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Comparison of Objectively and Subjectively Measured Physical Activity and Its Association With Cardiovascular Risk Markers in South African School Children

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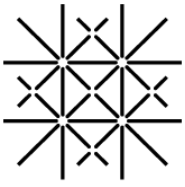

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KaziBantu

Healthy Schools for Healthy Communities

Abstract

Background

Cardiovascular diseases (CVDs) are the leading cause of death worldwide, accounting for one third of all global deaths. CVD prevention strategies should begin in early life since the onset of CVD is known to begin in childhood. The risk of CVD can be substantially reduced by focusing on lifestyle modifications. In particular, physical activity (PA) has received a lot of attention due to its beneficial effects on reducing the risk of CVD. An accurate and valid assessment of PA is required for studying its impact on health. Two commonly used assessment methods are questionnaires and motion sensors. However, the agreement between these methods is still a subject of discussion. This master's thesis aims to compare self-reported PA with accelerometer-measured PA and to investigate its association with different cardiovascular risk markers (CRMs) in school children from South Africa.

Methods

Cross-sectional data of 594 (302 boys, 292 girls) South African school children between the ages of 8 – 13 years was included in the analysis. The data was collected as part of the *KaziBantu* project. PA was assessed subjectively using the Physical Activity Questionnaire for Older Children (PAQ-C) and objectively using ActiGraph wGT3X-BT accelerometers. Selected CRMs consisted of body mass index (BMI), blood pressure (BP), blood lipid profile (BLP), and glycated hemoglobin (HbA1c). Body height and weight was measured by stadiometer and digital weighing scale. Resting BP was measured with the Omron M6 AC blood pressure monitor. The Alere Afinion AS 100 Analyzer was used to determine the BLP and HbA1c concentrations.

Results

PAQ-C scores and accelerometer-measured minutes of moderate- to vigorous-intensity physical activity (MVPA) were positively associated (ρ = 0.13, p = 0.002). 2.4% (R^2 = 0.024) of the variance of PAQ-C scores was explained by accelerometer-measured MVPA. MVPA was inversely associated with BMI (partial r = -0.20, p < 0.001), and sedentary behavior (SB) correlated positively with total cholesterol (TC), low-density lipoprotein (LDL), and non-high-density lipoprotein (Non-HDL) (partial r = 0.10 (TC); 0.13 (LDL); 0.12 (Non-HDL), p = 0.020 (TC); 0.004 (LDL); 0.007 (Non-HDL)). PAQ-C scores were inversely associated with systolic BP (partial r = -0.088, p = 0.035). Overall, the proportions of variance of individual CRMs explained by PAQ-C scores and ActiGraph MVPA were very small or negligible (η_p^2 = 0.00 – 0.04).

Conclusion

Based on the low correlation coefficient and the weak explanatory power, the findings of this study support the notion that significant discrepancies between the PAQ-C and the ActiGraph accelerometer for estimating PA levels in pediatric populations exist. Higher MVPA levels were associated with lower BMI and systolic BP, thus reducing CVD risk. Spending much time engaging in SB increased TC, LDL, and Non-HDL concentrations, thus increasing CVD risk. Measuring PA by accelerometer allowed for a more accurate CVD risk estimation than by PAQ-C.

Zusammenfassung

Hintergrund: Herz-Kreislauf-Erkrankungen (HKE) sind die häufigste Todesursache weltweit und machen einen Drittel aller Todesfälle aus. Da der Ursprung von HKE in der Kindheit liegt, sollten Präventionsstrategien in jungem Alter ansetzen. Das Risiko für HKE kann durch Veränderungen des Lebensstils erheblich reduziert werden. Insbesondere körperliche Aktivität (KA) hat aufgrund ihrer positiven Auswirkungen auf das HKE-Risiko viel Aufmerksamkeit erhalten. Um die Effekte von KA auf die Gesundheit zu untersuchen sind akkurate und valide Messmethoden notwendig. Zwei häufig verwendete Methoden sind Fragebögen und Bewegungssensoren. Die Übereinstimmung zwischen diesen Methoden ist jedoch noch Gegenstand von Diskussionen. Ziel dieser Masterarbeit ist es, selbstberichtete KA mit beschleunigungsmesser-ermittelter KA zu vergleichen und die Assoziation von KA mit verschiedenen kardiovaskulären Risikomarkern (KRM) bei Schulkindern aus Südafrika zu untersuchen.

Methoden: Für die Analyse wurden Querschnittsdaten von 594 (302 Jungen, 292 Mädchen) südafrikanischen Schulkindern im Alter von 8 – 13 Jahren berücksichtigt. Die Daten wurden im Rahmen des *KaziBantu*-Projekts erhoben. KA wurde mit dem «Physical Activity Questionnaire for Older Children" (PAQ-C) und mit ActiGraph wGT3X-BT Beschleunigungsmessern beurteilt. Als KRM wurden der Body-Mass-Index (BMI), Blutdruck (BD), Blutfettwerte (BFW) und glykiertes Hämoglobin (HbA1c) gewählt. Körpergrösse und -gewicht wurden mit einem Stadiometer und einer digitalen Waage gemessen. Der Ruhe-Blutdruck wurde mit dem Blutdruckmessgerät Omron M6 AC gemessen. Zur Bestimmung der BFW und der HbA1c-Konzentration wurde der Alere Afinion AS 100 Analyser verwendet.

Ergebnisse: PAQ-C-Punkte und mit Beschleunigungsmesser ermittelte Minuten mässiger- bis hoch-intensiver körperlicher Aktivität (MHKA) waren positiv assoziiert (ρ = 0.13, p = 0.002). 2.4% (R^2 = 0.024) der Varianz der PAQ-C-Punkte wurde durch beschleunigungsmesser-ermittelte MHKA erklärt. MHKA war umgekehrt assoziiert mit BMI (partielles r = -0.20, p < 0.001) und sitzendes Verhalten korrelierte positiv mit Gesamtcholesterin (GC), Low-Density Lipoprotein (LDL) und Non-High-Density Lipoprotein (Non-HDL) (partielles r = 0.10 (GC); 0.13 (LDL); 0.12 (Non-HDL), p = 0.020 (GC); 0.004 (LDL); 0.007 (Non-HDL)). PAQ-C-Punkte waren umgekehrt mit dem systolischen BD assoziiert (partielles r = -0.088, p = 0.035). Insgesamt waren die Anteile der Varianz der KRM, die durch PAQ-C-Punkte und ActiGraph MHKA erklärt wurden, sehr gering oder vernachlässigbar (η_p^2 = 0.00 – 0.04).

Schlussfolgerungen: Basierend auf dem niedrigen Korrelationskoeffizienten und der schwachen Erklärungskraft stützen die Ergebnisse dieser Studie die Annahme, dass signifikante Diskrepanzen zwischen dem PAQ-C und dem ActiGraph-Beschleunigungsmesser für die Schätzung von KA in pädiatrischen Populationen bestehen. Höhere MHKA-Spiegel waren mit niedrigerem BMI und systolischem BD verbunden, wodurch sich das HKE-Risiko reduziert. Viel Zeit mit sitzenden Tätigkeiten zu verbringen, erhöhte GC-, LDL und Non-HDL-Konzentrationen und somit auch das HKE-Risiko. Die Messung von KA mit einem Beschleunigungsmesser ermöglichte eine genauere HKE-Risikoabschätzung als mit dem PAQ-C.

Opsomming

Agtergrond: Kardiovaskulêre siektes (KVS) is die grootste oorsaak van sterftes wêreldwyd, wat verantwoordelik is vir een derde van alle globale sterftes. KVS-voorkomingstrategieë moet vroeg in die lewe begin, aangesien dit bekend is dat die aanvang van KVS in die kinderjare begin. Die risiko van KVS kan aansienlik verminder word deur op lewenstyl aanpassings te fokus. Veral fisieke aktiwiteit (FA) het baie aandag gekry as gevolg van die voordelige uitwerking daarvan op die vermindering van die risiko van KVS. 'n Akkurate en geldige assessering van FA word vereis om die impak daarvan op gesondheid te bestudeer. Twee algemeen gebruikte assesserings metodes is vraelyste en beweging sensors. Die ooreenkoms tussen hierdie metodes is egter steeds 'n onderwerp van bespreking. Hierdie meestersgraad tesis het ten doel om self-gerapporteerde FA met versnellingsmeter-gemete FA te vergelyk en om die verband daarvan met verskillende kardiovaskulêre risiko merkers (KRM) by skoolkinders van Suid-Afrika te ondersoek.

Metodes: Deursneedata von 594 (302 seuns, 292 meisies) Suid-Afrikaanse skoolkinders tussen die ouderdomme von 8 – 13 jaar is by die analise ingesluit. Die data is ingesamel as deel van die *KaziBantu*-projek. FA is geassesseer met behulp van die "Physical Activity Questionnaire for Older Children" (PAQ-C) en met behulp van ActiGraph wGT3X-BT versnellingsmeters. Geselekteerde KRM bestaan uit body mass index (BMI), bloeddruk (BD), bloedlipiedprofiel (BLP), en geglykeer hemoglobien (HbA1c). Liggaam hoogte en gewig is gemeet deur stadiometer en digitale weegskaal. Rustende BD is gemeet met die Omron M6 AC bloeddruk monitor. Die Alere Afinion AS 100 Analyzer is gebruik om die BLP en HbA1c konsentrasies te bepaal.

Resultate: PAQ-C tellings en versnellingsmeter-gemete minute van matige tot hoog intensiteit fisieke aktiwiteit (MHFA) word positief geassosieer (ρ = 0.13, p = 0.002). 2.4% (R^2 = 0.024) van die variansie van PAQ-C tellings is verklaar deur versnellingsmeter-gemete MHFA. MHFA word omgekeerd geassosieer met BMI (gedeeltelik r = -0.20, p < 0.001), en sittende gedrag (SG) korreleer positief met totale cholesterol (TC), lae-digtheid lipoproteïen (LDL) en nie-hoë-digtheid lipoproteïen (Nie-HDL) (gedeeltelik r = 0.10 (TC); 0.13 (LDL); 0.12 (Nie-HDL), p = 0.020 (TC); 0.004 (LDL); 0.007 (Nie-HDL)). PAQ-C tellings word omgekeerd geassosieer met sistoliese BD (gedeeltelike r = -0.088, p = 0.035). Oor die algemeen is die variansie verhoudings van individuele KRM wat deur PAQ-C tellings en ActiGraph MHFA verduidelik word, baie klein of onbeduidend (η_p^2 = 0.00 – 0.04).

Konklusie: Gebaseer op die lae korrelasiekoëffisiënt en die swak vermoë om variansie te verklaar, ondersteun die bevindinge van hierdie studie die idee dat beduidende verskille tussen die PAQ-C en die ActiGraph versnellingsmeter vir die skatting van FA vlakke in pediatriese populasies bestaan. Hoër MHFA-vlakke word geassosieer met laer BMI en sistoliese BD, en verminder dus KVS risiko. Om baie tyd aan SG te bestee, verhoog TC, LDL, en Nie-HDL konsentrasies, wat dus die risiko van KVS verhoog. Die meting van FA deur versnellingsmeter maak voorsiening vir 'n meer akkurate KVS risiko skatting as deur PAQ-C.

