insight on the state of family medicine and primary health care training in selected African countries.

Word limit	800 words
References	10 or less

BOOK REVIEWS

Book reviews are brief articles providing insights or opinions on new books within the research field of the journal. Please contact the editor if you would like to suggest a book for review.

Word limit	1000 words

SCIENTIFIC LETTERS

A discussion on a particular topic, whereby the authors raise their opinion on a particular aspect of family medicine and primary health care studies or their reaction to a previously published article in the *African Journal of Primary Health Care & Family Medicine*. This section encourages debate amongst authors and readers on topical issues of national and global importance to the field of family medicine and primary health care studies. Letters will be published at the editors' discretion. In the case of critical letters, the original author will be given an opportunity to provide a short rebuttal which will be published along with the critical letter.

Word limit	2500-4000 words (excluding the structured abstract and references)
Structured abstract	250 words
References	20 or less
Tables/Figures	no more than 1 Tables/Figure

CONFERENCE REPORTS

The publication of conference reports are arranged with the Editor-in-Chief.

Word limit	1500 words
References	6 or less
Tables/Figures	no more than 1 Table/Figure

OPINION PAPERS

Short opinion pieces or personal perspectives (not research papers) personal viewpoint on family medicine and primary health care research that provides a contextual and holistic view of family medicine as practised across the continent. With rare exceptions, these essays are meant to express a personal viewpoint and should have no more than two authors.

Word limit	2000 words (excluding the structured abstract and references)
Structured abstract	250 words
References	15 or less
Tables/Figures	no more than 2 Tables/Figure
Ethical statement	should be included in the manuscript, if applicable

ORIGINAL RESEARCH ARTICLES

An original article provides an overview of innovative research in a particular field within or related to the focus and scope of the journal, presented according to a clear and well-structured format. Systematic reviews should follow the same basic structure as other original research articles. The aim and objectives should focus on a clinical question that will be addressed in the review. The methods section should describe in detail the search strategy, criteria used to select or reject articles, attempts made to obtain all important and relevant studies and deal with publication bias (including grey and unpublished literature), how the quality of included studies was appraised, the methodology used to extract and/or analyse data. Results should describe the homogeneity of the different findings, clearly present the overall results and any meta-analysis.

Word limit	3500-7000 words (excluding the structured abstract and references)
Structured abstract	250 words to cover a Background, Aim, Setting, Methods, Results and Conclusion
References	60 or less
Tables/Figures	no more than 7 Tables/Figure
Ethical statement	should be included in the manuscript

Compulsory supplementary file	ethical clearance letter/certificate
Language	only manuscripts presented in English or French will be considered

OBITUARIES

Is a news article that reports the recent passing of a person, typically along with an account of the person's work achievement and life.

Word limit	400 words
Photo	a photograph of the deceased

REVIEW ARTICLES

These must be critical reviews of the literature on topics that have social, economic or scientific values, and must be within the focus and scope of the journal.

Word limit	2500-4000 words (excluding the structured abstract and references)
Structured abstract	250 words to cover a Background, Aim, Method, Results and Conclusion
References	50 or less
Tables/Figures	no more than 4 Tables/Figure
Ethical statement	should be included in the manuscript, if applicable
Language	only manuscripts presented in English or French will be considered

CORRESPONDENCE

They may be subjected to the peer review process and their eventual placement is at the discretion of the editorial team. Kindly include a correspondence address.

Word limit	400 words (excluding the references)
Abstract	n/a
References	10 or less
Tables/Figures	no more than 1 Tables/Figure

PATIENT STUDIES

A detailed account of a specific patient as a case study. The patient study should highlight a critical issue that is relevant to the field of family medicine and primary care.

Word limit	1500 words (excluding the unstructured abstract and references)
Unstructured abstract	75 words to cover a Background, Aim, Method, Results and Conclusion
References	15 or less
Tables/Figures	no more than 6 Tables/Figure
Ethical statement	should be included in the manuscript
Compulsory supplementary file	ethical clearance letter/certificate

COVER LETTER

The format of the compulsory cover letter forms part of your submission. Kindly download and complete, in English, the provided **cover letter**.

Anyone that has made a significant contribution to the research and the paper must be listed as an author in your cover letter. Contributions that fall short of meeting the criteria as stipulated in our policy should rather be mentioned in the 'Acknowledgements' section of the manuscript.
Read our **authorship** guidelines and **author contribution** statement policies.

ORIGINAL RESEARCH ARTICLE FULL STRUCTURE

Title: The article's full title should contain a maximum of 95 characters (including spaces).

