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

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

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Co-promoter: Prof MA Monyeki
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Graduation: July 2020
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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.

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

Signature of co-promoter: ___________________________ Date: 17/03/2020 (Prof SJ Brits)
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“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 ($\beta = 0.151, p = 0.027$) 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
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 bydra 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 asseesseer 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 ≤ 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-oortuigige 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) (β = 0.15; p = 0.027) positiief 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-oortuigige 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 geklassificeer. '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 ouerdomsgroep, 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 positiief 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 intervensi studies word voorgestel om effektiewe intervensiies 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
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<td>Common carotid artery</td>
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<td>CDC</td>
<td>Centers for Disease Control</td>
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<td>CIMT</td>
<td>Carotid intima–media thickness</td>
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<td>FA</td>
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<td>FITT</td>
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<tr>
<td>HbA1C</td>
<td>Haemoglobin A1c</td>
</tr>
<tr>
<td>HDL</td>
<td>High-density lipoprotein</td>
</tr>
<tr>
<td>HIV</td>
<td>Human immunodeficiency virus</td>
</tr>
<tr>
<td>HPA</td>
<td>Hypothalamic-pituitary-adrenal</td>
</tr>
<tr>
<td>HREC</td>
<td>Health research ethics committee</td>
</tr>
<tr>
<td>IDF</td>
<td>International Diabetes Federation</td>
</tr>
<tr>
<td>IMT</td>
<td>Intima–media thickness</td>
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<tr>
<td>IPAQ</td>
<td>International Physical Activity Questionnaire</td>
</tr>
<tr>
<td>ISAK</td>
<td>International Society for the Advancement of Kinanthropometry</td>
</tr>
<tr>
<td>JIS</td>
<td>Joint Interim Statement</td>
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<tr>
<td>KIMD</td>
<td>Karotis intima–media dikte</td>
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<tr>
<td>KVSs</td>
<td>Kardiovaskulêre siektes</td>
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<td>LDL</td>
<td>Low-density lipoprotein</td>
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<tr>
<td>LPA</td>
<td>Light physical activity</td>
</tr>
<tr>
<td>METs</td>
<td>Metabolic equivalent of task</td>
</tr>
<tr>
<td>MRC</td>
<td>Medical Research Council</td>
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<tr>
<td>MS</td>
<td>Cardio-metabolic syndrome</td>
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<tr>
<td>MVPA</td>
<td>Moderate-to-vigorous physical activity</td>
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<tr>
<td>NCD</td>
<td>Non-communicable disease</td>
</tr>
<tr>
<td>NCEP ATP III</td>
<td>National Cholesterol Education Program Adult Treatment Panel III</td>
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<tr>
<td>NOSs</td>
<td>Nie-oordraagbare siektes</td>
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<tr>
<td>NRF</td>
<td>National Research Foundation</td>
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<td>NWU</td>
<td>North-West University</td>
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<td>PA</td>
<td>Physical activity</td>
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<td>PaCT</td>
<td>Partnership for Cohort Research and Training</td>
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<tr>
<td>PAL</td>
<td>Physical activity level</td>
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<tr>
<td>PhASRec</td>
<td>Physical Activity, Sport and Recreation research focus area</td>
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<tr>
<td>REE</td>
<td>Resting energy expenditure</td>
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<tr>
<td>RMR</td>
<td>Resting metabolic rate</td>
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<tr>
<td>ROS</td>
<td>Reactive oxygen species</td>
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<tr>
<td>SABPA</td>
<td>Sympathetic Activity and Ambulatory Blood Pressure in Africans</td>
</tr>
<tr>
<td>SAJRSPER</td>
<td>South African Journal for Research in Sport, Physical Education and Recreation</td>
</tr>
<tr>
<td>SBP</td>
<td>Systolic blood pressure</td>
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<tr>
<td>SBRN</td>
<td>Sedentary Behaviour Research Network</td>
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<tr>
<td>Acronym</td>
<td>Definition</td>
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<td>------------------------------------------------</td>
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<tr>
<td>SMAC</td>
<td>Sequential multiple analyser computer</td>
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<tr>
<td>SPSS</td>
<td>Statistical Package for Social Science</td>
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<tr>
<td>ST</td>
<td>Sedentary time</td>
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<td>StatsSA</td>
<td>Statistics South Africa</td>
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<tr>
<td>TC</td>
<td>Total cholesterol</td>
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<td>TEE</td>
<td>Total energy expenditure</td>
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<td>TG</td>
<td>Triglycerides</td>
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<td>VAT</td>
<td>Visceral adipose tissue</td>
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<td>VPA</td>
<td>Vigorous physical activity</td>
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<td>WC</td>
<td>Waist circumference</td>
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<td>WHO</td>
<td>World Health Organization</td>
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<tr>
<td>WHR</td>
<td>Waist-to-hip ratio</td>
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<td>WHtR</td>
<td>Waist-to-height ratio</td>
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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, hyperglycaemia 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 hyperglycaemia, hypertension, high serum triglycerides, low high-density lipoprotein (HDL) cholesterol and insulin resistance, which lead to a higher risk in developing a CVD (Akbari 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, hyperglycaemia, 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 were 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


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 intima–media 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 O₂ 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)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Intensity</th>
<th>Duration</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerobic activity</td>
<td>Moderate</td>
<td>Minimum 30 minutes</td>
<td>5 days per week</td>
</tr>
<tr>
<td></td>
<td>Vigorous</td>
<td>Minimum 20 minutes</td>
<td>3 days per week</td>
</tr>
<tr>
<td>Muscle strength and</td>
<td>Amount:</td>
<td>Repetitions:</td>
<td></td>
</tr>
<tr>
<td>flexibility</td>
<td>8–10 exercises</td>
<td>8–12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Major muscle groups</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 et 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 (^2H) and oxygen (^18O)
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.,
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; Westerterp, 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 (Akbari 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)

<table>
<thead>
<tr>
<th>Cardio-metabolic syndrome</th>
<th>NCEP ATP III (3+ criteria)</th>
<th>WHO (impaired glucose, impaired fasting glucose or type 2 diabetes, + 2 or more criteria)</th>
<th>IDF (central obesity + 2 of the remaining criteria)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdominal obesity</td>
<td>WC Men &gt;102 cm Women &gt;88 cm</td>
<td>BMI ≥30 kg/m² WHR Men &gt;0.90 Women &gt;0.85</td>
<td>WC European men ≥94 cm European women ≥80 cm, with ethnicity-specific values for other groups</td>
</tr>
<tr>
<td>Lipid profile</td>
<td>High TG ≥150 mg/dL (1.7 mmol/L)</td>
<td>Low HDL Men: &lt;40 mg/dL (1.0 mmol/L) Women: &lt;50 mg/dL (1.3 mmol/L)</td>
<td>Low HDL Men &lt;35 mg/dL (0.9 mmol/L) Women &lt;39 mg/dL (1.0 mmol/L)</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>≥130/85 mmHg</td>
<td>≥140/90 mmHg</td>
<td>130/85 mmHg or treatment for previously diagnosed hypertension</td>
</tr>
<tr>
<td>Glucose</td>
<td>Fasting glucose ≥110 mg/dL (6.1 mmol/L)</td>
<td>Impaired glucose regulation or type 2 diabetes Insulin resistance</td>
<td>Fasting glucose ≥100 mg/dL (5.6 mmol/L) or previously diagnosed with type 2 diabetes</td>
</tr>
<tr>
<td>Microalbuminuria</td>
<td>Urinary albumin excretion of 20 μg/min or albumin to creatinine ratio of ≥30 mg/g</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 intima–media 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., 2007:76).
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).

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).
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)

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

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)

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

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 (Kozáková 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 (Kozáková et al., 2010:1517). Indicating that vigorous PA contributed to decreased IMT (Kozáková 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

<table>
<thead>
<tr>
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<th>Participants:</th>
<th>Measurement of PA:</th>
<th>Results:</th>
<th>Conclusion:</th>
</tr>
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<tr>
<td>(Kozáková et al., 2010:1511-1519)</td>
<td>To investigate if ST and PA levels are independently associated with CIMT</td>
<td>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.</td>
<td>Accelerometer (single-axis model AM7164) at the small of the back from waking until sleep time over 7 days; IPAQ.</td>
<td>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.</td>
<td>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.</td>
</tr>
<tr>
<td>(Ried-Larsen et al., 2013:168–177)</td>
<td>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)</td>
<td>A cross-sectional study based on the EYHS in 2009–2010 follow-up data (N=397), mean age 15.6±0.4 years.</td>
<td>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 &lt; 1.5 METs. MVPA expressed as ~4 METs. VPA expressed as ~6 METs.</td>
<td>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 &lt; 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.</td>
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</table>

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)