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List of Abbreviations

BMI	Body mass index
BP	Blood pressure
BLP	Blood lipid profile
CVD	Cardiovascular disease
CRM	Cardiovascular risk marker
DBP	Diastolic blood pressure
HbA1c	Glycated hemoglobin
HDL	High-density lipoprotein
IQR	Interquartile range
LDL	Low-density lipoprotein
MPA	Moderate-intensity physical activity
MVPA	Moderate- to vigorous-intensity physical activity
Non-HDL	Non-high-density lipoprotein
PA	Physical activity
PAQ-C	Physical Activity Questionnaire for Older Children
PE	Physical education
SB	Sedentary behavior
SBP	Systolic blood pressure
SD	Standard deviation
SSA	Sub-Saharan Africa
TC	Total cholesterol
TC/HDL	Ratio between total cholesterol and high-density lipoprotein
TG	Triglycerides
VPA	Vigorous-intensity physical activity
WHO	World Health Organization

1 Introduction

Unhealthy lifestyles pose a serious health risk to humanity and have become a growing concern. Although modern technology has simplified life in many ways, it has also caused people to be less physically active. Increasing levels of sedentary behaviors (SB), obesity, and noncommunicable diseases worldwide pose a threat to public health, and action is required to counteract this trend (Wagner & Brath, 2012). Physical activity (PA) plays a significant role in overcoming the trend, as it is associated with various physical and mental benefits, of which the biggest benefit may be lowering the risk of cardiovascular disease (CVD). CVDs are disorders of the heart and blood vessels, and the leading cause of death worldwide (Physical Activity Guidelines Advisory Committee, 2009; WHO, 2020c). They are usually associated with a buildup of fatty deposits on the inner walls of the arteries (i.e., atherosclerosis). CVD is highly preventable by focusing on behavioral risk factors, such as unhealthy diet, obesity, smoking, and physical inactivity (WHO, 2021d).

Globally, more than 75% of deaths from CVDs occur in low- and middle-income countries, where health care services are less comprehensive and progressive. Of all income groups, the lowest socioeconomic groups often suffer the most from ill health, yet they benefit the least from health services (Ataguba et al., 2011). One of the most vulnerable groups has been identified as children and adolescents from lower socioeconomic areas (Blum, 2007). Since unhealthy lifestyles during youth are often maintained in adulthood, ensuring that children and adolescents are healthy and maintain active lifestyles is important (Telama et al., 2014).

Various biological measurements can predict the likelihood of developing CVD; they are called cardiovascular risk markers (CRMs). Some of the classic CRMs are age, blood pressure (BP), cholesterol concentrations, and body mass index (BMI). A rather novel marker for risk prediction is glycated hemoglobin (HbA1c) (Folsom, 2013). PA has been shown to have beneficial effects in reducing the risk of CVD, which can be observed through the CRMs (Andersen et al., 2011; Boniol et al., 2017). However, to make legitimate assumptions about the association between PA and CRMs, valid methods for assessing PA must be used. An accurate measurement of PA is crucial for understanding the dose-response relationship between PA and health, and helps developing PA intervention programs (Sirard & Pate, 2001). Various methods and instruments have been used to measure PA in a free-living environment, and each method has its own strengths and limitations. Two important, widely used methods are subjective self-reporting and objective measurement using accelerometers (Chomistek et al., 2017; Marasso et al., 2021). However, the agreement between these two methods was questioned in numerous studies (Ben Jemaa et al., 2018; Marasso et al., 2021).

This master's thesis aims to compare self-reported PA with accelerometer-measured PA and to investigate its association with different CRMs among school children from South Africa. The data that is used for this analysis was collected as part of the *KaziBantu* project in Gqeberha, South Africa. The *KaziBantu* project is a school-based intervention program that attempts to effectuate sustainable lifestyle changes to achieve better health within disadvantaged communities.

2 Theoretical Background and Current State of Research

This chapter provides an overview of the theoretical background of PA and presents the practices used to measure PA levels in research settings. Furthermore, the chapter describes selected CRMs, including BP, BMI, blood lipid profiles (BLPs), and HbA1c. The current knowledge about the relationship between PA and these CRMs is then discussed. All aspects of this chapter focus particularly on children and adolescents.

2.1 Physical Activity

The World Health Organization (WHO) defines PA as “any bodily movement produced by skeletal muscles that requires energy expenditure” (WHO, 2020b). PA not only includes formal exercise but also movement that is performed during leisure time, as part of work, or for transportation. The most popular ways to be active include walking, cycling, running, and playing sports. PA varies not only in type but also in duration, frequency, and intensity. Commonly, PA is categorized into three intensity groups: low/light, middle/moderate and high/vigorous intensity. SB is the lowest intensity of PA and includes activities with low energy expenditure such as sitting or lying (Tremblay et al., 2017).

Physical inactivity is defined as failure to meet the 2020 “WHO guidelines on physical activity and sedentary behaviour” (WHO, 2020a). Based on these guidelines, children and adolescents should perform at least 60 minutes of moderate- to vigorous-intensity PA (MVPA) per day, while adults should perform at least 150 - 300 minutes of moderate-intensity PA (MPA) or at least 75 - 150 minutes of vigorous-intensity PA (VPA) per week. An equivalent combination of moderate- and vigorous-intensity activities throughout the week is also acceptable.

PA and health are closely related; regular PA is a protective factor against many noncommunicable diseases. For example, it reduces the risk of type 2 diabetes, stroke, CVD mortality, high BP, and different cancers (I.-M. Lee et al., 2012; WHO, 2020b). Further benefits of PA include antidepressant effects in people with depression, delayed onset of dementia, and contribution to weight control (Livingston et al., 2017; Schuch et al., 2016; WHO, 2010).

In contrast, being inactive, or exhibiting high levels of SB, is associated with an elevated risk for CVD, diabetes, and cancer mortality (Ekelund et al., 2019). Physical inactivity even ranks as the fourth leading risk factor for all-cause mortality, behind high BP, tobacco use, and high blood glucose (Figure 1) (WHO, 2009). Sufficiently active people have a 20 - 30% lower mortality risk compared to insufficiently active people (WHO, 2020b).

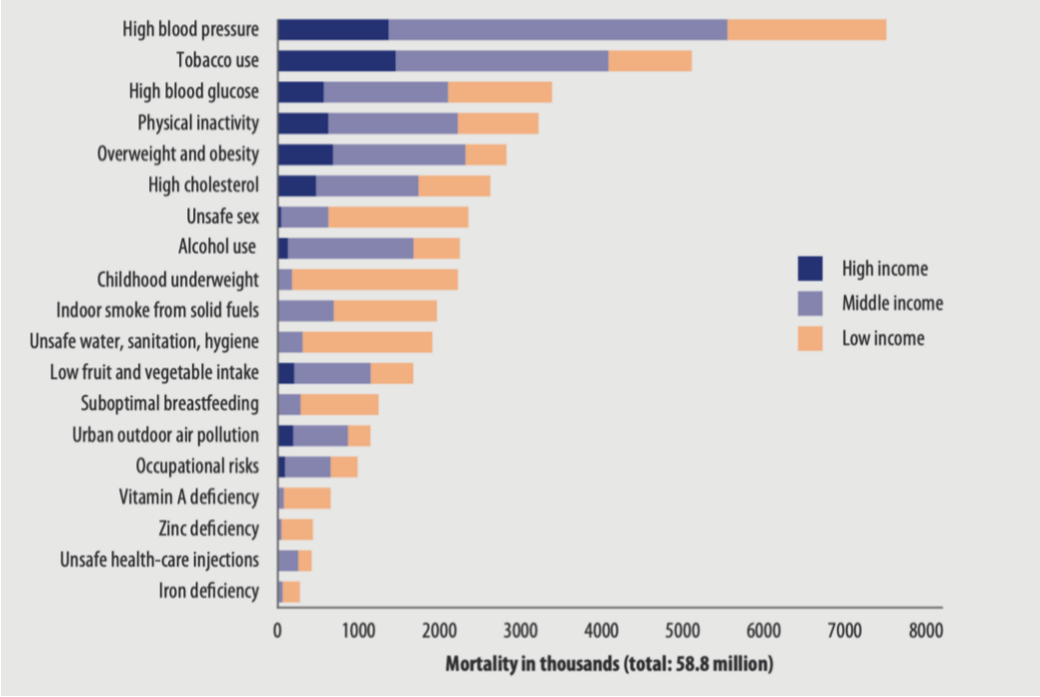

Figure 1: Deaths Attributed to 19 Leading Risk Factors, by Country Income Level, 2004. Source: (WHO, 2009)

Despite the many advantages of PA for general health, only 72.5% of adults and 19% of adolescents globally were sufficiently physically active in 2016 (Guthold et al., 2018, 2020). International progress to increase PA has been weak, and trends show that insufficient improvements in global PA levels have been achieved since 2001 (WHO, 2020b).

For adults, the prevalence of insufficient PA in high-income countries is more than double that in low-income countries (Guthold et al., 2018). Wealthier countries benefit from modern technology, which simplifies lives but leads to more SB - for example, through facilitated motorized transportation. In low-income countries, people are more active, both for transportation and at work. However, due to quickly increasing urbanization, some countries are recording rapidly rising levels of insufficient PA (Miao & Wu, 2016). This decline in PA, combined with increased SB, is referred to as the “physical activity transition” (Katzmarzyk & Mason, 2009). These global shifts in PA are particularly dangerous to the wellbeing of younger generations due to the likelihood of long-term comorbidities attributed to physical inactivity (S. Muthuri et al., 2014).

Although communicable diseases are the predominant public health issue in populations of Sub-Saharan Africa (SSA), concern is growing about the rise of noncommunicable diseases such as diabetes, high BP, and CVD (Unwin et al., 2001). Due to urbanization and socioeconomic transformations, the economy of SSA is shifting from one based on manual labor to one utilizing mechanized manufacturing. Thus, high energy-expenditure activities, such as physical labor, have shifted to low energy-expenditure activities, such as desk work (Katzmarzyk & Mason, 2009). Reduced levels of PA are likely one of the main reasons for the

increased burden of preventable noncommunicable diseases in SSA (Tremblay et al., 2010), and the long-term health consequences for children affected by this trend are of particular concern.

In South Africa, PA transitions are not well monitored, particularly among children and adolescents. However, South Africa may be in the early stages of PA transition, and the population could therefore be responsive to early PA intervention strategies (S. Muthuri et al., 2014). About 48 – 51.7% of South African children currently meet the WHO recommendation of 60 minutes of MVPA per day (S. K. Muthuri et al., 2016; Roman-Viñas et al., 2016). Different South African studies have found average daily MVPA levels ranging from 56.6 – 64.9 minutes (Van Biljon et al., 2018; van Niekerk et al., 2016). However, PA levels among South African children do not seem to be improving, and screen-time is increasing (Draper et al., 2019).

2.1.1 Physical Activity Among Children and Adolescents

Being physically active at a young age is of great importance for numerous reasons. One reason is the biological carry-over effect into adulthood, whereby the biological effects of PA in childhood influence the adult's health status. Another reason is the persistence of PA from childhood into adulthood. In other words, active children become active adults (Boreham & Riddoch, 2001; Telama, 2009).

In general, children and adolescents profit from the same PA benefits as do adults. Regular PA reduces the risk of developing conditions like CVD, type 2 diabetes, cancer, and high BP. Additionally, regular PA provides health-related advantages that are particularly important in earlier life. For example, PA plays a crucial role in the mechanical loading of bone structures in a child's body. Before puberty, bones are better at adapting to mechanical loading and at gaining bone mineral (Parfitt, 1994). When compared to their peers, children who are more physically active have healthier bones because they have greater bone mass and higher bone density (Physical Activity Guidelines Advisory Committee, 2018). As a result, they are better protected against osteoporosis, fractures, and other bone-related diseases (WHO, 2020a).

Another aspect specifically important for younger populations is the relationship between PA and academic achievement; physically active students tend to have better grades, and higher activity and fitness levels are related to improved cognitive performances (e.g., concentration or memory). More active children and adolescents also display better school attendance and classroom behaviors (Centers for Disease Control and Prevention, 2010; Michael et al., 2015).