Abstract: The abstract, written in English, should be no longer than 250 words and must be written in the past tense. The abstract should give a succinct account of the objectives, methods, results and significance of the matter. The structured abstract for an Original Research article should consist of six paragraphs labelled Background, Aim, Setting, Methods, Results and Conclusion.

Background: Summarise the social value (importance, relevance) and scientific value (knowledge gap) that your study addresses.

Aim: State the overall aim of the study.

Setting: State the setting for the study.

Methods: Clearly express the basic design of the study, and name or briefly describe the methods used without going into excessive detail.

Results: State the main findings.

Conclusion: State your conclusion and any key implications or recommendations.
Do not cite references and do not use abbreviations excessively in the abstract.

Introduction: The introduction must contain your argument for the social and scientific value of the study, as well as the aim and objectives:

- Social value: The first part of the introduction should make a clear and logical argument for the importance or relevance of the study. Your argument should be supported by use of evidence from the literature.
- Scientific value: The second part of the introduction should make a clear and logical argument for the originality of the study. This should include a summary of what is already known about the research question or specific topic, and should clarify the knowledge gap that this study will address. Your argument should be supported by use of evidence from the literature.
- Conceptual framework: In some research articles it will also be important to describe the underlying theoretical basis for the research and how these theories are linked together in a conceptual framework. The theoretical evidence used to construct the conceptual framework should be referenced from the literature.
- Aim and objectives: The introduction should conclude with a clear summary of the aim and objectives of this study.

Research methods and design: This must address the following:

- Study design: An outline of the type of study design.
- Setting: A description of the setting for the study; for example, the type of community from which the participants came or the nature of the health system and services in which the study is conducted.
- Study population and sampling strategy: Describe the study population and any inclusion or exclusion criteria. Describe the intended sample size and your sample size calculation or justification. Describe the sampling strategy used. Describe in practical terms how this was implemented.
- Intervention (if appropriate): If there were intervention and comparison groups, describe the intervention in detail and what happened to the comparison groups.
- Data collection: Define the data collection tools that were used and their validity. Describe in practical terms how data were collected and any key issues involved, e.g. language barriers.
- Data analysis: Describe how data were captured, checked and cleaned. Describe the analysis process, for example, the statistical tests used or steps followed in qualitative data analysis.
- Ethical considerations: Approval must have been obtained for all studies from the author's institution or other relevant ethics committee and the institution’s name and permit numbers should be stated here.

Results: Present the results of your study in a logical sequence that addresses the aim and objectives of your study. Use tables and figures as required to present your findings. Use quotations as required to

establish your interpretation of qualitative data. All units should conform to the **SI convention** and be abbreviated accordingly. Metric units and their international symbols are used throughout, as is the decimal point (not the decimal comma).

Discussion: The discussion section should address the following four elements:

- Key findings: Summarise the key findings without reiterating details of the results.
- Discussion of key findings: Explain how the key findings relate to previous research or to existing knowledge, practice or policy.
- Strengths and limitations: Describe the strengths and limitations of your methods and what the reader should take into account when interpreting your results.
- Implications or recommendations: State the implications of your study or recommendations for future research (questions that remain unanswered), policy or practice. Make sure that the recommendations flow directly from your findings.

Conclusion: Provide a brief conclusion that summarises the results and their meaning or significance in relation to each objective of the study.

Acknowledgements: Those who contributed to the work but do not meet our authorship criteria should be listed in the Acknowledgments with a description of the contribution. Authors are responsible for ensuring that anyone named in the Acknowledgments agrees to be named.
Also provide the following, each under their own heading:

- Competing interests: This section should list specific competing interests associated with any of the authors. If authors declare that no competing interests exist, the article will include a statement to this effect: *The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.* Read our **policy on competing interests**.
- Author contributions: All authors must meet the criteria for authorship as outlined in the **authorship policy** and **author contribution** statement policies.
- Funding: Provide information on funding if relevant
- Disclaimer: A statement that the views expressed in the submitted article are his or her own and not an official position of the institution or funder.

References: Authors should provide direct references to original research sources whenever possible. References should not be used by authors, editors, or peer reviewers to promote self-interests. Refer to the journal referencing style downloadable on our *Formatting Requirements* page.

FORMATTING REQUIREMENTS

File format

The document uploaded during Step 2 of the submission process:

Microsoft Word (.doc/.docx): We can accept Word 2003 DOC files and Word 2007 DOCX files.

Rich Text Format (RTF): Users of other word processing packages should save or convert their files to RTF before uploading. Many free tools are available that will make this process easier.