<table>
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</tr>
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<tbody>
<tr>
<td>(Ried-Larsen et al., 2014:1502–1507)</td>
<td>To investigate the association between PA and subclinical carotid CVD across childhood</td>
<td>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.</td>
<td>ActiGraph model GT3X or model GT1M for at least five consecutive days and removed while showering, bathing and swimming or during sleep time.</td>
<td>No associations were observed between MVPA or VPA and CIMT or any measures of arterial stiffness.</td>
<td>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.</td>
</tr>
<tr>
<td>(Gomez-Marcos et al., 2014:366–372)</td>
<td>To determine the relationship between regular PA and vascular structure and function-based CIMT</td>
<td>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.</td>
<td>PA recall estimated by ActiGraph (GT3X) MVPA was considered as activity accumulated from all bouts lasting at least 1 minute.</td>
<td>CIMT and vigorous-intensity PA day time were negatively and statistically significantly related ($r = -0.74$; $p &lt; 0.01$). However, PA counts/min ($r = 0.077$), LPA ($r = -0.087$) and PA in METs/hour/week ($r = -0.017$) were not significantly correlated to CIMT, although not significant. The study indicated that MPA ($r = 0.028$) was positively associated with CIMT, although not significant.</td>
<td>PA assessed by counts/min and time spent in MPA, VPA indicated a negative association with central and peripheral augmentation index.</td>
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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.
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<tr>
<td>(Huynh et al., 2015:355–360)</td>
<td>To determine the association of different types of PA with carotid dispensability and the mechanisms involved</td>
<td>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)</td>
<td>Australian: Yamax Digi walker SW-200 pedometers for 7 days and Finland: Omron Walking Style One (HJ-152 R-E) pedometers.</td>
<td>Vigorous leisure time was positively associated with CD (men: $r = 0.07$, $p &lt; 0.01$; women: $r = 0.05$, $p &lt; 0.05$) Total PA was not associated with CD (men: $r = -0.02$; $p &gt; 0.05$; women: $r = -0.01$; $p &gt; 0.05$) Steps per day not associated with CD (men: $r = 0.00$; $p &gt; 0.05$; women $r = 0.03$; $p &gt;0.05$) Men lower CD ($1.82\pm0.64 %/10 \text{mmHg}$) than women ($2.15\pm0.78 % / 10 \text{mmHg}$).</td>
<td>Vigorous leisure-time PA, but not total PA or LPA, was associated with CD in young and mid-aged adults.</td>
</tr>
<tr>
<td>(Ried-Larsen et al., 2015:107–112)</td>
<td>To determine the associations between mean exposure to or the change in MVPA from adolescence to adulthood and subclinical atherosclerosis in adulthood</td>
<td>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.</td>
<td>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 $&gt;$4 METs at age 15 years.</td>
<td>MVPA decreased by 6.1 (22.0) min/day from adolescence to adulthood; mean MVPA = 20.6 (11.7) min/day, there was no significant change ($p &gt; 0.05$) between men and women. Men spent more time in MVPA than women. Baseline MVPA positively associated with adult IMT (std.$\beta = 0.12$, $p = 0.02$). Adjusted for sex, height and cohort. At follow-up MVPA was marginally associated</td>
<td>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.</td>
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</table>

**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)

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<td>(Parsons et al., 2016:194–199)</td>
<td>To determine the association between objectively measured PA, sedentary time and non-invasive vascular measures, markers for CVD</td>
<td>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.</td>
<td>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) (&lt;1.5 MET), light activity (1.5–3 MET) and moderate and vigorous activity (≥3 MET).</td>
<td>With CIMT (std.β = 0.10, p = 0.07). Mean exposure to MVPA activities were significant with all outcomes (IMT) (p &lt; 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 &lt; 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.</td>
<td>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.</td>
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<tr>
<td>(Ascenso et al., 2016:391–398)</td>
<td>To determine the associations between sedentary behaviour, PA and CRF, with CIMT in obese adolescents</td>
<td>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.</td>
<td>ActiGraph GT3X worn above the right hip, near the iliac crest, for seven consecutive days, except during sleep, bathing or swimming.</td>
<td>Sedentary men had significantly higher CIMT ($p &lt; 0.001$). 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.</td>
<td>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.</td>
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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)
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<td>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.</td>
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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.
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https://doi.org/10.1016/j.cbpa.2010.04.013


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CHAPTER 3:
ARTICLE 1

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

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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≤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 ≤ 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; however, high levels of physical inactivity continue to be a major public health concern in the 21st century. 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. One in five adults globally does not meet the PA recommendations. In South Africa, more than one-third (38.2%) of the population does not participate in sufficient PA, and in a 51-country survey the country was ranked as having the third-highest prevalence of physical inactivity. Physical inactivity, obesity and hypertension are directly associated with the risk of developing cardiovascular disease (CVD) and atherosclerosis.

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. Additionally, C-reactive protein (CRP) as a biomarker for atherosclerosis has been linked to an increase in carotid intima-media thickness (CIMT) progression. Weingärtner and colleagues 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 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, before they occur. Koolhaas et al. 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. 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. A study in Caucasian men and women indicated a positive association between CIMT and time spent sedentary and a negative association with light PA, while another study in Danish adolescents did not find any associations between moderate-to-vigorous PA or vigorous PA and CIMT.

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. 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. The high job demands together with a lack of PA may lead to high blood pressure, heart disease, stroke, diabetes and cancer. Cardiovascular disease and physical inactivity are among the significant causes of mortality and morbidity in both the general...
population and in teachers. The environment, as well as the prevalence of increased cardiovascular disease may increase the development of atherosclerosis in teachers and may be identified 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. 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. 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
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. The participants BMI were classified according to the cut-off points of the American College of Sports Medicine (ACSM) 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 and time restrictions during clinical data collection. Therefore, self-reported PA was used to programme the ActiHeart for each participant.

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).

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. The participants PAL was calculated as TEE/resting energy expenditure (REE). 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. Images were digitised and imported to Artery Measurement Systems automated software (AMS, Gothenburg, Sweden, v1.130) for analysing CIMT. 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. 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.

**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. 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 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. 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.

**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.

**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/m²; underweight = ≤18.5 kg/m²; overweight = 25–29.9 kg/m²; obesity = ≥30 kg/m². 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

<table>
<thead>
<tr>
<th>Group (N=215)</th>
<th>n</th>
<th>Mean±SD</th>
<th>t</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIMT (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>104</td>
<td>0.74±0.16</td>
<td>4.930</td>
<td>193.82</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Female</td>
<td>111</td>
<td>0.66±0.12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young adult (total group)</td>
<td>57</td>
<td>0.64±0.16</td>
<td>-3.614</td>
<td>87.309</td>
<td>0.001*</td>
</tr>
<tr>
<td>Middle adult (total group)</td>
<td>158</td>
<td>0.73±0.14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young adult males</td>
<td>26</td>
<td>0.71±0.18</td>
<td>3.330</td>
<td>40.33</td>
<td>0.002*</td>
</tr>
<tr>
<td>Young adult females</td>
<td>31</td>
<td>0.58±0.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle adult males</td>
<td>78</td>
<td>0.77±0.15</td>
<td>3.702</td>
<td>143.21</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Middle adult females</td>
<td>80</td>
<td>0.69±0.11</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Female Age group</th>
<th>n</th>
<th>Mean±SD</th>
<th>t</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIMT (mm) Young adulthood</td>
<td>31</td>
<td>0.58±0.11</td>
<td>-4.616</td>
<td>54.81</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Middle adulthood</td>
<td>80</td>
<td>0.69±0.11</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Males Age group</th>
<th>n</th>
<th>Mean±SD</th>
<th>t</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIMT (mm) Young adulthood</td>
<td>26</td>
<td>0.71±0.18</td>
<td>-1.335</td>
<td>37.09</td>
<td>0.19</td>
</tr>
<tr>
<td>Middle adulthood</td>
<td>78</td>
<td>0.77±0.15</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 \( p \leq 0.05 \).
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