2.2 Measuring Physical Activity

Studies examining PA levels and patterns in a free-living environment must have reliable and valid tools to accurately assess PA (Prince et al., 2008). PA can be measured in different ways, and instruments used to assess and measure PA can be broadly separated into two groups: objective and subjective methods. Objective methods include laboratory instruments, motion sensors, heart rate monitors, and direct observations, while subjective methods all contain some sort of self-reporting (Prince et al., 2008; Skender et al., 2016). The doubly labeled water

method, which measures CO_2 production over a certain period, is seen as the gold standard for validating PA assessments. However, this method is expensive, time consuming, and unable to assess PA intensity or frequency (Westerterp, 2009). Some key features should be considered when choosing a PA measurement method for a research study. These include the objectivity of the data, subject burden, cost of administration, and quality of PA (i.e., activity type, intensity, frequency, duration) (Sylvia et al., 2014).

In the following chapters, subjective self-reporting and objective measurement with an accelerometer will be discussed in further detail. These two methods are widely used in PA research (Chomistek et al., 2017; Marasso et al., 2021). Specifically, the Physical Activity Questionnaire for Older Children (PAQ-C) and the ActiGraph accelerometer will be presented, since these instruments were used for data collection for this master's thesis.

2.2.1 Self-Reporting Methods

Self-reporting is one of the easiest and most commonly used methods for measuring a population's PA levels (Sallis, 1991). Self-reporting always involves questions to which the participants respond with their personal opinions. Questionnaires and interviews are examples of self-reporting tools. Assessing PA using questionnaires is regarded as particularly useful for studies as questionnaires provide a convenient way to assess activity patterns across large populations in a short period of time (Benítez-Porres, 2016, p.). Questionnaires can be easily administered and are usually low in cost, characteristics which make them attractive for epidemiological studies with large numbers of participants. However, the self-reporting has its limitations. Participants might not be able to recall their PA levels accurately and may have difficulties understanding the questions - especially participants from younger populations (Sallis, 1991). Participants might also exaggerate their PA levels to make themselves seem more active. For this reason, studies based on self-reporting often face validity issues. Furthermore, self-reporting makes precisely assessing the frequency, intensity, and duration of a participant's activities difficult.

Due to these limitations, in 1997, Crocker et al. attempted to create a self-reporting instrument for children that was valid and reliable in assessing PA patterns. They created the PAQ-C, which is now widely used in research settings (Marasso et al., 2021). In addition to the PAQ-C, many other PA questionnaires are available to researchers. While no PA questionnaire emerges as the best in terms of reliability and validity, the PAQ-C appears to be one the most promising (Chinapaw et al., 2010).

2.2.2 The Physical Activity Questionnaire for Older Children (PAQ-C)

The PAQ-C is a tool used to evaluate PA levels of school-aged children (from approximately 8 – 14 years of age). It is intended to assess habitual MVPA and was developed within the framework of the Saskatchewan Pediatric Bone Mineral Accrual Study (Kowalski et al., 2004; S. G. Trost, 2007). The PAQ-C was designed as a self-reporting 7-day recall questionnaire and can be conducted in a classroom setting. It consists of 10 closed-ended questions (also called items) that cover different aspects of a child's PA. Answers to item 1 provide information

about all spare-time activities of the previous 7 days and function as memory cues to enhance recall ability. Questions 2 - 8 ascertain the child's PA levels at recess, right after school, in the evenings, and over the weekend. These questions also cover the lunch-time behaviors, effort made during physical education (PE) and a general self-assessment of the PA levels. The frequency of PA during the previous 7 days is determined by Question 9 (Kowalski et al., 2004). Each of the 9 items is scored on a scale between 1 and 5. Calculating the mean of the items results in a final PA summary score. A score of 1 indicates the lowest PA level, while a score of 5 indicates the highest PA level (Kowalski et al., 2004). The tenth question of the PAQ-C assesses whether sickness or other events prevented the child from performing normal levels of PA in the past 7 days and is not included in the summary PA score. The official version of the PAQ-C can be found in Appendix 1 (page 77).

Strengths of the PAQ-C

The main advantage of the PAQ-C, as for most questionnaires, is its ease of use and low cost. The PAQ-C can measure general PA levels quickly and effectively (Crocker et al., 1997).

To examine different psychometric properties of the questionnaire, Crocker et al. analyzed the PAQ-C in three studies (Crocker et al., 1997). The first study found that the PAQ-C had acceptable measurement properties. The reliability of the item scale was acceptable for both females and males, and all correlations of the item scale were above 0.30. The results of the second study, which examined 84 students ranging in age from 9 - 14 years, supported the test-retest reliability of the PAQ-C for both males and females after 1 week. In the third study, the averages of 2 or 3 PAQ-C scores collected during the fall, winter, and spring seasons were examined to investigate the questionnaire's reliability as a composite yearly activity score. The results showed that the composite scores were reliable for both younger and older participants. Thus, the authors concluded that the PAQ-C to demonstrated acceptable measurement properties, reliability, and internal consistency (Crocker et al., 1997). Various other studies have confirmed the adequacy of these psychometric properties (Janz et al., 2008; Venetsanou et al., 2020; Wang et al., 2016). In a sample of children and adolescents with congenital heart disease, the PAQ-C demonstrated good validity and reliability compared to data derived from an accelerometer (Voss et al., 2017). Additionally, the PAQ-C was significantly associated with enjoyment perception, BMI, and cardiorespiratory fitness (Gobbi et al., 2016).

In 2011, Biddle and colleagues reviewed numerous self-reporting instruments used to assess PA in children and adolescents. Of the instruments, they found the PAQ-C to be one of the most suitable and feasible for the use in larger surveys (Biddle et al., 2011).

Limitations of the PAQ-C

The PAQ-C was designed to measure general MVPA levels. It provides a summary activity score but cannot be used to calculate estimates of caloric expenditures (Crocker et al., 1997). Additionally, the outcome score cannot be readily interpreted, as relating the score to established international PA recommendations is difficult (Biddle et al., 2011). Another limitation is that the PAQ-C does not discriminate between specific activity intensities; it does not differentiate between light, moderate, and vigorous activities. Furthermore, the PAQ-C

should not be used to measure PA during holiday periods, as it is only appropriate when used during the school year (Kowalski et al., 2004).

2.2.3 Accelerometers

An alternative approach to self-reporting methods is the objective assessment of PA using devices like pedometers and accelerometers. Accelerometers are considered one of the most accurate methods for measuring PA (Evenson et al., 2008). These devices measure accelerations produced by body movement and are usually worn around the hip or wrist (I.-M. Lee & Shiroma, 2014). With the help of the acceleration recordings generated by the sensors, researchers are able not only to quantify the energy expenditure but also to estimate the intensity, duration, and frequency of PA objectively (Marasso et al., 2021). The data obtained from the devices are usually classified with the help of thresholds, which are used to divide a person's daily PA into intensity-categories. These categories are usually defined as SB, light activity, moderate activity, and vigorous activity. Based on these categories, accelerometer measurements can more accurately determine activity dose than self-reported methods. Considering the limitations of self-reported methods and the laboriousness of other objective instruments (e.g., doubly labeled water), accelerometry has become one of the most favorable methods for measuring PA (Troiano et al., 2008).

Strengths of Accelerometers

An important advantage of objective methods, such as accelerometry, is the avoidance of reporting bias. Children (or their families) have a tendency to overestimate their PA (Caballero et al., 2003; J. J. Reilly, 2006). For example, the Scottish Health Survey 2003 found that more than 75% of children (age 6 - 10) subjectively reported meeting the recommended 60 minutes of MVPA per day, while other studies from the UK that assessed MVPA using accelerometers reported a prevalence of less than 5% (Ness et al., 2007; J. Reilly et al., 2004; Riddoch et al., 2007).

Another significant advantage of objective measurement methods is that they provide more accurate information about the intensity, frequency, and duration of movement (Welk et al., 2000). This information allows dose-response relationships between PA and health to be investigated so that recommendations for public health can be made (Ness et al., 2007). Additionally, accelerometers have become more feasible for large-scale studies, thanks to declining costs (I.-M. Lee & Shiroma, 2014).

Objective methods also seem to be more successful at identifying relationships between PA and health parameters. After systematic reviews using subjective methods concluded that the relationship between PA and obesity was unclear (due to inadequate quantification of PA), studies using accelerometers were able to identify a relationship between the two (Mallam, 2003; Ness et al., 2007; Wareham et al., 2005).

Limitations of Accelerometers

Although costs have declined, accelerometer technology is still costly, and the administration is time consuming, especially in large-scale populations (Prince et al., 2008). Participants are often required to wear the device for up to seven days, and a research team has to set up the accelerometers and process copious data (Shephard, 2002).

Another main limitation for accelerometers that are worn around the hip (standard position) is the incapability of measuring upper body movement. Sensors can malfunction, and participants might not comply with wearing the device because of the sensors' appearance. Furthermore, the sensors cannot detect when a person is carrying any weight. This is not optimal since carrying a heavy load expends more energy than carrying nothing. Accelerometers are also unable to distinguish between different body postures (e.g., sitting, lying, or standing) and cannot be used to measure water activities (Janz et al., 2008; I.-M. Lee & Shiroma, 2014).

Finally, different thresholds are used to define SB and light, moderate, or vigorous activity. Thus, the estimated time spent in those categories can vary significantly, depending on the chosen threshold (Loprinzi et al., 2012).

2.2.4 The ActiGraph

Accelerometers manufactured by ActiGraph, Inc., have been successfully used in many PA studies on children and adolescents (Janz et al., 2008). In fact, these accelerometers are the most frequently used for the objective assessment of PA in research settings (Wijndaele et al., 2015). ActiGraph accelerometers have been shown to be reliable and valid for assessing various types of PA (Santos-Lozano et al., 2013). ActiGraph measurements have also been shown to agree strongly with the indirect calorimetry method used in laboratory treadmill tests and also to have moderate validity compared to the doubly labeled water method (Ekelund et al., 2001; S. G. Trost et al., 2006).

ActiGraph accelerometers used to be uniaxial, meaning they could only detect vertical accelerations. In 2009, ActiGraph released their first triaxial activity monitor (GT3X), which measured accelerations in three orthogonal planes: vertical, horizontal right-left, and horizontal front-back (Sasaki et al., 2011). The GT3X weighed 27 g and was 3.8 cm x 3.7 cm x 1.8 cm. The device could measure accelerations ranging from 0.05 – 2 g, and the accelerations were digitized by a converter at a rate of 30 Hz (Benítez-Porres et al., 2016). The successor of the GT3X is called wGT3X-BT, and is the latest ActiGraph accelerometer model (Figure 2). The wGT3X-BT is equipped with Bluetooth technology and weighs only 19 g, with dimensions of 4.6 cm x 3.3 cm x 1.5 cm. Its dynamic range is $\pm$8G, and it comes at a sample rate of 30 - 100 Hz (ActiGraph, LLC., n.d.).

Figure 2: The ActiGraph wGT3X-BT.

Source: (ActiGraph, LLC., n.d.)

2.2.5 Direct Comparison of Objective Versus Subjective Methods

Both subjective methods, such as the PAQ-C, and objective methods, like accelerometer measurements, have been found to be valid tools for assessing children's general PA. Nonetheless, many studies have exposed differences and a lack of agreement between the two methods. The following sections present study results that support both the accordance and deviation of the subjective and objective methods for measuring PA. Specifically, the PAQ-C is compared to the ActiGraph accelerometer's measurements of PA.