The AOSIS house style

The manuscript must adhere to the **AOSIS house style guide**.

Referencing style guide

The manuscript must adhere to the **Vancouver referencing style**.

Language

Manuscripts must be written in British English, according to the Oxford English Dictionary [avoid Americanisms (e.g. use ‘s’ and not ‘z’ spellings), set your version of Microsoft Word to UK English]. Refer to the AOSIS house style guide for more information.

Page and line numbers

Include page numbers and line numbers in the manuscript file.

Font type

Use a standard font size in any standard font family.

Special characters

Refer to our AOSIS house style guide on math and Unicode font guidelines.

Line spacing

1.5

Headings

Ensure that formatting for headings is consistent in the manuscript. Limit manuscript sections and sub-sections to four heading levels. Make sure heading levels are clearly indicated in the manuscript text. Do not number headings

APPENDIX E

PROOF OF ARTICLE SUBMISSION

CARDIOVASCULAR JOURNAL OF AFRICA

From: "CardioVascular Journal of Africa" <em@editorialmanager.com>
To: "Tamrin Veldsman" <tamrin.veldsman@nwu.ac.za>
Date: 2020/01/30 12:17
Subject: A manuscript number has been assigned to Relationship between physical activity and carotid intima–media thickness among teachers in South Africa: the SABPA study

Dear Ms Veldsman,

Your submission entitled "Relationship between physical activity and carotid intima–media thickness among teachers in South Africa: the SABPA study" has been been received online and assigned the following manuscript number: CVJSA-D-20-00011.

You are required to submit the off-line documents which is available on our website www.cvja.co.za or click on the following link :
(http://www.cvja.co.za/downloads/CVJA_Offline_Document.pdf)
Please complete these offline documents which require signatures and e-mail it to info@clinicscardive.com or fax to +2786 664 4202.

You will be able to check on the progress of your paper by logging on to Editorial Manager as an author. The URL is https://www.editorialmanager.com/cvjsa/.

Thank you for submitting your work to this journal.

Kind regards,

Marcelle Ayres, Admin
Editorial Assistant
CardioVascular Journal of Africa

In compliance with data protection regulations, you may request that we remove your personal registration details at any time. (Use the following URL: https://www.editorialmanager.com/cvjsa/login.asp?a=r). Please contact the publication office if you have any questions.

CardioVascular Journal of Africa

Relationship between physical activity and carotid intima–media thickness among teachers in South Africa: the SABPA study

--Manuscript Draft--

Manuscript Number:	
Full Title:	Relationship between physical activity and carotid intima–media thickness among teachers in South Africa: the SABPA study
Article Type:	Original Article
Section/Category:	Epidemiology Section
Keywords:	Carotid intima-media thickness; physical activity; South Africa
Corresponding Author:	Tamrin Veldsman, M.Sc North-West University Potchefstroom, North West SOUTH AFRICA
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	North-West University
Corresponding Author's Secondary Institution:	
First Author:	Tamrin Veldsman, M.Sc
First Author Secondary Information:	
Order of Authors:	Tamrin Veldsman, M.Sc
	Mariette Swanepoel, PhD
	Andries Monyeki, PhD
	Sanette Brits, PhD
	Leoné Malan, RN, PhD
Order of Authors Secondary Information:	
Manuscript Region of Origin:	SOUTH AFRICA
Abstract:	Objective To determine the relationship between objectively measured physical activity (PA) and carotid intima–media thickness (CIMT) in teachers in South Africa. Methods A cross-sectional study was conducted among 215 teachers aged 25–65 years (mean age 49.67±8.43 years) who participated in the Sympathetic Activity and Ambulatory Blood Pressure in Africans (SABPA) prospective cohort study. CIMT was measured using SonoSite Micromaxx ultrasound, following over seven consecutive days. Other measurements obtained included; body mass index (BMI), waist circumference (WC), 24-hour ambulatory blood pressure (AMBP), C-reactive protein (CRP) and fasting blood total cholesterol (TC). Data were analysed using Statistical Package for Social Sciences (SPSS) version 25. Results The prevalence of obesity according to body mass index (BMI) and sedentary behaviour was above 30%; hypertension 38.9% and 41.1% CRP. Male teachers showed higher mean values for CIMT than female teachers (0.75±0.16 mm vs 0.66±0.12 mm; p≤0.05). A borderline negative association existed between CIMT and mean seven-day awake metabolic equivalent of task (r =–0.19; p=0.08) in female

Powered by Editorial Manager® and ProduXion Manager® from Aries Systems Corporation