<table>
<thead>
<tr>
<th></th>
<th>Hypertensive n(%)</th>
<th>Normotensive n(%)</th>
<th>Chi-square</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total group (N=216)</td>
<td>84(38.9)</td>
<td>132(61.1)</td>
<td>10.667</td>
<td>0.001*</td>
</tr>
<tr>
<td>Young adults (n=57)</td>
<td>21(36.8)</td>
<td>36(63.2)</td>
<td>3.947</td>
<td>0.05*</td>
</tr>
<tr>
<td>Middle adults (n=159)</td>
<td>63(39.6)</td>
<td>96(60.4)</td>
<td>6.849</td>
<td>0.01*</td>
</tr>
<tr>
<td>Sedentary (n=71)</td>
<td>38(53.5)</td>
<td>33(46.5)</td>
<td>0.352</td>
<td>0.55</td>
</tr>
<tr>
<td>Light PA (n=145)</td>
<td>46(31.7)</td>
<td>99(68.3)</td>
<td>19.372</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Sedentary males (n=46)</td>
<td>30(65.2)</td>
<td>16(34.8)</td>
<td>4.261</td>
<td>0.04*</td>
</tr>
<tr>
<td>Sedentary females (n=25)</td>
<td>8(32.0)</td>
<td>17(68.0)</td>
<td>3.240</td>
<td>0.07</td>
</tr>
<tr>
<td>Light PA males (n=58)</td>
<td>28(48.3)</td>
<td>30(51.7)</td>
<td>0.069</td>
<td>0.80</td>
</tr>
<tr>
<td>Light PA females (n=87)</td>
<td>18(20.7)</td>
<td>69(79.3)</td>
<td>28.897</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Increased CRP</th>
<th>No risk CRP</th>
<th>Chi-square</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total group (n=214)</td>
<td>88(41.1)</td>
<td>126(58.9)</td>
<td>6.748</td>
<td>0.01*</td>
</tr>
<tr>
<td>Young adults (n=56)</td>
<td>30(53.6)</td>
<td>26(46.4)</td>
<td>0.286</td>
<td>0.59</td>
</tr>
<tr>
<td>Middle adults (n=158)</td>
<td>58(36.7)</td>
<td>100(63.3)</td>
<td>11.165</td>
<td>0.001*</td>
</tr>
<tr>
<td>Sedentary (n=71)</td>
<td>34(47.9)</td>
<td>37(52.1)</td>
<td>0.127</td>
<td>0.72</td>
</tr>
<tr>
<td>Light PA (n=143)</td>
<td>54(37.8)</td>
<td>89(62.2)</td>
<td>8.566</td>
<td>0.003*</td>
</tr>
<tr>
<td>Sedentary males (n=46)</td>
<td>22(48.0)</td>
<td>24(52.0)</td>
<td>0.087</td>
<td>0.77</td>
</tr>
<tr>
<td>Sedentary females (n=25)</td>
<td>12(48.0)</td>
<td>13(52.0)</td>
<td>0.040</td>
<td>0.84</td>
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<tr>
<td>Light PA males (n=58)</td>
<td>14(24.0)</td>
<td>44(76.0)</td>
<td>15.517</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Light PA females (n=87)</td>
<td>40(47.0)</td>
<td>45(53.0)</td>
<td>0.294</td>
<td>0.59</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Activity classification</th>
<th>n</th>
<th>Mean±SD</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>71</td>
<td>48.73±9.32</td>
<td>0.26</td>
</tr>
<tr>
<td>Light PA</td>
<td>145</td>
<td>50.12±7.96</td>
<td>0.36</td>
</tr>
<tr>
<td>Height (cm)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Sedentary</td>
<td>71</td>
<td>170.04±10.32</td>
<td></td>
</tr>
<tr>
<td>Light PA</td>
<td>145</td>
<td>168.67±10.12</td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>71</td>
<td>85.96±21.94</td>
<td>0.26</td>
</tr>
<tr>
<td>Light PA</td>
<td>145</td>
<td>82.52±18.36</td>
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<tr>
<td>BMI (kg/m²)</td>
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<tr>
<td>Sedentary</td>
<td>71</td>
<td>29.58±6.89</td>
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</tr>
<tr>
<td>Light PA</td>
<td>145</td>
<td>29.26±6.30</td>
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<tr>
<td>WC (cm)</td>
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<td></td>
<td></td>
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<tr>
<td>Sedentary</td>
<td>71</td>
<td>99.32±17.90</td>
<td>0.08*</td>
</tr>
<tr>
<td>Light PA</td>
<td>145</td>
<td>94.97±14.71</td>
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</tr>
<tr>
<td>WHtR</td>
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<tr>
<td>Sedentary</td>
<td>71</td>
<td>0.58±0.10</td>
<td>0.13</td>
</tr>
<tr>
<td>Light PA</td>
<td>145</td>
<td>0.56±0.09</td>
<td></td>
</tr>
<tr>
<td>Total cholesterol (mmol/L)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>71</td>
<td>4.59±1.13</td>
<td>0.20</td>
</tr>
<tr>
<td>Light PA</td>
<td>144</td>
<td>4.39±0.97</td>
<td></td>
</tr>
<tr>
<td>CRP (mg/dl)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>71</td>
<td>4.87±6.29</td>
<td>0.16</td>
</tr>
<tr>
<td>Light PA</td>
<td>143</td>
<td>3.69±4.34</td>
<td></td>
</tr>
<tr>
<td>AMBP SBP (mmHg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>71</td>
<td>135.04±19.43</td>
<td>0.02*</td>
</tr>
<tr>
<td>Light PA</td>
<td>145</td>
<td>126.62±15.68</td>
<td></td>
</tr>
<tr>
<td>AMBP DP (mmHg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>71</td>
<td>83.48±11.24</td>
<td>0.001*</td>
</tr>
<tr>
<td>Light PA</td>
<td>145</td>
<td>78.07±10.18</td>
<td></td>
</tr>
<tr>
<td>CIMT (mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>70</td>
<td>0.70±0.17</td>
<td>0.74</td>
</tr>
<tr>
<td>Light PA</td>
<td>145</td>
<td>0.71±0.14</td>
<td></td>
</tr>
<tr>
<td>Mean 7-day awake METs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>71</td>
<td>1.32±0.10</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Light PA</td>
<td>145</td>
<td>2.28±0.62</td>
<td></td>
</tr>
<tr>
<td>AEE (kcal/wk)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>71</td>
<td>796.85±722.17</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Light PA</td>
<td>145</td>
<td>1476.97±1124.39</td>
<td></td>
</tr>
<tr>
<td>TEE (kcal/wk)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>71</td>
<td>2814.87±843.07</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Light PA</td>
<td>145</td>
<td>3482.10±1478.56</td>
<td></td>
</tr>
<tr>
<td>PAL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>71</td>
<td>1.49±0.14</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Light PA</td>
<td>145</td>
<td>2.34±0.62</td>
<td></td>
</tr>
</tbody>
</table>

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 ≤ 0.05.

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

<table>
<thead>
<tr>
<th>Sex</th>
<th>Males</th>
<th>Females</th>
<th>p-value</th>
<th>Males</th>
<th>Females</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>Mean±SD</td>
<td>p-value</td>
<td>n</td>
<td>Mean±SD</td>
<td>p-value</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>Sedentary</td>
<td>46</td>
<td>0.55</td>
<td>25</td>
<td>47.8±4.8</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>Light PA</td>
<td>58</td>
<td>50.2±4.7</td>
<td>87</td>
<td>50.0±4.8</td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>Sedentary</td>
<td>46</td>
<td>175.0±6.9</td>
<td>0.07</td>
<td>25</td>
<td>160.9±5.9</td>
</tr>
<tr>
<td></td>
<td>Light PA</td>
<td>58</td>
<td>177.9±7.0</td>
<td>87</td>
<td>162.4±6.4</td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>Sedentary</td>
<td>46</td>
<td>90.6±18.2</td>
<td>0.93</td>
<td>25</td>
<td>77.4±24.9</td>
</tr>
<tr>
<td></td>
<td>Light PA</td>
<td>58</td>
<td>90.8±14.6</td>
<td>87</td>
<td>76.9±18.5</td>
<td></td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>Sedentary</td>
<td>46</td>
<td>29.4±5.2</td>
<td>0.50</td>
<td>25</td>
<td>29.8±9.0</td>
</tr>
<tr>
<td></td>
<td>Light PA</td>
<td>58</td>
<td>28.7±4.1</td>
<td>87</td>
<td>29.5±4.2</td>
<td></td>
</tr>
<tr>
<td>WC (cm)</td>
<td>Sedentary</td>
<td>46</td>
<td>0.59±0.08</td>
<td>0.12</td>
<td>25</td>
<td>0.57±0.13</td>
</tr>
<tr>
<td></td>
<td>Light PA</td>
<td>58</td>
<td>0.57±0.06</td>
<td>87</td>
<td>0.56±0.10</td>
<td></td>
</tr>
<tr>
<td>TC (mmol/L)</td>
<td>Sedentary</td>
<td>46</td>
<td>4.7±1.15</td>
<td>0.10</td>
<td>25</td>
<td>4.3±1.08</td>
</tr>
<tr>
<td></td>
<td>Light PA</td>
<td>58</td>
<td>4.3±0.84</td>
<td>87</td>
<td>4.4±1.04</td>
<td></td>
</tr>
<tr>
<td>CRP (mg/dL)</td>
<td>Sedentary</td>
<td>46</td>
<td>5.25±7.03</td>
<td>0.01*</td>
<td>25</td>
<td>4.1±4.72</td>
</tr>
<tr>
<td></td>
<td>Light PA</td>
<td>58</td>
<td>2.17±2.36</td>
<td>85</td>
<td>4.7±5.04</td>
<td></td>
</tr>
<tr>
<td>AMBP (mmHg)</td>
<td>Sedentary</td>
<td>46</td>
<td>138.9±17.94</td>
<td>0.01*</td>
<td>25</td>
<td>127.9±20.39</td>
</tr>
<tr>
<td></td>
<td>Light PA</td>
<td>58</td>
<td>130.2±11.99</td>
<td>87</td>
<td>124.2±17.38</td>
<td></td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>Sedentary</td>
<td>46</td>
<td>86.1±9.90</td>
<td>0.02*</td>
<td>25</td>
<td>78.5±12.09</td>
</tr>
<tr>
<td></td>
<td>Light PA</td>
<td>58</td>
<td>81.8±8.74</td>
<td>87</td>
<td>75.5±10.36</td>
<td></td>
</tr>
<tr>
<td>CIMT (mm)</td>
<td>Sedentary</td>
<td>46</td>
<td>0.75±0.16</td>
<td>0.99</td>
<td>25</td>
<td>0.59±0.12</td>
</tr>
<tr>
<td></td>
<td>Light PA</td>
<td>58</td>
<td>0.75±0.16</td>
<td>87</td>
<td>0.68±0.12</td>
<td></td>
</tr>
<tr>
<td>AEE (kcal/wk)</td>
<td>Sedentary</td>
<td>46</td>
<td>808.3±752.47</td>
<td>&lt;0.001*</td>
<td>25</td>
<td>775.6±677.33</td>
</tr>
<tr>
<td></td>
<td>Light PA</td>
<td>58</td>
<td>1839.4±1439.69</td>
<td>87</td>
<td>1235.3±771.65</td>
<td></td>
</tr>
<tr>
<td>TEE (kcal/wk)</td>
<td>Sedentary</td>
<td>46</td>
<td>2952.0±810.30</td>
<td>&lt;0.001*</td>
<td>25</td>
<td>2562.4±859.94</td>
</tr>
<tr>
<td></td>
<td>Light PA</td>
<td>58</td>
<td>4032.4±1722.01</td>
<td>87</td>
<td>3115.2±1163.92</td>
<td></td>
</tr>
<tr>
<td>Mean 7-day awake METs</td>
<td>Sedentary</td>
<td>46</td>
<td>1.29±0.10</td>
<td>&lt;0.001*</td>
<td>25</td>
<td>1.36±0.09</td>
</tr>
<tr>
<td></td>
<td>Light PA</td>
<td>58</td>
<td>2.43±0.79</td>
<td>87</td>
<td>2.17±0.47</td>
<td></td>
</tr>
<tr>
<td>PAL</td>
<td>Sedentary</td>
<td>46</td>
<td>1.46±0.13</td>
<td>&lt;0.001*</td>
<td>25</td>
<td>1.55±0.14</td>
</tr>
<tr>
<td></td>
<td>Light PA</td>
<td>58</td>
<td>2.47±0.76</td>
<td>87</td>
<td>2.25±0.49</td>
<td></td>
</tr>
</tbody>
</table>