Accordance

Many studies have agreed on the existence of a significant positive association between the PAQ-C and PA measurements using an accelerometer. The developers of the PAQ-C first compared the questionnaire to an objective method (accelerometer) in 1997, and they found a significant and moderate correlation between the two methods (Kowalski et al., 1997). Since then, many other studies have showed confirmatory results. For example, a Chinese study that compared the PAQ-C to an ActiGraph accelerometer found significant correlations between PAQ-C scores and MVPA measured by the accelerometer (Wang et al., 2016). A study from Italy also found a significant correlation between the two, with a correlation coefficient of $\rho = 0.30$ (Gobbi et al., 2016). Additionally, studies from Greece, England, and the USA confirmed the convergent validity between PAQ-C scores and accelerometry-based MVPA (Fairclough et al., 2011; Janz et al., 2008; Venetsanou et al., 2020). PAQ-C scores were also found to be inversely correlated with time spent in SB as measured by an accelerometer (Voss et al., 2017).

Some studies have examined the relationship between the individual questions from the PAQ-C and accelerometer measurements of PA. One study found significant correlations for items 6, 8, and 9 (Benítez-Porres, 2016). Another study showed that items 2, 3, 5, 7, and 9 were positively correlated with the average MVPA measured by an ActiGraph accelerometer (Venetsanou et al., 2020). Yet another study found significant correlations for items 1, 4, 5, 6, 7, 8, and 9 (Voss et al., 2017). These studies also mentioned that overall, the associations with

accelerometer measurements were stronger for the total PAQ-C score than for the individual item scores.

Discrepancies

Although the agreement between the PAQ-C and accelerometer-measured PA has been verified by different studies, a body of literature exposing discrepancies between the two methods also exists.

When Ben Jemaa and colleagues directly compared objective and subjective PA measurement methods, they found that the correlation between mean PAQ-C scores and average MVPA from ActiGraph measurements among Tunisian children was not significant (Ben Jemaa et al., 2018). Similarly, a Spanish study questioned the validity of the PAQ-C because it reported only weak correlations between PAQ-C scores and accelerometer-measured MVPA and total PA (Benítez-Porres et al., 2016). Low correlation coefficients between PAQ-C scores and ActiGraph-measured minutes of MVPA per day were also found among Chinese children (Chan et al., 2019). Furthermore, a 2021 systematic review that aimed to summarize the evidence on the convergent validity of the PAQ-C to estimate PA levels in children concluded that the PAQ-C and accelerometers have an inconsistent ability to measure the same construct (i.e., PA) (Marasso et al., 2021).

In addition to these weak associations between PAQ-C and ActiGraph accelerometers, the two methods have also been found to be inconsistent with each other in detecting relationships with different parameters. For example, fundamental movement skills were associated with PA measurements from the accelerometer, but not with PAQ-C scores. In contrast, the relationship between PA and physical competence was only significant for self-reported PA and not accelerometer-measured PA (Chan et al., 2019). Another study that investigated the relationship between PA and bone mineral content showed that the accelerometer measurement was more likely to detect associations between the two variables than the PAQ-C (Janz et al., 2008). In a Kenyan study, the only significant associations between ActiGraph measurements and self-reported PA levels were found among the under- and healthy-weight children, which indicated that the strength of association between the objective and subjective methods can vary according to weight status (S. K. Muthuri et al., 2015).

2.3 Cardiovascular Risk Markers

CRMs are specific body measurements that can indicate the likelihood of developing CVD. This chapter describes the four risk markers selected for this study: BP, BMI, BLP, and HbA1c.

2.3.1 Blood Pressure

BP is the force per area of blood pushing against the walls of the body's blood vessels (Klabunde, 2012). This pressure is created by the heart, which pumps blood into the circulatory system. BP is usually categorized as systolic and diastolic blood pressure. Systolic blood pressure (SBP) is defined as the maximum pressure during a heartbeat (contraction of the left ventricle), while diastolic blood pressure (DBP) indicates the minimum pressure between

heartbeats (relaxation of the left ventricle). BP is measured in mmHg (millimeters of mercury). For adults, the reference value for a normal BP is 120/80 mmHg, where 120mmHg represents the SBP and 80mmHg represents the DBP (Centers for Disease Control and Prevention, 2021b). For children, reference values are lower than adults' and vary depending on age and height.

A BP that is constantly too high is called hypertension or raised (also elevated) BP. An elevated BP requires the heart to pump harder to move blood into the system. Hypertension has serious implications for physical health. High pressure in the arteries can lead to aneurysms and weak spots that make the vessels more likely to rupture and become clogged. It dramatically increases the risk of CVD, such as heart attacks and strokes (WHO, 2021b). Hypertension is the leading mortality risk factor, accounting for about 12.8% of all deaths worldwide. It is sometimes referred to as the "silent killer" because affected people often experience no symptoms. An estimated 1.13 billion people worldwide have hypertension, yet less than 20% of these people have their BP under control (WHO, 2021b). Due to a rise of hypertension risk factors, low- and middle-income countries have seen the largest increase in the prevalence of hypertension (WHO, 2021b).

Pediatric Hypertension

Children are defined as hypertensive when their BP is greater than that found in the ninety-fifth percentile of their respective category (Kay et al., 2001). Categories and reference values for children are adjusted for age, sex, and height. High BP among children and adolescents is a growing health concern. Almost 20% of adolescents are at risk for hypertension (McNiece et al., 2007). Various studies have found that children with hypertension are likely to remain hypertensive in adulthood; the risk of becoming a hypertensive adult is 2.4 times greater for children with a BP greater than the ninetieth percentile when compared to those with a BP below the ninetieth percentile (Mahoney et al., 1991).

As children rarely experience heart failure or coronary artery disease as a cause of high BP, an association between the treatment of high BP and the reduction of cardiovascular risk for children is difficult to find (Kay et al., 2001). Nonetheless, high BP has been associated with atherosclerotic lesions in the aorta and coronary arteries in young adulthood (Berenson et al., 1998). Childhood hypertension is also associated with hyperlipidemia, insulin resistance, and pathologic transformations of the blood vessels (Martino et al., 2013; Urbina et al., 2011). The latter can be detected through the carotid intima-media thickness.

However, treating childhood hypertension with medication poses certain risks. Children treated for hypertension come into contact with drugs at a critical stage of development and are exposed to the drugs for an extended period, and little is known about long-term outcomes (Kay et al., 2001). Thus, nonpharmacological therapy is advised for treating pediatric hypertension. This therapy includes weight reduction, physical exercise, and dietary interventions (National High Blood Pressure Education Program Working Group on Hypertension Control in Children and Adolescents, 1996). Reducing weight plays a major role in lowering the BP of overweight children (Rocchini et al., 1988). However, weight reductions have proven to be difficult to achieve, not only for children but also for adults. One possible

method to reduce weight, lower both SBP and DBP, and decrease cardiovascular risk factors simultaneously is physical exercise (National High Blood Pressure Education Program Working Group on Hypertension Control in Children and Adolescents, 1996).

Relationship Between Blood Pressure and Physical Activity

PA's impact on BP is well established; increasing levels of PA is one of the most important and recommended lifestyle changes for preventing hypertension (Brook et al., 2013). The favorable effects of PA were discovered in 1968 by Paffenbarger et al., who showed that active men were less likely to become hypertensive later in life (Paffenbarger et al., 1968). Since then, many additional studies have provided verification of the protective effects of PA against hypertension. PA and the development of hypertension are inversely associated (Carnethon et al., 2010); the more active and fit people are, the lower their risk of developing hypertension (Chase et al., 2009). A clear dose-response relationship has not yet been established, but higher PA levels seem to have substantial benefits in terms of reducing hypertension (Pavey et al., 2013). The effects of PA on BP have also been shown in randomized controlled trials. An intervention in the form of aerobic exercise training led to a reduction of 4.3 mmHg for SBP and 1.7 mmHg for DBP among prehypertensive individuals (Cornelissen & Smart, 2013).

In children, it has been observed that higher levels of MVPA were associated with lower BP, whereas SB was related to an increased risk of hypertension (Ekelund et al., 2012; Pouliou et al., 2012). Playing video games and watching television, for instance, was positively correlated with DBP (Gopinath et al., 2012). However, the inverse association between MVPA levels and BP values was not detected in other studies, and the effect of SB on BP can be mediated by adiposity (Ekelund et al., 2006; Lazarou et al., 2009; Pinto et al., 2011).

Since the root causes of hypertension are multifactorial, the mechanism by which PA reduces BP are not yet fully understood (Diaz & Shimbo, 2013). Possible mechanisms are presented in Table 1.

Table 1: Mechanisms by Which PA Might Prevent the Development of Hypertension.

Proposed by Diaz & Shimbo (Diaz & Shimbo, 2013)

↓ Vascular resistance	↑ Endothelial function
↓ Arterial stiffness	↑ Insulin sensitivity/ glucose handling
↓ Oxidative stress	↑ Renal function
↓ Inflammation	↑ Sodium handling
↓ Body weight/body mass	↑ Baroreflex sensitivity
↓ Sympathetic activity	↑ Parasympathetic activity
↓ Renin-angiotensin system activity	↑ Angiogenesis
↓ Vascular responsiveness to adrenergic- and endothelin-receptor stimulation	↑ Arteriogenesis
↓ Intima-media thickness	↑ Arterial compliance
↓ Psychosocial stress	↑ Arterial lumen diameter

2.3.2 Body Mass Index (BMI)

Body mass index (BMI) is a measurement of an individual's weight in relation to their height. More precisely, it relates body mass to the square of body height (kg/m^2). BMI is used to categorize people as underweight, normal weight, overweight, or obese. Overweight and obesity are characterized by excess weight in the form of body fat. As BMI does not directly measure body fat, muscular people can have a high BMI, even if they do not carry excess body fat. However, for the majority of people, the BMI provides an adequate estimate of body fat (Billewicz et al., 1962).

About Overweight and Obesity

Adults are considered overweight when their BMI is 25 – 30 and obese when their BMI is higher than 30. Obesity is particularly regarded as a serious medical issue, one that is associated with various health problems and an increased risk of diabetes, high BP, certain cancers, CVD, and musculoskeletal disorders (WHO, 2021c). Compared to normal weight, obesity increases an individual's all-cause mortality risk by 18% (Flegal et al., 2013).

Obesity is caused by an imbalance between energy input and output. The body stores excess energy as fat when more calories are consumed than are burned through daily activities, PA, or exercise. Multiple risk factors contribute to overweight and obesity, including family history, certain diseases and medications, age, stress, and socioeconomic issues (Mayo Clinic Staff, 2021). Another major factor is an individual's lifestyle choices. Negative lifestyle choices, such as an unhealthy diet and physical inactivity, cause a more frequent imbalance between energy input and output.

Many complications and health problems are linked to obesity, including CVD. Overweight and obese individuals are more likely to be hypertensive and have abnormal cholesterol levels, which are CRMs for heart conditions and stroke. Hypertension is one of the most common complications linked to obesity; about 30% of hypertensive individuals are obese (Macmohan et al., 1987). Even modest weight reductions (5 - 10% of initial weight) can lower and potentially normalize BP (Mertens & van Gaal, 2000).

Obese individuals also show worse levels of blood lipid parameters compared to normal-weight individuals (Bhatti et al., 2001). In 1980, researchers investigated the relationship between obesity and lipoprotein cholesterol and found that obesity is associated with increased levels of low-density lipoprotein (LDL), decreased levels of high-density lipoprotein (HDL) and a higher ratio of total cholesterol (TC) to HDL (Garrison et al., 1980).

Overweight and Obesity Among Children and Adolescents

Children and adolescents are also categorized into weight categories based on BMI. However, since their body composition varies greatly as they age and differs between boys and girls, the categorization thresholds are adjusted for age and sex.
Childhood weight gain is caused by similar factors as it is for adults. These include eating high-calorie foods and spending too much time engaging in SB, such as watching television (Centers for Disease Control and Prevention, 2021a).