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 ≤ 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

<table>
<thead>
<tr>
<th></th>
<th>Sedentary group</th>
<th></th>
<th>Light physical activity group</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CIMT (mm)</td>
<td>BMI (kg/m$^2$)</td>
<td>WC (cm)</td>
<td>WHtR</td>
</tr>
<tr>
<td>CIMT (mm)</td>
<td>$r$</td>
<td>-0.05</td>
<td>0.14</td>
<td>0.05</td>
</tr>
<tr>
<td>$p$</td>
<td>-</td>
<td>0.66</td>
<td>0.25</td>
<td>0.70</td>
</tr>
<tr>
<td>AEE (kcal/wk)</td>
<td>$r$</td>
<td>-0.17</td>
<td>0.02</td>
<td>-0.02</td>
</tr>
<tr>
<td>$p$</td>
<td>0.15</td>
<td>0.86</td>
<td>0.86</td>
<td>0.75</td>
</tr>
<tr>
<td>Mean 7-day awake METs</td>
<td>$r$</td>
<td>-0.20</td>
<td>0.07</td>
<td>-0.06</td>
</tr>
<tr>
<td>$p$</td>
<td>0.11</td>
<td>0.57</td>
<td>0.64</td>
<td>0.93</td>
</tr>
<tr>
<td>TEE (kcal/wk)</td>
<td>$r$</td>
<td>-0.05</td>
<td>0.14</td>
<td>0.18</td>
</tr>
<tr>
<td>$p$</td>
<td>0.66</td>
<td>0.23</td>
<td>0.13</td>
<td>0.24</td>
</tr>
<tr>
<td>PAL</td>
<td>$r$</td>
<td>-0.30*</td>
<td>0.13</td>
<td>-0.02</td>
</tr>
<tr>
<td>$p$</td>
<td>0.01</td>
<td>0.30</td>
<td>0.89</td>
<td>0.24</td>
</tr>
</tbody>
</table>

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 | | Females (n=19) | | |
|-----------|-----------|------------|------------|------------|------------|------------|------------|------------|
|           | Males (n=41) | | | | | | | |
| Mean 7-day | | | | | | | | |
| awake METs | | | | | | | | |
| 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* |
| AEE (kcal/wk) | | | | | | | | |
| 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) | | | | | | | | |
| 0.09 | 0.95 | – | 0.28 | -0.31 | 0.37 | 0.97 | – | 0.53 | 0.16 |
| p | 0.09 | – | <0.001* | 0.06* | 0.05* | 0.10 | <0.001* | – | 0.01* | 0.48 |
| PAL 7-day | | | | | | | | |
| 0.09 | 0.39 | 0.28 | – | -0.08 | 0.80 | 0.55 | 0.53 | – | 0.09 |
| p | 0.58 | 0.07* | 0.05* | 0.59 | – | 0.35 | 0.44 | 0.48 | 0.71 | – |
| CIMT (mm) | | | | | | | | |
| 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) | | | | | | | | |
| Mean 7-day | | | | | | | | |
| awake METs | | | | | | | | |
| 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) | | | | | | | | |
| 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 | | | | | | | | |
| 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 | | | | | | | | |
| 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) | | | | | | | | |
| 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 ≤ 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 Contrasting, 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 Kozâkovà 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, Kadoglu 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/m² 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 Kozáková 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

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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, 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, and most recently to a study by Muluvhu and colleagues 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.

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.
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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


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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 aktiviteit status in die verband tussen obesiteit en karotis intima-media dikte in stedelike Suid Afrikaanse onderwysers: die SABPA-studie

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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 ≥25 kg/m²) (WHO, 2017a) and 27% were obese (BMI ≥30 kg/m²) (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/m²), 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 (1.3MTM 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 ≤ 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)

<table>
<thead>
<tr>
<th></th>
<th>Total group (N=216)</th>
<th>Male teachers (n=104)</th>
<th>Female teachers (n=112)</th>
<th>p-value for sex differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>49.67±8.44</td>
<td>49.79±8.48</td>
<td>49.55±8.43</td>
<td>0.84</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>169.12±10.18</td>
<td>176.6±7.90</td>
<td>162.14±6.37</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>83.65±19.62</td>
<td>90.75±16.51</td>
<td>77.06±20.04</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>29.3±6.49</td>
<td>29.06±4.77</td>
<td>29.64±7.76</td>
<td>0.51</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>96.40±15.92</td>
<td>102.12±12.79</td>
<td>91.08±16.74</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.57±0.09</td>
<td>0.58±0.07</td>
<td>0.56±0.11</td>
<td>0.21</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>129.11±18.29</td>
<td>134.57±16.56</td>
<td>124.04±18.42</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>86.22±11.33</td>
<td>90.87±10.42</td>
<td>81.91±10.44</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>CIMT (mm)</td>
<td>0.70±0.15</td>
<td>0.75±0.16</td>
<td>0.66±0.12</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Underweight, n (%)</td>
<td>1 (1)</td>
<td>0 (0)</td>
<td>1 (1)</td>
<td></td>
</tr>
<tr>
<td>Normal weight, n (%)</td>
<td>57 (26)</td>
<td>22 (21)</td>
<td>35 (31)</td>
<td></td>
</tr>
<tr>
<td>Overweight, n (%)</td>
<td>74 (34)</td>
<td>44 (42)</td>
<td>30 (27)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Obesity, n (%)</td>
<td>84 (39)</td>
<td>38 (37)</td>
<td>46 (41)</td>
<td></td>
</tr>
<tr>
<td>Diabetes, n (%)</td>
<td>22 (10)</td>
<td>17 (17)</td>
<td>5 (5)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Self-reported smoking, n (%)</td>
<td>30 (14)</td>
<td>21 (20)</td>
<td>9 (8)</td>
<td></td>
</tr>
<tr>
<td>NO</td>
<td>185 (86)</td>
<td>82 (80)</td>
<td>103 (92)</td>
<td></td>
</tr>
<tr>
<td>Self-reported alcohol use, n (%)</td>
<td>104 (48)</td>
<td>68 (66)</td>
<td>36 (32)</td>
<td></td>
</tr>
<tr>
<td>NO</td>
<td>111 (52)</td>
<td>35 (34)</td>
<td>76 (68)</td>
<td>0.51</td>
</tr>
<tr>
<td>Hypertension medication, n (%)</td>
<td>67 (31)</td>
<td>39 (38)</td>
<td>28 (25)</td>
<td>0.36</td>
</tr>
<tr>
<td>MS, n (%)</td>
<td>63 (29)</td>
<td>48 (46)</td>
<td>15 (13)</td>
<td>0.02*</td>
</tr>
<tr>
<td>PA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary, n (%)</td>
<td>71 (33)</td>
<td>46 (44)</td>
<td>25 (22)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Light PA, n (%)</td>
<td>145 (67)</td>
<td>58 (56)</td>
<td>87 (78)</td>
<td>0.06</td>
</tr>
<tr>
<td>CRP, n (%)</td>
<td>88 (41)</td>
<td>36 (35)</td>
<td>52 (47)</td>
<td></td>
</tr>
<tr>
<td>Moderate atherosclerosis risk (&gt;0.75 mm)</td>
<td>74 (34)</td>
<td>49 (47)</td>
<td>25 (22)</td>
<td></td>
</tr>
<tr>
<td>No atherosclerosis risk (&lt;0.75 mm)</td>
<td>141 (66)</td>
<td>55 (53)</td>
<td>86 (78)</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