The negative effects of excess weight in childhood and adolescence are also similar as those in adulthood. Although cardiovascular risk outcomes do not necessarily occur in school-aged populations, most common CRMs do, including hypertension, dyslipidemia, and abnormal endothelial function (Steinberger & Daniels, 2003). Another negative aspect of obesity relevant for children is the social problems, such as bullying at school, which can affect obese children (Beck, 2016). Low self-esteem, negative self-perception, and depression can also occur due to stereotyping and social rejection (Doak et al., 2006). Furthermore, obese children and adolescents are likely to remain obese as adults, and obesity-related disease risk factors in adulthood are expected to be more severe if the individuals were obese in childhood (Bass & Eneli, 2015; Gordon-Larsen et al., 2010).

Trends in Overweight and Obesity

Over the past several decades, the number of overweight adults globally has risen dramatically and is now estimated to be higher than 1.9 billion; more than one out of three adults are overweight worldwide. Concerning trends are also observable in children and adolescents. In 1975, just 4% of children and adolescents were overweight, but in 2016, 18% were overweight (WHO, 2021c). Childhood obesity used to be viewed as a problem found only in developed, high-income countries. However, since the late twentieth century, the prevalence of childhood obesity has increased in low- and middle-income countries (Gupta et al., 2012). For example, some of the highest growth rates for overweight and obesity are found in Africa, where the number of overweight or obese children has more than doubled from 1990 - 2010 (de Onis et al., 2010). A decline in PA and an unhealthy diet are thought to be the two main causes for the increasing prevalence of overweight and obesity in developing countries (Boutayeb & Boutayeb, 2005), and South Africa has not been spared from this trend. From 1994 – 2004, the prevalence of overweight and obesity has increased from 1.2 - 13% and 0.2 - 3.3%, respectively, among South African primary school children (M. E. G. Armstrong et al., 2011). In 2017, more than 28% of girls and 13% of boys were reported overweight or obese in a population of learners from Western Cape (Negash et al., 2017). According to South African studies, the prevalence of overweight and obesity not only differs significantly between males and females but also between ethnic groups and geographic areas (Rossouw et al., 2012).
Like many other developing countries, South Africa suffers from the simultaneous existence of overweight and undernutrition among children and adolescents (Rossouw et al., 2012).

Relationship Between Physical Activity and BMI

PA and diet are central components to preventing obesity and to losing weight (Hills & Byrne, 2006). Body weight and PA are directly associated, since more energy is expended when PA levels are high. Therefore, PA can help reduce weight. As mentioned earlier, PA also has a positive effect on the prevention of various illnesses (Strong et al., 2005). Hence, the promotion of an active lifestyle should not be limited to overweight individuals but should also be recommended to normal-weight individuals. People with a normal BMI but poor fitness have a higher mortality risk than people with a high BMI but good fitness, which shows the significant role PA plays in the prevention of illness (Fogelholm, 2010). Overweight and obese people are usually less active, prefer SB, and have poorer motor skills than normal-weight individuals (Hills et al., 2007; Marshall et al., 2004; Okely et al., 2004). The combination of low PA levels

and overweight results in reduced fitness and limits the motivation to participate in physical exercise and sports (Hills et al., 2011).

Upon close examination of the relationship between PA and BMI, several explanations emerge regarding the association between higher PA levels and a lower prevalence of overweight (Dwyer et al., 2007). First, PA helps prevent weight gain while also helping to lose weight by increasing energy expenditure and suppressing appetite. Second, overweight poses difficulties for practicing PA, since overweight increases musculoskeletal pain and discomfort (Hills et al., 2011). Third, adherence to regular PA might represent a generally healthier lifestyle (e.g., better self-control). All three factors likely contribute to PA's decrease of the risk for overweight.

Relationship Between Physical Activity and BMI Among Children and Adolescents

When compared to their non-obese peers, obese individuals accumulate significantly less MVPA and report lower levels of PA self-efficacy (S. Trost et al., 2001). A significant inverse correlation exists between PA and body composition; the more active children are, the lower their body fat percentage and BMI (Abbott & Davies, 2004). In an intervention study in which obese children participated in weekly physical training sessions for four months, the children increased their fat-free mass and reduced their fat mass more than the children who did not attend these training sessions (Owens et al., 1999). However, such advances in health can be lost if regular PA is not maintained (Gutin et al., 1999).

Paradoxically, some previous findings have suggested that no significant association exists between PA and adiposity in youth (Bar-Or & Baranowski, 1994). Certain literature has indicated that children and adolescents are sufficiently active in many regions and that normal-weight individuals are not more active than their obese peers (Hills et al., 2011; Mota et al., 2008). However, these discrepant findings may stem from the difficulties of gathering valid measurements of PA in children. Most of this evidence is based on self-reported PA levels, which are subject to substantial recall bias, especially among children (M. I. Goran, 1998).

In addition to maintaining adequate levels of PA, reducing SB is also important. SB, such as watching television, is thought to contribute to weight gain by replacing time spent performing PA and by increasing the amount of high-calorie food consumed during a resting state (Robinson, 2001). An intervention that discouraged television usage in a group of children resulted in decreased waist circumference and BMI after seven months, although the intervention did not yield significant increases in MVPA (Robinson, 1999).

2.3.3 Blood Lipid Profile

A BLP is collected as part of a medical test that screens for abnormalities in blood lipids. The BLP usually includes a measurement of LDL cholesterol, HDL cholesterol, triglycerides (TG), TC, and the difference between TC and HDL (Non-HDL). Another indicator used to inspect abnormalities of blood lipid concentrations is the ratio of TC to HDL (TC/HDL). Dyslipidemia is a disorder that occurs when either one or a combination of lipid parameters are abnormal. It is characterized by elevated levels of LDL, Non-HDL, TC, TG, TC/HDL, and/or a decreased level of HDL. Dyslipidemia contributes to endothelial dysfunction and vessel inflammation. These

malfunctions promote atherosclerosis, which is the main cause of CVD (Srikanth & Deedwania, 2016). According to the WHO, 39% of adults worldwide showed raised TC concentrations in 2008 (WHO, 2022). Dyslipidemia can be inherited or can be caused by lifestyle factors and underlying diseases, such as obesity, diabetes, harmful alcohol use, or excessive consumption of saturated and trans fats (Yanai & Yoshida, 2021).

Lipoproteins function as vehicles that transport cholesterol through the blood. While HDL transports cholesterol to the liver, LDL takes cholesterol to the arteries, where it may collect in the walls and contribute to a buildup of plaque (Bhatt, 2018). LDL is believed to be the primary driver of atheromatous plaque formation (Borén et al., 2020). A large intervention study showed that a reduction of 1 mmol/l in LDL resulted in a 25% decreased relative risk for major vascular events (Silverman et al., 2016). An opposite association is present for HDL. Higher levels of HDL are favorable, while low levels of HDL are associated with an elevated risk for CVD (Toth et al., 2013). The Framingham Study was the first to report promising results about the inverse relationship between HDL levels and CVD back in 1964 (Kannel et al., 1964). Thereafter, the hypothesis that HDL is the “good” cholesterol that has protective properties against atherosclerosis was formed. However, although HDL is a valuable biomarker for estimating cardiovascular risk, whether raising HDL levels with interventions actually reduces cardiovascular risk is still unclear (Rader & Hovingh, 2014). Experts agree that reducing LDL and Non-HDL should continue to be the main therapeutic goal for individuals at risk for CVD (Toth et al., 2013).

Studies have also shown a clear association between TG-containing lipoproteins and cardiovascular risk. Using an intervention to reduce TG levels seems to have a positive effect on cardiovascular risk. However, randomized intervention trials in populations with high TG levels are scarce (Esan & Wierzbicki, 2021).

Furthermore, elevated levels of TC are associated with an increased risk for CVD. Among young adults, individuals with increased TC levels were 1.21 times more likely to be at risk for ischemic heart disease and 1.24 times more likely to be at risk for cerebrovascular disease (Jeong et al., 2018).

The TC/HDL ratio has also proved to be a valid biomarker. This ratio has been shown to effectively predict the risk for cardiovascular events and was successfully used as a predictor for ischemic heart disease risk in the Quebec Cardiovascular Study (Lamarche et al., 1996; Ridker, 2000). The use of the TC/HDL ratio is especially beneficial for patients with coronary heart disease; one of the most common lipoprotein phenotypes among these patients includes high levels of TC and low levels of HDL. This demonstrates the importance of the TC/HDL ratio (Austin et al., 1990), which has been found to be superior to TC or LDL at measuring the risk for coronary heart disease (Kinosian, 1994).

Pediatric Dyslipidemia

Although the negative health consequences of atherosclerosis typically occur at older ages, the atherosclerotic process itself begins in childhood (Pathobiological Determinants of Atherosclerosis in Youth (PDAY) Research Group, 1993). Children and adolescents with

abnormal lipid profiles are more likely to carry that risk factor into adulthood (Eisenmann et al., 2004). Thus, identification of dyslipidemia during youth is crucial for preventing atherosclerotic processes and premature CVD. Normative data on serum lipid and lipoprotein concentrations as recommended for children are presented in Table 2. The values have been adapted from the "Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents: Summary Report" (Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents, 2011).

Table 2: Ranges of Acceptable, Borderline, and High Serum Lipid and Lipoprotein Concentrations for Children and Adolescents.

Source: (Orimadegun, 2021)

Category	Acceptable mg/dL (mmol/L)	Borderline mg/dL (mmol/L)	High mg/dL (mmol/L)
TC	<170 (4.4)	170 to 199 (4.4 to 5.2)	≥200 (5.2)
LDL-C	<110 (2.8)	110 to 129 (2.8 to 3.3)	≥130 (3.4)
Non-HDL-C	<120 (3.1)	120 to 144 (3.1 to 3.7)	≥145 (3.8)
ApoB	<90 (2.3)	90 to 109 (2.3 to 2.8)	≥110 (2.8)
TG			
0 to 9 years	<75 (0.8)	75 to 99 (0.8 to 1.1)	≥100 (1.1)
10 to 19 years	<90 (1 mmol/L)	90 to 129 (1 to 1.5)	≥130 (1.5)
HDL-C	>45 (1.2)	40 to 45 (1 to 1.2)	<40 (1)
ApoA-1	>120 (3.1)	115 to 120 (3 to 3.1)	<115 (3)

Lipid disorders are rare in children and adolescents in Africa, and little literature on the topic exists. However, recent data suggest that the prevalence of dyslipidemia is increasing in African youth, partly due to the adoption of western world lifestyles (Sliwa, 2016). Although early detection of pediatric dyslipidemia through screening tests can reduce the risk of illness, screening for hyperlipidemia in children and adolescents is not a regular procedure in most parts of Africa (Orimadegun, 2021).

Relationship Between Physical Activity and Blood Lipid Profile Parameters

PA is a key element to preventing and treating abnormal lipid profiles (Craig et al., 1996). Physically active children and adolescents show a lower risk for dyslipidemia, while SB is associated with an increased risk of dyslipidemia (Zheng et al., 2016). Becoming more physically active and losing weight results in decreased TG levels and increased HDL concentrations. However, the effect of lowering LDL levels through PA is modest and still a topic of controversy (American Diabetes Association, 2004).

Adolescents who engage in at least 60 minutes of MVPA per day are almost five times less likely to have high-risk HDL levels and 10 times less likely to have high-risk TG values compared to those who perform no daily MVPA (0 minutes). Even small amounts of daily MVPA (e.g., 15 minutes) have been attributed to substantial reductions in the probability of having unhealthy HDL and TG levels (LeBlanc & Janssen, 2010). The results of a study with data from more than 20'000 children revealed that HDL concentrations were directly associated with MVPA, while TG concentrations were inversely associated with MVPA, regardless of the amount of sedentary time (Ekelund et al., 2012). Many other studies have also reported a significant relationship between PA and HDL and TG levels. For example, a Thai study found higher HDL levels and lower TG concentrations among individuals with high PA levels compared to those with low PA levels (Dancy et al., 2008). Regarding the specific exercise behavior, endurance athletes record 40 - 50% higher HDL and 20% lower TG concentrations than sedentary individuals (Sady et al., 1988; Thompson et al., 1984). One study of female runners showed that HDL concentrations increased by an average of 1.33 mg/dl for every 10 additional kilometers run per week. However, the study showed no significant differences between groups of varying kilometers run per week regarding LDL levels (Williams, 1996). Research about the relationship between PA and LDL is controversial (N. Armstrong & Simons-Morton, 1994; Thompson et al., 2001). In contrast to differences in HDL levels, LDL levels are only slightly lower (8 - 10%) in endurance athletes compared to sedentary individuals (Thompson et al., 2001). In fact, most of the data regarding PA and BLPs suggest that PA and exercise do not significantly lower LDL or TC, independent of weight changes (Ahmed et al., 2012). However, data indicate that regular PA can alter LDL particle size, even when the total amount of LDL remains constant (Halle et al., 1997). Small and dense LDL particles have a stronger impact on atherosclerosis, and PA appears to reduce cardiovascular risk by increasing LDL particle size, rather than lowering overall LDL concentrations (Kraus et al., 2002).

Nonetheless, inverse associations between PA and LDL and PA and TC have been found. However, theses associations can be largely explained by differences in BMI and smoking habits. In contrast, the positive relationship between PA and HDL was found to be independent of BMI, smoking, and dietary habits (Panagiotakos et al., 2003). In accordance with the above-mentioned findings regarding the effect of PA on HDL concentrations, the TC/HDL ratio has also been reported to be significantly correlated to PA levels (Twisk et al., 2000).

2.3.4 Glycated Hemoglobin

HbA1c is part of the hemoglobin in the red blood cells (erythrocytes), which carry oxygen throughout the body. When sugars, such as glucose, enter the bloodstream, they bind with hemoglobin in a process called glycation. The amount of sugar that glycates with hemoglobin is proportional to the total amount of sugar in the body (Chandalia & Krishnaswamy, 2002). Measures of HbA1c reflect an individual's average blood sugar level for the previous 8 - 12 weeks. Interpretation of HbA1c values is limited to this range because red blood cells have an average lifespan of 100 - 120 days. In contrast, plasma glucose tests measure the concentration of glucose at a single point in time and reveal no average level over a period.

The term “HbA1c” is a combination of “Hb” for hemoglobin, “A” for type A, and “1c” for the number of separated fractions (Peterson et al., 1998). HbA1c was first separated from other forms of hemoglobin in 1958 (Huisman et al., 1958). HbA1c values are given as a percentage of the total hemoglobin (%) or in millimoles of HbA1c per mol hemoglobin (mmol/mol).

When individuals’ consumption of sugar increases, so does the amount of glucose in their blood and, therefore, the fraction of HbA1c. Higher amounts of HbA1c signalize poorer control of blood sugar levels. Because of this mechanism, HbA1c measurements can be used to diagnose diabetes mellitus and to screen people at high risk. Diabetes is a metabolic disease characterized by a high blood sugar level, which leads to complications in many of the body’s systems over time. There are two main types of diabetes; type 1 diabetes is based on a lack of insulin, while type 2 diabetics use insulin ineffectively. The number of people with diabetes has grown dramatically (WHO, 2021a). For many years, diabetes has been diagnosed solely based on plasma glucose. However, since the HbA1c measurement has become more standardized, it is now recommended as a means of diagnosing for diabetes (American Diabetes Association, 2010a). Compared to plasma glucose levels, HbA1c has less day-to-day variability and does not require the patient to fast beforehand (WHO, 2011).

Thresholds for diagnosing and classifying diabetes were first established using the observed relationship between fasting plasma glucose and HbA1c levels in microvascular diseases, such as retinopathy (American Diabetes Association, 2010b). Individuals with an HbA1c of 6.5% (47 mmol/mol) or higher are diagnosed with diabetes. Individuals with values between 5.7 and 6.4% are at risk for becoming diabetic and are called prediabetic (American Diabetes Association, 2010a). One study found that individuals with HbA1c levels between 6.0 - 6.5% are at a 4.5 - times greater risk of developing diabetes within a timespan of 6 years compared to individuals with levels between 5.0 and 5.5% (Selvin et al., 2010).

HbA1c is related to CVD and has been shown to be a valuable marker of cardiovascular risk. In a population of nondiabetic people, elevated HbA1c values were associated with an increased risk for coronary heart disease and stroke (Selvin et al., 2010). Type 2 diabetics are more likely to have CVD and have a twofold greater risk of dying from CVD. Nonetheless, the exact mechanisms by which glucose influences atherosclerosis and the development of CVD is still unclear. The negative effects of diseases that often accompany diabetes, such as hypertension and dyslipidemia, are much better understood (Conget & Gimenez, 2009).
Intensively controlling blood glucose with medication in diabetes patients significantly decreases the progression of microvascular disease (UK Prospective Diabetes Study (UKPDS) Group, 1998). However, a convincing positive effect of glucose management on CVD has not yet been established. Intensive medical therapy to reduce HbA1c in type 2 diabetics did not reduce the occurrence of cardiovascular events and even increased mortality (The Action to Control Cardiovascular Risk in Diabetes Study Group, 2008).
Type 2 diabetes used to be diagnosed only in adults and was known as adult-onset diabetes. However, it now increasingly occurs in children and adolescents, where it is often undiagnosed. The global rise of physical inactivity and overweight are believed to play a crucial role in this trend (Roglic & World Health Organization, 2016).

Relationship Between Physical Activity and Glycated Hemoglobin

Physical exercise is a safe method for improving glucose control and is a central component of diabetes management, along with dietary modifications and pharmacological treatment (American Diabetes Association, 2010a). A meta-analysis from 2017 investigated the effects of PA on glucose control in children and adults and found that increasing PA by 100 minutes per week decreases the level of fasting plasma glucose by an average of -2.75 mg/dl and the HbA1c level by -0.14%. The type and intensity of PA did not significantly influence these changes; only the duration of PA was positively associated with decreasing glucose levels (Boniol et al., 2017). The study also emphasized that these changes are modest when compared to reductions achieved by medication, such as metformin (Buse et al., 2016). Dietary interventions have also been shown to reduced HbA1c levels slightly more effectively than PA (Ajala et al., 2013). However, such dietary programs showed poorer long-term compliance than PA interventions (Lindahl et al., 2009).

When the dose-response relationship between PA and HbA1c levels among adults was further explored, a curvilinear association was found. A greater decrease of HbA1c values through MVPA was recorded in individuals who were typically inactive. Individuals that were already quite active could not expect an equally large reduction in HbA1c from extra MVPA (Gay et al., 2016). This finding aligns with the recommendation that engaging in some PA is healthier than being entirely sedentary.

Gay and colleagues found that in individuals with a low risk of type 2 diabetes, the relationship between MVPA and HbA1c is not significant (Gay et al., 2016). However, in patients with type 2 diabetes, HbA1c levels were reduced by -0.16% for every 100 minutes of extra PA per week (Boniol et al., 2017). One study examined exercise training as well as PA and found that exercise is associated with an HbA1c reduction of -0.67% in type 2 diabetics. Patients who met recommendations and exercised for more than 150 minutes per week reduced their HbA1c level significantly more than individuals with exercise durations of less than 150 minutes (-0.89% versus -0.36%). When compared to structured exercise training, advised PA from an expert did not result in an equally strong decline of HbA1c; the study showed that PA advice was associated with HbA1c reductions only when supplemented by a dietary cointervention (Umpierre et al., 2011).

In type 2 diabetic children and adolescents, increased PA was associated with lower HbA1c and BMI values (Herbst et al., 2015). Likewise, among children and adolescents with type 1 diabetes, an inverse dose-response relationship was found between PA and HbA1c. After grouping the children and adolescents according to their PA levels, the least active group showed considerably higher HbA1c values than did the most active group (8.8% versus 7.7%). Consequently, diabetic children and adolescents are encouraged to engage in PA every day (Beraki et al., 2014; Herbst et al., 2015).

The influence of PA seems to be different for healthy children who are not diagnosed with diabetes. Among a large sample of healthy children and adolescents, HbA1c values were not associated with PA (Hovestadt et al., 2021). Jansen and colleagues found that several lifestyle factors related to an elevated risk for diabetes were not associated with HbA1c values in children approximately 12 years of age (Jansen et al., 2015). Instead, these lifestyle factors, such as PA, seem to have a bigger effect on HbA1c levels later in adulthood or after puberty.

3 Purpose of the Study and Research Questions

Developing an efficient, practical, and accurate method for measuring habitual PA in children and adolescents is an important and valuable task for learning about the impact of PA and identifying unhealthy lifestyles (Benítez-Porres et al., 2016). The PAQ-C and ActiGraph accelerometer are used in many countries and cultures as instruments for measuring PA. Therefore, the degree to which these two methods accord regarding the estimation of PA levels must be determined. However, the literature regarding the relationship between the PAQ-C and accelerometer technology is controversial. Although significant correlations have been found, many studies have suggested a lack of agreement between the two methods. Therefore, the first focus of this study is to compare mean PAQ-C scores with MVPA levels derived from ActiGraph accelerometers. The study will concentrate on MVPA since it is the unit in which PA recommendations and guidelines are given. PAQ-C scores will also be compared to accelerometry-derived measures of SB, light intensity PA (LPA), and the total amount of PA achieved by study participants. Furthermore, the ActiGraph measurements of PA will be compared to individual PAQ-C questions to determine and compare their strength of association with the accelerometer measurements.

The PAQ-C has only rarely been used and examined in South African populations. One study found that the PAQ-C scores correlated moderately with the daily number of steps among primary school children from Gauteng (Malan & Nolte, 2017). Another study with 8-year-old children from a black South African population reported a poor level of agreement between the PAQ-C and ActiGraph accelerometers for measuring PA levels (Sedumedi et al., 2021). The analyses of this master's thesis will provide further information for better understanding the convergent validity of the PAQ-C among South African schoolchildren. They will also deliver details about PA patterns and behaviors of the students from Gqeberha.

Accounting for 32% of all global deaths, CVD is the leading cause of death worldwide. Through focus on behavioral risk factors, however, CVD can mostly be prevented (WHO, 2021d). Such risk factors include the harmful use of alcohol and tobacco, unhealthy diet, and physical inactivity. As the second focus of this master's thesis, the relationship between PA and risk markers for CVD will be examined in depth. Thereby, the extent to which PA and SB influence CRMs among school children from South Africa will be demonstrated. The investigation will reveal the possible importance of PA during childhood in terms of cardiovascular health.

By comparing two methods of measuring PA (PAQ-C and accelerometer) and their association with selected CRMs, this study may expose the possible superiority of one method over the other.

Consideration of the theoretical framework about subjective and objective measurements of PA, as well as their association with CRMs, resulted in the formulation of the following research questions:

- How does the PAQ-C determine the amount of PA compared to accelerometer measurements (ActiGraph accelerometer), and how do the two methods correlate with each other in a population of South African school children from Gqeberha?

- How are both methods associated with BP, BMI, HbA1c, and BLP values, and which method performs better at explaining variability in these CRMs?

These two research questions build the foundation of this master's thesis.