Underweight = BMI <18.5 kg/m²; normal weight = BMI 18.5–24.9 kg/m²; overweight = BMI 25.0–29.9 kg/m²; obesity = BMI ≥30 kg/m²; 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/m²; \( p < 0.001 \)), 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/m²; 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

<table>
<thead>
<tr>
<th>BMI classification</th>
<th>Sedentary</th>
<th>Light PA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean±SD</td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>21</td>
<td>46.38±9.56</td>
</tr>
<tr>
<td>Overweight</td>
<td>22</td>
<td>50.45±10.53</td>
</tr>
<tr>
<td>Obesity</td>
<td>28</td>
<td>49.14±8.03</td>
</tr>
<tr>
<td><strong>Height (cm)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>21</td>
<td>166.80±8.98</td>
</tr>
<tr>
<td>Overweight</td>
<td>22</td>
<td>171.52±10.30</td>
</tr>
<tr>
<td>Obesity</td>
<td>28</td>
<td>171.31±11.06</td>
</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>21</td>
<td>62.53±10.17</td>
</tr>
<tr>
<td>Overweight</td>
<td>22</td>
<td>83.33±11.12</td>
</tr>
<tr>
<td>Obesity</td>
<td>28</td>
<td>105.59±15.59</td>
</tr>
<tr>
<td><strong>BMI (kg/m²)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>21</td>
<td>22.35±2.01</td>
</tr>
<tr>
<td>Overweight</td>
<td>22</td>
<td>28.15±1.32</td>
</tr>
<tr>
<td>Obesity</td>
<td>28</td>
<td>36.13±5.65</td>
</tr>
<tr>
<td><strong>WC (cm)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>21</td>
<td>80.50±9.07</td>
</tr>
<tr>
<td>Overweight</td>
<td>22</td>
<td>97.21±7.75</td>
</tr>
<tr>
<td>Obesity</td>
<td>28</td>
<td>115.10±13.64</td>
</tr>
<tr>
<td><strong>WHtR</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>21</td>
<td>0.48±0.47</td>
</tr>
<tr>
<td>Overweight</td>
<td>22</td>
<td>0.57±0.03</td>
</tr>
<tr>
<td>Obesity</td>
<td>28</td>
<td>0.67±0.09</td>
</tr>
<tr>
<td><strong>SBP (mmHg)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>21</td>
<td>127.76±19.40</td>
</tr>
<tr>
<td>Overweight</td>
<td>22</td>
<td>133.27±21.67</td>
</tr>
<tr>
<td>Obesity</td>
<td>28</td>
<td>137.57±18.81</td>
</tr>
<tr>
<td><strong>DBP (mmHg)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>21</td>
<td>85.24±13.44</td>
</tr>
<tr>
<td>Overweight</td>
<td>22</td>
<td>90.05±13.19</td>
</tr>
<tr>
<td>Obesity</td>
<td>28</td>
<td>90.36±10.77</td>
</tr>
<tr>
<td><strong>CIMT (mm)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>21</td>
<td>0.68±0.17</td>
</tr>
<tr>
<td>Overweight</td>
<td>22</td>
<td>0.73±0.18</td>
</tr>
<tr>
<td>Obesity</td>
<td>28</td>
<td>0.68±0.16</td>
</tr>
<tr>
<td><strong>AEE (kcal/wk)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>21</td>
<td>1011.05±981.51</td>
</tr>
<tr>
<td>Overweight</td>
<td>22</td>
<td>668.94±501.01</td>
</tr>
<tr>
<td>Obesity</td>
<td>28</td>
<td>736.70±692.23</td>
</tr>
<tr>
<td><strong>TEE (kcal/wk)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight</td>
<td>21</td>
<td>2850.17±1165.5</td>
</tr>
<tr>
<td>Overweight</td>
<td>22</td>
<td>2665.20±592.79</td>
</tr>
<tr>
<td>Obesity</td>
<td>28</td>
<td>2906.01±755.57</td>
</tr>
<tr>
<td><strong>PAL</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight</td>
<td>–</td>
<td>1.20</td>
</tr>
</tbody>
</table>

Sedentary = ≤1.5 metabolic equivalent of task (METs); light physical activity (PA) = 1.5–3 METs; normal weight = BMI 18.5–24.9 kg/m²; overweight = BMI 25–29.9 kg/m²; obesity = BMI >30 kg/m².

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 ≤ 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

<table>
<thead>
<tr>
<th>WHtR category</th>
<th>Sedentary</th>
<th></th>
<th>Light PA</th>
<th></th>
<th>p-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean±SD</td>
<td>p-value</td>
<td>n</td>
<td>Mean±SD</td>
<td>p-value</td>
</tr>
<tr>
<td>Age (years)</td>
<td>&lt;0.5</td>
<td>44</td>
<td>47.32±10.21</td>
<td>0.08</td>
<td>95</td>
<td>49.96±7.56</td>
</tr>
<tr>
<td></td>
<td>≥0.5</td>
<td>27</td>
<td>51.04±7.27</td>
<td>0.89</td>
<td>49</td>
<td>50.67±4.68</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>&lt;0.5</td>
<td>44</td>
<td>170.17±11.33</td>
<td>&lt;0.001*</td>
<td>95</td>
<td>169.79±10.16</td>
</tr>
<tr>
<td></td>
<td>≥0.5</td>
<td>27</td>
<td>169.83±8.64</td>
<td>0.09</td>
<td>49</td>
<td>169.60±9.88</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>&lt;0.5</td>
<td>44</td>
<td>75.27±17.77</td>
<td>&lt;0.001*</td>
<td>95</td>
<td>75.64±13.17</td>
</tr>
<tr>
<td></td>
<td>≥0.5</td>
<td>27</td>
<td>103.37±16.29</td>
<td>&lt;0.001*</td>
<td>49</td>
<td>96.36±19.23</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>&lt;0.5</td>
<td>44</td>
<td>25.67±3.77</td>
<td>&lt;0.001*</td>
<td>95</td>
<td>26.24±3.49</td>
</tr>
<tr>
<td></td>
<td>≥0.5</td>
<td>27</td>
<td>35.96±6.01</td>
<td>&lt;0.001*</td>
<td>49</td>
<td>35.26±6.28</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>&lt;0.5</td>
<td>44</td>
<td>170.17±11.33</td>
<td>&lt;0.001*</td>
<td>95</td>
<td>169.79±10.16</td>
</tr>
<tr>
<td></td>
<td>≥0.5</td>
<td>27</td>
<td>169.83±8.64</td>
<td>0.09</td>
<td>49</td>
<td>169.60±9.88</td>
</tr>
<tr>
<td>WHtR</td>
<td>&lt;0.5</td>
<td>44</td>
<td>0.52±0.05</td>
<td>&lt;0.001*</td>
<td>95</td>
<td>0.52±0.05</td>
</tr>
<tr>
<td></td>
<td>≥0.5</td>
<td>27</td>
<td>0.68±0.08</td>
<td>&lt;0.001*</td>
<td>49</td>
<td>0.66±0.06</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>&lt;0.5</td>
<td>44</td>
<td>127.09±18.01</td>
<td>&lt;0.001*</td>
<td>95</td>
<td>122.51±14.61</td>
</tr>
<tr>
<td></td>
<td>≥0.5</td>
<td>27</td>
<td>143.52±19.25</td>
<td>&lt;0.001*</td>
<td>49</td>
<td>135.96±18.21</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>&lt;0.5</td>
<td>44</td>
<td>86.45±11.93</td>
<td>0.03*</td>
<td>95</td>
<td>82.37±9.92</td>
</tr>
<tr>
<td></td>
<td>≥0.5</td>
<td>27</td>
<td>92.48±10.67</td>
<td>0.06*</td>
<td>49</td>
<td>91.06±11.17</td>
</tr>
<tr>
<td>CIMT (mm)</td>
<td>&lt;0.5</td>
<td>44</td>
<td>0.70±0.17</td>
<td>0.73</td>
<td>95</td>
<td>0.71±0.14</td>
</tr>
<tr>
<td></td>
<td>≥0.5</td>
<td>27</td>
<td>0.69±0.16</td>
<td>0.73</td>
<td>49</td>
<td>0.71±0.16</td>
</tr>
<tr>
<td>AEE (kcal/wk)</td>
<td>&lt;0.5</td>
<td>12</td>
<td>819.09±970.19</td>
<td>0.93</td>
<td>28</td>
<td>1238.22±153.10</td>
</tr>
<tr>
<td></td>
<td>≥0.5</td>
<td>59</td>
<td>792.33±671.42</td>
<td>0.93</td>
<td>116</td>
<td>1485.69±98.92</td>
</tr>
<tr>
<td>TEE (kcal/wk)</td>
<td>&lt;0.5</td>
<td>12</td>
<td>2578.99±1292.64</td>
<td>0.47</td>
<td>28</td>
<td>3085.28±304.02</td>
</tr>
<tr>
<td></td>
<td>≥0.5</td>
<td>59</td>
<td>2862.85±725.99</td>
<td>0.47</td>
<td>116</td>
<td>3520.39±121.17</td>
</tr>
<tr>
<td>PAL (kcal/wk)</td>
<td>&lt;0.5</td>
<td>12</td>
<td>1.42±0.11</td>
<td>0.05*</td>
<td>28</td>
<td>2.12±0.45</td>
</tr>
<tr>
<td></td>
<td>≥0.5</td>
<td>59</td>
<td>1.50±0.14</td>
<td>0.05*</td>
<td>116</td>
<td>2.36±0.59</td>
</tr>
</tbody>
</table>

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 $p ≤ 0.05$.