4 Hypotheses

Hypotheses were drawn for the main research questions. Derived from the theoretical background, the following presumptions were put forth:

1. The PAQ-C and accelerometer measurements of PA are associated.

- PAQ-C scores are positively correlated with ActiGraph measurements of MVPA and total PA. They are inversely correlated with ActiGraph measurements of SB.
- PAQ-C item scores are positively correlated with ActiGraph measurements of MVPA and total PA. They are inversely correlated with ActiGraph measurements of SB.

2. Selected CRMs are associated with PAQ-C scores and accelerometer measurements of PA.

- PAQ-C scores and accelerometer measured minutes of MVPA per day are inversely associated with SBP, DBP, BMI, HbA1c, TC, TG, LDL, Non-HDL, and TC/HDL.
- PAQ-C scores and accelerometer measured minutes of MVPA per day are positively associated with HDL.
- The time spent engaging in SB is positively associated with SBP, DBP, BMI, HbA1c, TC, TG, LDL, Non-HDL, and TC/HDL.
- The time spent engaging in SB is inversely associated with HDL.

3. Accelerometer-measured minutes of MVPA per day are better able to explain variability within BP, BMI, HbA1c, and BLP parameters than PAQ-C scores.

5 Methods

In this chapter the methodological design and data gathering of the *KaziBantu* project is described. The *KaziBantu* project is the framework in which this master's thesis occurs. The following sections focus on describing the project's methods and procedures which are relevant for the research questions of this master's thesis. For detailed and more extensive information about the background, goals and methods of the *KaziBantu* project, consult the associated study protocol by Müller et al. (Müller et al., 2019).

5.1 The *KaziBantu* Project

The *KaziBantu* project is an intervention program that has been introduced at various primary schools in Gqeberha, South Africa. It pursues the goal of promoting a healthy lifestyle and raising awareness among school children and teachers. More precisely, as the program's website states, it "*aims to consolidate the practice of physical education and to ensure the physical literacy and healthy active living of school children and teachers in South Africa*." (KaziBantu, n.d.). The program includes sports and dance lessons, as well as hygiene and nutrition education classes that have been incorporated into the weekly class schedule. With this multi-layered approach, the program provides opportunities for PA and teaches about health-related topics to create a sustainable positive impact. The name "*KaziBantu*" can be translated to "Active People".

5.2 *KaziBantu* Study Design

The intervention of the *KaziBantu* program was designed as a 36-week randomized controlled trial. A total of 8 schools were included in the study, which were divided into an intervention group (4 schools) and a control group (4 schools). The study was structured such that after the completion of baseline assessment in early 2019, children from the 4 intervention schools participated in a health promotion program (*KaziKidz*) for 32 weeks. As part of the *KaziKidz* program, children took part in 3 health and nutrition education lessons, as well as weekly physical education and moving-to-music lessons. Children of the control schools carried out their routine subject schedules. After 36 weeks, follow-up data were collected. Figure 3 gives an overview of the KaziBantu study design.

For this master's thesis, only data collected during baseline assessment in early 2019 are used.

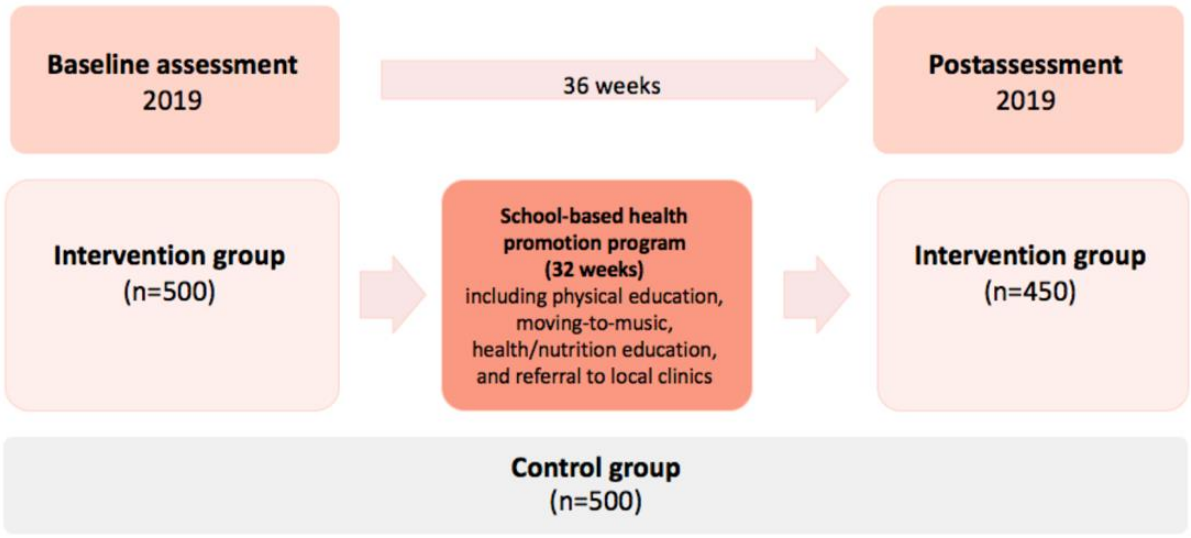

Figure 3: The Study Design of the KaziBantu Intervention Program for Children.
Source: (Müller et al., 2019)

5.3 *KaziBantu* Study Procedure During Baseline Assessment

At each of the 8 schools, data collection took place during usual school times. A team of researchers, healthcare workers, project employees and university students conducted the examinations and assessments, while adhering to standardized protocols.

The following measurements and tests were performed on the children:

- Anthropometric and clinical examinations (health examination, body height and weight, waist, and hip circumference, BLP, BP, HbA1c)
- Physical fitness and activity (20-m shuttle run, upper body strength, objective physical activity via ActiGraph, PAQ-C)
- Cognitive and academic performance (social and demographic background, school grades, school schedules)
- Psychosocial health (Health Behaviors in School-age Children Survey, Kidscreen-10, academic self-concept)

5.4 *KaziBantu* Study Area

All 8 primary schools that participated in the study are located in disadvantaged areas of Gqeberha, South Africa. Half of the schools are situated in townships, while the other half belong to the northern areas of Gqeberha. Even though Apartheid laws have been abolished since the early 1990s, the effects of racial segregation are still visible in South Africa. People from the township areas are predominantly black and Xhosa speaking, while people from the northern areas are typically colored and Afrikaans speaking (Müller et al., 2019).
The school's neighborhoods are characterized by low standards of living. They struggle with poverty, high unemployment- and crime rates, as well as undesirable schooling conditions.

Classes often hold a large number of students and teachers are poorly qualified. With regards to PE, they face barriers such as unsuitable facilities and equipment, unengaged PE teachers, and a general neglection of PE. In fact, PE even lost its status as an independent subject in 1997. PE is now taught as part of the subject “Life Orientation” (Rajput & van Deventer, 2010). Children’s physical and academic development is also being negatively affected by malnutrition and a lack of health care accessibility (Walter, 2014).

Figure 4 shows the geographical location of the 8 schools that participated in the study. The figure also displays which schools belong to Township Schools (red dots) and which belong to Northern Area Schools (blue dots). It is further indicated which schools were assigned to the intervention condition and which schools functioned as control schools.

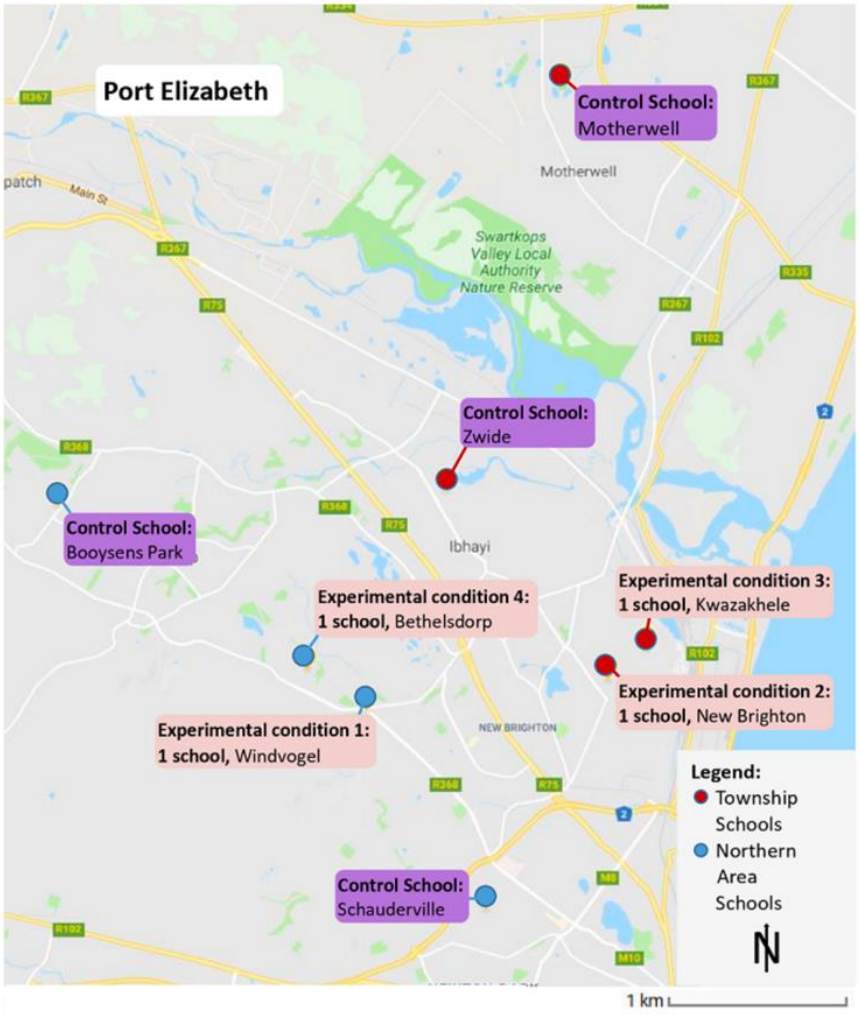

Figure 4: Study Area (Gqeberha, South Africa) with Schools Participating in the KaziBantu Program.

Source: Kartendaten, AfriGID (Pty) Ltd. (Müller et al., 2019)

5.5 *KaziBantu* Study Participants

Data of 981 children were initially collected during baseline assessment in early 2019. The children had an age between 8 and 16 years and were attending grades 4 to 6. This study sample included as few as 4 children at age 14, no child at age 15, and only 1 child at age 16. To avoid misrepresentation of age groups, only children between the ages of 8 and 13 were allowed to be retained in the final study sample.

The final study sample consisted of 594 children (50.8% boys and 49.2% girls) with an average age of 10.4 years (standard deviation $\pm$ 1.2). 51.7% of the study participants were going to Township Schools and 48.3% were visiting Northern Area Schools. 29.5% of the children were 4^{th} graders, 34% were 5^{th} graders, and 36.5% were 6^{th} graders. See chapter "5.9 Data Cleansing" for more information about the process of data cleansing.

5.6 Ethical Clearance

Each possible participant was informed about the study's objectives, procedures, risks, and benefits. Participation in the study was voluntary and withdrawing was possible at any time with no further consequences. Oral approval had to be given by participating children, while corresponding parents or guardians had to sign a written informed consent.

The methods and procedures of the *KaziBantu* study comply with the Declaration of Helsinki and have received ethical approval from the Nelson Mandela University Ethics Committee, Eastern Cape Department of Health, and Eastern Cape Department of Education. The study was also cleared by the ethical review board of the Ethics Committee Northwest and Central Switzerland.