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

<table>
<thead>
<tr>
<th>Sedentary</th>
<th>Overweight (n=22)</th>
<th>Obese (n=28)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age (years)</td>
<td>BMI (kg/m²)</td>
</tr>
<tr>
<td>Age</td>
<td>r</td>
<td>-0.12</td>
</tr>
<tr>
<td>(years)</td>
<td>p</td>
<td>-0.60</td>
</tr>
<tr>
<td>BMI</td>
<td>r</td>
<td>-0.12</td>
</tr>
<tr>
<td>(kg/m²)</td>
<td>p</td>
<td>0.60</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>r</td>
<td>0.01</td>
</tr>
<tr>
<td>(mm)</td>
<td>p</td>
<td>0.98</td>
</tr>
<tr>
<td>CIMT</td>
<td>r</td>
<td>0.05</td>
</tr>
<tr>
<td>(mm)</td>
<td>p</td>
<td>0.83</td>
</tr>
<tr>
<td>WHtR</td>
<td>r</td>
<td>0.03</td>
</tr>
<tr>
<td>(mm)</td>
<td>p</td>
<td>0.90</td>
</tr>
<tr>
<td>AEE (kcal/wk)</td>
<td>r</td>
<td>-0.01</td>
</tr>
<tr>
<td>Light PA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overweight (n=104)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>r</td>
<td>0.12</td>
</tr>
<tr>
<td>(years)</td>
<td>p</td>
<td>0.23</td>
</tr>
<tr>
<td>BMI</td>
<td>r</td>
<td>0.12</td>
</tr>
<tr>
<td>(kg/m²)</td>
<td>p</td>
<td>0.23</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>r</td>
<td>0.08</td>
</tr>
<tr>
<td>(mm)</td>
<td>p</td>
<td>0.45</td>
</tr>
<tr>
<td>CIMT</td>
<td>r</td>
<td>0.28**</td>
</tr>
<tr>
<td>(mm)</td>
<td>p</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>WHtR</td>
<td>r</td>
<td>0.27**</td>
</tr>
<tr>
<td>(mm)</td>
<td>p</td>
<td>0.01</td>
</tr>
<tr>
<td>AEE (kcal/wk)</td>
<td>r</td>
<td>0.04</td>
</tr>
<tr>
<td>Light PA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overweight (n=112)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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/m²; overweight = BMI 25–29.9 kg/m²; obese = BMI ≥30 kg/m².

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 ≤ 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 \((\beta)\) and \(p\)-values (95\% confidence interval) for the relationship between carotid intima-media thickness and body composition, controlling for physical activity

<table>
<thead>
<tr>
<th>Variables</th>
<th>‘Crude’</th>
<th>‘Crude’ + PA</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI (kg/m(^2))</td>
<td>-0.023</td>
<td>-0.022</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>0.151 *</td>
<td>0.152 *</td>
</tr>
<tr>
<td>WHtR</td>
<td>0.043</td>
<td>0.043</td>
</tr>
</tbody>
</table>

\(\beta = \) 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 \((\beta = 0.227; p = 0.001)\) and sex \((\beta = -0.183; p = 0.033)\) were significant predictors, and WC \((\beta = 0.382; p = 0.061)\) and total cholesterol \((\beta = 0.125; p = 0.066)\) 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

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

\(\beta = \) 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/m²), 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

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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


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

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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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{1,4,5}

The global prevalence of MS is estimated to be between 17\% and 25\%.\textsuperscript{6} In urban South Africa, MS varies between 0\% and 50\% or higher depending on the definition of MS used and the population studied.\textsuperscript{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\textsuperscript{7}, and in Gauteng Province, South Africa, 29\% of Africans were diagnosed with MS.\textsuperscript{8} The variance in the prevalence may be explained by differences in the MS diagnostic criteria.\textsuperscript{9} Regarding the different diagnostic criteria for MS,\textsuperscript{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.\textsuperscript{1}

Physical inactivity is a major risk factor in the development of MS and increases the odds of developing MS by 73\%.\textsuperscript{11,12} The increasing prevalence of physical inactivity and obesity may lead to an increased global prevalence of MS.\textsuperscript{1,9} Physical inactivity is inversely associated with health outcomes.\textsuperscript{13} Additionally, in both self-reported\textsuperscript{14,15} and objective data\textsuperscript{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.\textsuperscript{1} Moderate and high levels of PA are associated with reduced odds of developing MS.\textsuperscript{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.\textsuperscript{13}

Teachers are considered to be physically inactive and spent most of their working time in sedentary or light energy-cost activities.\textsuperscript{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.\textsuperscript{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 dysfunction21 and cortisol data22-23 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™ 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, respectively¹, 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 biokinetist (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). 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.

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 and 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 ≤ 0.05.

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), 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.

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.

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
The second highest prevalence cardio-metabolic risk factor was having BP equal to or higher than 130/85 mmHg (70%). 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 WHR ($p < 0.001$; 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

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<tr>
<th></th>
<th>MS</th>
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</tr>
<tr>
<td>HDL (mmol/L)</td>
<td>YES</td>
<td>62</td>
<td>0.99±0.34</td>
<td>-1.36</td>
<td>212</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>NO</td>
<td>152</td>
<td>1.06±0.33</td>
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<tr>
<td>Glucose (mmol/L)</td>
<td>YES</td>
<td>62</td>
<td>6.34±2.92</td>
<td>7.32</td>
<td>212</td>
<td>&lt;0.001²</td>
</tr>
<tr>
<td></td>
<td>NO</td>
<td>152</td>
<td>4.48±0.74</td>
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<tr>
<td>TG (mmol/L)</td>
<td>YES</td>
<td>62</td>
<td>1.80±1.10</td>
<td>7.083</td>
<td>213</td>
<td>&lt;0.001²</td>
</tr>
<tr>
<td></td>
<td>NO</td>
<td>153</td>
<td>1.02±0.50</td>
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<td>SBP (mmHg)</td>
<td>YES</td>
<td>63</td>
<td>141.98±15.14</td>
<td>7.432</td>
<td>214</td>
<td>&lt;0.001²</td>
</tr>
<tr>
<td></td>
<td>NO</td>
<td>153</td>
<td>123.80±16.80</td>
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<td>DBP (mmHg)</td>
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<td>93.95±8.73</td>
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<td></td>
<td>NO</td>
<td>153</td>
<td>83.04±10.74</td>
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<tr>
<td>WHR</td>
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<td>5.332</td>
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<td>NO</td>
<td>153</td>
<td>0.55±0.08</td>
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</table>

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; WHR = waist-to-height ratio.

²The level of significance is set as $p ≤ 0.05$. 

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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

<table>
<thead>
<tr>
<th></th>
<th>BMI (kg/m²)</th>
<th>WC (cm)</th>
<th>Smoking</th>
<th>Alcohol use</th>
<th>GGT (U/L)</th>
<th>Glucose (mmol/L)</th>
<th>TC (mmol/L)</th>
<th>TG (mmol/L)</th>
<th>SBP (mmHg)</th>
<th>DBP (mmHg)</th>
<th>WHR</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEE (kcal/wk)</td>
<td>r -0.04</td>
<td>-0.02</td>
<td>0.01</td>
<td>0.06</td>
<td>-0.19</td>
<td>-0.10</td>
<td>0.07</td>
<td>-0.11</td>
<td>-0.07</td>
<td>-0.08</td>
<td>-0.08</td>
</tr>
<tr>
<td>p</td>
<td>0.53</td>
<td>0.73</td>
<td>0.89</td>
<td>0.38</td>
<td>0.01</td>
<td>0.12</td>
<td>0.31</td>
<td>0.33</td>
<td>0.24</td>
<td>0.26</td>
<td></td>
</tr>
<tr>
<td>TEE (kcal/wk)</td>
<td>r 0.09</td>
<td>0.17</td>
<td>-0.05</td>
<td>-0.01</td>
<td>-0.07</td>
<td>-0.003</td>
<td>0.07</td>
<td>0.03</td>
<td>0.04</td>
<td>0.06</td>
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</tr>
<tr>
<td>p</td>
<td>0.21</td>
<td>0.02</td>
<td>0.44</td>
<td>0.89</td>
<td>0.31</td>
<td>0.96</td>
<td>0.29</td>
<td>0.72</td>
<td>0.71</td>
<td>0.60</td>
<td>0.40</td>
</tr>
<tr>
<td>PAL</td>
<td>r 0.10</td>
<td>0.001</td>
<td>-0.04</td>
<td>0.02</td>
<td>-0.16</td>
<td>-0.09</td>
<td>-0.05</td>
<td>-0.13</td>
<td>-0.07</td>
<td>-0.07</td>
<td>0.05</td>
</tr>
<tr>
<td>p</td>
<td>0.13</td>
<td>0.98</td>
<td>0.60</td>
<td>0.75</td>
<td>0.02</td>
<td>0.49</td>
<td>0.51</td>
<td>0.06</td>
<td>0.34</td>
<td>0.34</td>
<td>0.51</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>r -0.84</td>
<td>0.02</td>
<td>-0.03</td>
<td>0.28</td>
<td>0.35</td>
<td>0.08</td>
<td>0.25</td>
<td>0.33</td>
<td>0.29</td>
<td>0.91</td>
<td></td>
</tr>
<tr>
<td>p</td>
<td>&lt;0.001</td>
<td>0.77</td>
<td>0.70</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.27</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>WC (cm)</td>
<td>r 0.84</td>
<td>-0.06</td>
<td>-0.11</td>
<td>0.38</td>
<td>0.44</td>
<td>0.11</td>
<td>0.40</td>
<td>0.43</td>
<td>0.41</td>
<td>0.92</td>
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</tr>
<tr>
<td>p</td>
<td>&lt;0.001</td>
<td>0.40</td>
<td>0.10</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.11</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Smoking</td>
<td>r 0.02</td>
<td>-0.06</td>
<td>-0.18</td>
<td>-0.18</td>
<td>-0.04</td>
<td>-0.19</td>
<td>-0.24</td>
<td>-0.06</td>
<td>-0.08</td>
<td>-0.01</td>
<td></td>
</tr>
<tr>
<td>p</td>
<td>0.77</td>
<td>0.40</td>
<td>0.01</td>
<td>0.01</td>
<td>0.54</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.42</td>
<td>0.22</td>
<td>0.88</td>
<td></td>
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<tr>
<td>Alcohol use</td>
<td>r -0.03</td>
<td>-0.11</td>
<td>0.02</td>
<td>-0.29</td>
<td>-0.14</td>
<td>0.01</td>
<td>-0.21</td>
<td>-0.10</td>
<td>-0.12</td>
<td>-0.03</td>
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</tr>
<tr>
<td>p</td>
<td>0.70</td>
<td>0.10</td>
<td>0.01</td>
<td>&lt;0.001</td>
<td>0.05</td>
<td>0.89</td>
<td>&lt;0.001</td>
<td>0.15</td>
<td>0.09</td>
<td>0.62</td>
<td></td>
</tr>
<tr>
<td>GGT (U/L)</td>
<td>r 0.28</td>
<td>0.38</td>
<td>-0.18</td>
<td>-0.29</td>
<td>0.54</td>
<td>0.21</td>
<td>0.53</td>
<td>0.38</td>
<td>0.40</td>
<td>0.36</td>
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</tr>
<tr>
<td>p</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.01</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Glucose (mmol/L)</td>
<td>r 0.35</td>
<td>0.44</td>
<td>-0.04</td>
<td>-0.14</td>
<td>0.54</td>
<td>0.21</td>
<td>0.46</td>
<td>0.40</td>
<td>0.38</td>
<td>0.43</td>
<td></td>
</tr>
<tr>
<td>p</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.54</td>
<td>0.05</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
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<tr>
<td>TC (mmol/L)</td>
<td>r 0.08</td>
<td>0.11</td>
<td>-0.19</td>
<td>0.21</td>
<td>0.21</td>
<td>0.21</td>
<td>0.37</td>
<td>0.20</td>
<td>0.18</td>
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<tr>
<td>p</td>
<td>0.27</td>
<td>0.11</td>
<td>&lt;0.001</td>
<td>0.89</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
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<td></td>
</tr>
<tr>
<td>TG (mmol/L)</td>
<td>r 0.25</td>
<td>0.40</td>
<td>-0.24</td>
<td>-0.21</td>
<td>0.53</td>
<td>0.46</td>
<td>0.37</td>
<td>0.28</td>
<td>0.25</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>p</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>r 0.33</td>
<td>0.43</td>
<td>-0.06</td>
<td>-0.10</td>
<td>0.38</td>
<td>0.40</td>
<td>0.20</td>
<td>0.28</td>
<td>-</td>
<td>0.84</td>
<td>0.40</td>
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<tr>
<td>p</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.42</td>
<td>0.15</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>-</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>r 0.29</td>
<td>0.41</td>
<td>-0.08</td>
<td>-0.12</td>
<td>0.00</td>
<td>0.38</td>
<td>0.02</td>
<td>0.25</td>
<td>0.84</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>p</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.22</td>
<td>0.09</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>-</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>WHR</td>
<td>r 0.91</td>
<td>0.92</td>
<td>-0.01</td>
<td>-0.03</td>
<td>0.36</td>
<td>0.43</td>
<td>0.13</td>
<td>0.33</td>
<td>0.40</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>p</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.88</td>
<td>0.62</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
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<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td></td>
</tr>
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</table>

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; WHR = 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 (\(r = -0.20; p = 0.02\)) 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

<table>
<thead>
<tr>
<th>Age group</th>
<th>BMI (kg/m(^2))</th>
<th>WC (cm)</th>
<th>Smoking</th>
<th>Alcohol use</th>
<th>TC (mmol/L)</th>
<th>TG (mmol/L)</th>
<th>GGT (U/L)</th>
<th>SBP (mmHg)</th>
<th>DBP (mmHg)</th>
<th>WHtR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young adulthood = 25–44 years</td>
<td>0.16</td>
<td>-0.07</td>
<td>0.19</td>
<td>0.13</td>
<td>-0.02</td>
<td>-0.16</td>
<td>-0.23</td>
<td>0.28*</td>
<td>0.01</td>
<td>-0.04</td>
</tr>
<tr>
<td>Middle adulthood = 45–64 years</td>
<td>0.20</td>
<td>0.61</td>
<td>0.15</td>
<td>0.32</td>
<td>0.87</td>
<td>0.20</td>
<td>0.07</td>
<td>0.03</td>
<td>0.95</td>
<td>0.77</td>
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</tbody>
</table>

Mean 7-day awake METS

<table>
<thead>
<tr>
<th>Age group</th>
<th>BMI (kg/m(^2))</th>
<th>WC (cm)</th>
<th>Smoking</th>
<th>Alcohol use</th>
<th>TC (mmol/L)</th>
<th>TG (mmol/L)</th>
<th>GGT (U/L)</th>
<th>SBP (mmHg)</th>
<th>DBP (mmHg)</th>
<th>WHtR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young adulthood = 25–44 years</td>
<td>0.10</td>
<td>-0.01</td>
<td>0.10</td>
<td>0.14</td>
<td>-0.19</td>
<td>-0.29*</td>
<td>-0.25*</td>
<td>-0.07</td>
<td>0.02</td>
<td>0.05</td>
</tr>
<tr>
<td>Middle adulthood = 45–64 years</td>
<td>0.44</td>
<td>0.96</td>
<td>0.43</td>
<td>0.27</td>
<td>0.13</td>
<td>0.02</td>
<td>0.06</td>
<td>0.57</td>
<td>0.86</td>
<td>0.70</td>
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</table>

Mean 7-day awake METS

<table>
<thead>
<tr>
<th>Age group</th>
<th>BMI (kg/m(^2))</th>
<th>WC (cm)</th>
<th>Smoking</th>
<th>Alcohol use</th>
<th>TC (mmol/L)</th>
<th>TG (mmol/L)</th>
<th>GGT (U/L)</th>
<th>SBP (mmHg)</th>
<th>DBP (mmHg)</th>
<th>WHtR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young adulthood = 25–44 years</td>
<td>0.07</td>
<td>0.01</td>
<td>0.23*</td>
<td>0.13</td>
<td>0.07</td>
<td>-0.21</td>
<td>-0.24*</td>
<td>0.05</td>
<td>-0.09</td>
<td>0.05</td>
</tr>
<tr>
<td>Middle adulthood = 45–64 years</td>
<td>0.59</td>
<td>0.92</td>
<td>0.07</td>
<td>0.31</td>
<td>0.59</td>
<td>0.10</td>
<td>0.06</td>
<td>0.71</td>
<td>0.50</td>
<td>0.72</td>
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</table>

Mean 7-day awake METS

<table>
<thead>
<tr>
<th>Age group</th>
<th>BMI (kg/m(^2))</th>
<th>WC (cm)</th>
<th>Smoking</th>
<th>Alcohol use</th>
<th>TC (mmol/L)</th>
<th>TG (mmol/L)</th>
<th>GGT (U/L)</th>
<th>SBP (mmHg)</th>
<th>DBP (mmHg)</th>
<th>WHtR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young adulthood = 25–44 years</td>
<td>0.16</td>
<td>0.13</td>
<td>0.17</td>
<td>0.11</td>
<td>-0.01</td>
<td>-0.19</td>
<td>-0.23*</td>
<td>-0.04</td>
<td>-0.16</td>
<td>0.08</td>
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<tr>
<td>Middle adulthood = 45–64 years</td>
<td>0.23</td>
<td>0.33</td>
<td>0.17</td>
<td>0.41</td>
<td>0.95</td>
<td>0.14</td>
<td>0.07</td>
<td>0.74</td>
<td>0.20</td>
<td>0.55</td>
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Mean 7-day awake METS

<table>
<thead>
<tr>
<th>Age group</th>
<th>BMI (kg/m(^2))</th>
<th>WC (cm)</th>
<th>Smoking</th>
<th>Alcohol use</th>
<th>TC (mmol/L)</th>
<th>TG (mmol/L)</th>
<th>GGT (U/L)</th>
<th>SBP (mmHg)</th>
<th>DBP (mmHg)</th>
<th>WHtR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young adulthood = 25–44 years</td>
<td>0.16</td>
<td>0.05</td>
<td>0.05</td>
<td>0.06</td>
<td>-0.12</td>
<td>-0.20</td>
<td>-0.18</td>
<td>0.04</td>
<td>0.11</td>
<td>0.15</td>
</tr>
<tr>
<td>Middle adulthood = 45–64 years</td>
<td>0.22</td>
<td>0.67</td>
<td>0.69</td>
<td>0.65</td>
<td>0.35</td>
<td>0.12</td>
<td>0.17</td>
<td>0.78</td>
<td>0.40</td>
<td>0.23</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Mean 7-day awake METs</th>
<th>AEE (kcal/wk)</th>
<th>TEE (kcal/wk)</th>
<th>PAL</th>
<th>BMI (kg/m²)</th>
<th>WC (cm)</th>
<th>GGT (U/L)</th>
<th>Chol (mmol/L)</th>
<th>TG (mmol/L)</th>
<th>WHtR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean 7-day awake</td>
<td>r</td>
<td>0.65*</td>
<td>0.58*</td>
<td>0.55*</td>
<td>0.04</td>
<td>-0.19*</td>
<td>-0.13*</td>
<td>-0.19*</td>
<td>-0.03</td>
</tr>
<tr>
<td>METs</td>
<td>p</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.63</td>
<td>0.91</td>
<td>0.01</td>
<td>0.06</td>
<td>0.63</td>
</tr>
<tr>
<td>AEE (kcal/wk)</td>
<td>r</td>
<td>0.65*</td>
<td>0.96*</td>
<td>0.60*</td>
<td>0.004</td>
<td>-0.01</td>
<td>-0.18*</td>
<td>0.01</td>
<td>-0.20*</td>
</tr>
<tr>
<td>p&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.96</td>
<td>0.94</td>
<td>0.01</td>
<td>0.87</td>
<td>0.01</td>
<td>0.59</td>
<td></td>
</tr>
<tr>
<td>TEE (kcal/wk)</td>
<td>r</td>
<td>0.58*</td>
<td>0.96*</td>
<td>0.53*</td>
<td>0.07</td>
<td>0.06</td>
<td>-0.17*</td>
<td>0.02</td>
<td>-0.18*</td>
</tr>
<tr>
<td>p&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.29</td>
<td>0.39</td>
<td>0.02</td>
<td>0.74</td>
<td>0.01</td>
<td>0.71</td>
<td></td>
</tr>
<tr>
<td>PAL</td>
<td>r</td>
<td>0.55*</td>
<td>0.60*</td>
<td>0.53*</td>
<td>0.11</td>
<td>0.06</td>
<td>-0.12</td>
<td>-0.09</td>
<td>-0.15*</td>
</tr>
<tr>
<td>p&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.12</td>
<td>0.37</td>
<td>0.08*</td>
<td>0.20</td>
<td>0.03</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>r</td>
<td>0.04</td>
<td>0.004</td>
<td>0.07</td>
<td>0.11</td>
<td>&lt;0.001</td>
<td>0.06</td>
<td>0.13*</td>
<td>0.13*</td>
</tr>
<tr>
<td>p&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.06</td>
<td>0.04</td>
<td>&lt;0.001</td>
<td>0.12</td>
<td>0.16*</td>
<td>0.96*</td>
<td></td>
</tr>
<tr>
<td>WC (cm)</td>
<td>r</td>
<td>0.01</td>
<td>-0.01</td>
<td>0.06</td>
<td>0.06</td>
<td>0.04</td>
<td>0.04</td>
<td>0.18*</td>
<td>0.22*</td>
</tr>
<tr>
<td>p&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.37</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.12</td>
<td>0.16*</td>
<td>0.96*</td>
<td></td>
</tr>
<tr>
<td>GGT (U/L)</td>
<td>r</td>
<td>-0.19*</td>
<td>-0.18*</td>
<td>-0.17*</td>
<td>-0.12*</td>
<td>0.06</td>
<td>0.04</td>
<td>0.18*</td>
<td>0.22*</td>
</tr>
<tr>
<td>p&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.08</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.12</td>
<td>0.18*</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td>Chol (mmol/L)</td>
<td>r</td>
<td>-0.11*</td>
<td>-0.02</td>
<td>-0.09</td>
<td>0.13*</td>
<td>0.01</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>p&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.13</td>
<td>0.01</td>
<td>0.01</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>TG (mmol/L)</td>
<td>r</td>
<td>-0.19*</td>
<td>-0.19*</td>
<td>-0.15*</td>
<td>0.13*</td>
<td>0.02</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>p&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.07</td>
<td>0.02</td>
<td>0.01</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>WHtR</td>
<td>r</td>
<td>-0.03</td>
<td>-0.04</td>
<td>0.02</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.01</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>p&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.71</td>
<td>0.40</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td></td>
</tr>
</tbody>
</table>

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 ≤ 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

<table>
<thead>
<tr>
<th></th>
<th>MS participants</th>
<th>Non-MS participants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean 7-day METs</td>
<td>AEE (kcal/ wk)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>r</td>
<td>0.68†</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>AEE (kcal/ wk)</td>
<td>r</td>
<td>0.68†</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>r</td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>0.92</td>
</tr>
<tr>
<td>GGT (U/L)</td>
<td>r</td>
<td>-0.21</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>0.13</td>
</tr>
<tr>
<td>Chol (mmol / L)</td>
<td>r</td>
<td>-0.21</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>0.12</td>
</tr>
<tr>
<td>TG (mmol / L)</td>
<td>r</td>
<td>-0.28†</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>0.03</td>
</tr>
<tr>
<td>WHtR</td>
<td>r</td>
<td>-0.07</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>0.63</td>
</tr>
</tbody>
</table>

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 ≤ 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)\textsuperscript{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.\textsuperscript{32} According to Tchernof (1996)\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{35} The observed prevalence of MS in our study is similar to 29% reported in urban participants from Gauteng Province\textsuperscript{4}, 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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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).\textsuperscript{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. A systematic review by Piazza-Gardner and Barry (2012) 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. 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. 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. 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.

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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.

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REFERENCES


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 status, 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


APPENDIX A:

ETHICS DOCUMENTATION
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 Swanepeol
Student: T Veldsman

Ethics number: NWU - 00079 - 18 - A1

Application Type: Single Study
Commencement date: 2018/11/07
Expiry date: 2019/11/30
Risk: Minimal

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 (principal 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 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 enquires or requests for assistance.

Yours sincerely

[Signature]

Prof Wayne Towers
Chair NWU Health Research Ethics Committee
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 cardiometabolic 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-XXXXXX-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-XXXXXX-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

[Signature]

Prof Wayne Towers
Chairperson: NWU-HREC

[Signature]

Prof Minnie Greff
Head of Health Sciences Ethics Office for Research, Training and Support
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:** NWU-00036-07-S16

**Approval date:** 12 November 2007  **Expiry date:** 11 November 2012

Special conditions of the approval (if any): None

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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 deviation 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:
  - 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 M. Louwes
(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 B 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 your 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.

  o **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.

  o **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 Geldenhuyss will be contacted. Dr. Geldenhuyss 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.

  o **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 (Sympathetic activity and o Ambulatory Blood Pressure in Africans”).

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: 70010510240585
Member: Professional Editors’ Guild of South Africa
PO Box 482
Mahikeng
North West Province
Tel: 082 714 3003
msini@mweb.co.za

06/03/2020
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 parenthenses, 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

<table>
<thead>
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<td>DPI</td>
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<td>Compression Quality</td>
<td>Maximum</td>
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</table>


**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:


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:

<table>
<thead>
<tr>
<th>MARGINS</th>
<th>PAPER SIZE</th>
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<td>2.03 cm</td>
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<tr>
<td>Footer:</td>
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</table>
Original manuscripts may be submitted in English and should be sent to:

The Editor (Prof. Hanlie Moss)  
Editorial Office  
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

**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 potential referees, of which one 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 author(s) must be numbered according to their 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**


**Book**


**Chapter in book**


**Thesis/Dissertation**


**Proceedings of a conference**


**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.


**Newspaper**


**Electronic source**

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  250-4000 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.
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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.

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Thank you for submitting your work to this journal.

Kind regards,

Marcelle Ayres, Admin
Editorial Assistant
CardioVascular Journal of Africa

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# CardioVascular Journal of Africa

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

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## Abstract:

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 Micromax 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...