5.7 Data Collection

The two main parameters for answering the research questions of this study are the objective and the subjective PA measurements. Furthermore, data about BP, BLP, HbA1c, and BMI is necessary in order to be able to compare these health determinants to children's PA levels. Demographic and anthropometric information about the study participants will also be regarded.

5.7.1 Objective Assessment of Physical Activity Behavior

The objective PA measurement was conducted with the ActiGraph accelerometer device (ActiGraph wGT3X-BT, Pensacola, Florida, USA). Participants were directed to wear the device for one week (7 consecutive days) around the hip. They were allowed to remove the ActiGraph for activities that involved water contact (e.g., swimming or showering). Accelerometers were set up at a sampling rate of 30 Hz and ran on the latest firmware version (version 1.9.2). Analysis was carried out with the ActiLife software (version 6.13.4), using data set up at epochs of 10 seconds.

To be eligible for the data evaluation, the ActiGraph had to be worn for at least four valid weekdays and at least one weekend day. A day was considered valid if the ActiGraph had been worn for at least eight hours during that day. Sleep time was removed and during waking time, non-wear periods, defined and identified based on the Troiano 2007 algorithm, were excluded from the analysis. The Troiano technique for wear time validation was created as part of the analysis of the dataset from the National Health and Nutrition Examination Survey 2003-2004 (National Center for Health Statistics (U.S.), 2013). The algorithm regards non-wear time as a sequence of ≥60 consecutive minutes of 0 counts/minute (vertical axis), while a spike level of ≥100 counts/minute breaks the non-wear cycle, if maintained for at least 2 minutes. PA intensities were categorized according to the cut-off points from Evenson 2008 (for Children) (Evenson et al., 2008). One study that evaluated five different sets of cut points developed for ActiGraph accelerometers concluded that the Evenson cut points were the best overall performer in classification accuracy across all intensity levels (S. G. Trost et al., 2011). Following Evenson's cut points, the periods where the accelerometer measured ≤100 activity counts per minute, were defined as SB. LPA was defined as >100 and <2296 counts/min, MPA as ≥2296 and <4012 counts/min, and VPA was set up at ≥4012 activity counts/min.

Since the amount of time spent in different PA intensities is dependent on ActiGraph wear time, it was expressed as a percentage relative to wear time. The variable "Sedentary Time (%)" was defined as minutes spent engaging in SB as a percentage of valid wear time minutes from the accelerometer. Accordingly, the variables "Light Activity Time (%)", "Moderate Activity Time (%)", and "Vigorous Activity Time (%)" were defined as the time spent in either LPA, MPA, or VPA as a percentage of valid accelerometer wear time. The variable "Total PA (min)" was defined as the total time in minutes spent with LPA, MPA, or VPA as measured by the accelerometer. Furthermore, the average daily time that study participants spent engaging in MPA or VPA was combined to obtain the variable "ActiGraph MVPA (min/day)".

5.7.2 Subjective Assessment of Physical Activity Behavior

The PAQ-C was used for the subjective assessment of PA. In this questionnaire, children were asked about different aspects of their usual PA behavior and each of the questions required the children to assess their personal state of PA level. After completing the questionnaire, a summary activity score between 1 - 5 (1 = lowest PA level, 5 = highest PA level) was calculated. The questionnaire was filled out retrospectively over a period of one week. The PAQ-C is specifically designed for school children between the ages of 8 and 14. See "2.2.2 The Physical Activity Questionnaire for Older Children" for more information on the PAQ-C.

The original PAQ-C consists of 9 questions about PA behavior and a 10th question asking if some type of sickness has hindered the child from doing its normal physical activities. In the *KaziBantu* project, a modified version of the PAQ-C was utilized. Questions 1 and 9 were omitted from the questionnaire, leaving only items 2-8 for calculating the overall score. Removing these two questions was done for pragmatic reasons. Items 1 and 9 are lengthy and more elaborate than the other items, where only one box must be ticked. Omitting these items ensured that participating children were not overwhelmed by the questionnaire while saving time and labor for the evaluators. It can be assumed that tendencies of overall PAQ-C scores were not relevantly distorted by this procedure. However, comparisons of mean PAQ-

C scores of this study population with results from other studies must be interpreted with caution.

Children who reported a sickness in question 10 were not allowed to enter the final study population. Furthermore, study participants that failed to answer one or more questions were also excluded from the study sample.
While filling out the questionnaires, children were supervised and assisted by members of the *KaziBantu* team.

5.7.3 Assessment of Blood Pressure

Resting BP was measured after the learners were directed to be seated and to relax for five minutes. BP of the children was measured three times with a pause of one minute between each measurement. A calibrated Omron digital blood pressure monitor (Omron M6 AC model; Hoofddorp, The Netherlands) was used for the measurements. The cuff of the BP device was wrapped around the learner's left arm in a way that a finger could still fit between arm and cuff. A small and appropriate cuff size of 17 to 22 cm was used for the children (Omron CS2 Small Cuff; Hoofddorp, The Netherlands). Only the second and third measurements were used to calculate an average for systolic and diastolic BP. Measurements were performed by nurses or bio kineticists.
BP values will be reported in mmHg.

5.7.4 Assessment of Blood Lipid Profile and Glycated Hemoglobin

A point-of-care instrument (Alere Afinion AS 100 Analyzer, Abbott Technologies; Abbott Park, United States of America) was used to determine the BLP and HbA1c concentrations. The device delivered the results within 8 minutes. For the measurements, blood was collected from children's fingertips. A healthcare worker first cleaned the fingertips with an alcohol swab and then pricked it with a safety lancet. Two drops of blood were then carefully squeezed out of the finger, but only the second drop was collected for analysis.
All devices used were tested and calibrated before the measurement procedure (Müller et al., 2019).
The BLP included TC, LDL, HDL, TG, Non-HDL and the TC/HDL ratio. Apart from the TC/HDL ratio, values from the BLP will be reported in mmol/l.
HbA1c levels revealed participant's average plasma glucose level over the past 8 to12 weeks and will be reported as a percentage of the total hemoglobin (%).

5.7.5 Assessment of Body Mass Index

Body height of the children was measured by stadiometer with an accuracy of 0.1 cm. Participants were instructed to keep their back erect and their shoulders relaxed. Body weight was measured by standing on a digital weighing scale with an accuracy of 0.1 kg. For each participant, the BMI was then calculated by dividing body weight (kg) with the square of body height (m^2). Based on BMI values, children were classified as "Thin", "Normal weight", "Overweight", or "Obese". Cut-off values for this categorization are specific to sex and age and are based on reference data from the WHO (WHO, 2007). Values above +1 standard deviation (SD) are considered "Overweight" and if values exceed +2 SDs they fall into the category

"Obese". Children with BMI values below -2 SDs are considered "Thin" and values between -2 SDs and +1 SD are categorized as "Normal weight". Gender separate charts of BMI-for-age categorizations can be found in Appendix 2 (page 80).

5.7.6 Assessment of Demographic Background Information

Demographic background information, such as sex, age, and school location were derived from surveys. The children's ages (in years) were calculated based on their date of birth. For the question about sex, the only two possible outcomes were "Female" or "Male".

5.8 Statistical Analysis

The statistical analysis was conducted with the SPSS Statistics program (IBM SPSS Statistics for Mac, Version 27). Significance was set at $p < 0.05$ for all statistical analyses. Tables and graphs are used for visualizing data.

Descriptive statistics about selected variables were calculated as means ($\pm$SD), medians (with interquartile range (IQR)), numbers (n), and frequencies (%). To identify differences between boys and girls, independent two-sample t-Tests were conducted for continuous normal data. Mann-Whitney-U-Tests were used if variables were non-normally distributed within groups, and Pearson's chi-squared tests were used for categorical data. The assumption of normal distribution was checked through Kolmogorov-Smirnov tests and visual control of Q-Q plots. The plots were examined for how well the points lay on the diagonal and whether they were arranged in a pattern. Since Kolmogorov-Smirnov tests are sensitive to large sample sizes, controlling Q-Q plots was considered determinative.

5.8.1 Hypothesis 1

The relationship between PAQ-C scores and accelerometry-derived PA metrics was assessed using Spearman's rank correlation coefficients (ρ). Within this analysis, the accelerometer measurements were additionally compared to the individual PAQ-C items. Cohen's correlation guidelines were used to evaluate effect sizes: $|\rho| = 0.1$ small effect size, $|\rho| = 0.3$ medium effect size, $|\rho| = 0.5$ large effect size (Cohen, 1988).
A simple linear regression model was additionally conducted to examine the functional association between ActiGraph-measured minutes of MVPA per day and PAQ-C scores. The assumptions of normally distributed residuals and homoscedasticity (homogeneity of variances) were examined through Q-Q plot and Tukey-Anscombe-Plot (predicted values vs. standardized residuals) (see Appendix 4: Details on the Outcomes of the Statistical Analyses for Chapter 6.2). R^2 was used to assess effect sizes according to Cohen's guidelines: $R^2 < 0.02$ for very weak, $0.02 \leq R^2 < 0.13$ for weak, $0.13 \leq R^2 < 0.26$ for moderate, and $R^2 \geq 0.26$ for substantial effect size (Cohen, 1988).

5.8.2 Hypothesis 2

Bivariate and partial Pearson correlation coefficients were used to describe the associations of ActiGraph MVPA, sedentary time, and PAQ-C scores with BMI, BP, HbA1c, and BLP parameters. Partial correlations were adjusted for the influence of height, weight, sex, and age.

As an exception, the partial correlation with BMI was only controlled for sex and age. Since the BMI is calculated based on height and weight, it did not make sense to control for their impact. Cohen's correlation guidelines were used to evaluate effect sizes: $|r| = 0.1$ small effect size, $|r| = 0.3$ medium effect size, $|r| = 0.5$ large effect size (Cohen, 1988).

5.8.3 Hypothesis 3

Multivariable linear regression models (univariate analyses of variance = ANCOVAs) were conducted to further investigate the effect of PA on the selected CRMs and to compare the ability of ActiGraph MVPA and PAQ-C scores to explain variance of the CRMs. The assumption of normally distributed residuals and homoscedasticity (homogeneity of variances) were examined through Q-Q plots and Tukey-Anscombe-Plots (predicted values vs. standardized residuals). In cases where the assumptions were not considered fulfilled, bootstrapping with 1000 samples was applied and parameters were estimated with robust standard errors if necessary.

Apart from ActiGraph MVPA and PAQ-C score, the control variables height, weight, sex, and age were included in the ANCOVAs, so that their influence could be accounted for. Height and weight were not included in the ANCOVA model with BMI as the dependent variable, for the same reason as described in "5.8.2 Hypothesis 2". Partial eta squared (η_p^2) was used to assess the proportion of variance accounted for by each variable in the model. The following reference values were used to interpret partial eta squared: 0.01 for small effect size, 0.06 for medium effect size, and 0.14 for large effect size (Cohen, 1988).

5.9 Data Cleansing

After excluding 14 children due to not giving consent or leaving school, the study population consisted of 967 children (495 boys and 472 girls) between the ages of 8 and 16 years. 142 children were then excluded because of missing information in the PAQ-C and/or invalid data from the ActiGraph measurement. Another 202 children reported that they were experiencing some sort of illness that prevented them from doing normal physical activities in the PAQ-C and were therefore excluded. Due to missing data about height and/or weight, a further 27 children were excluded from the study sample. Lastly, 2 children were excluded for having an age outside the range of 8 to 13 years. Figure 5 gives an overview about the process of data cleaning.

The final study population included in the statistical analyses consisted of 594 children (302 boys and 292 girls) between the ages of 8 and 13 years. This sample still contained some children who were missing values in certain CRMs. Therefore, the number of learners included in the statistical analyses of CRMs varied. The exact number of participants included is indicated for all statistical procedures in chapter "6 Results".

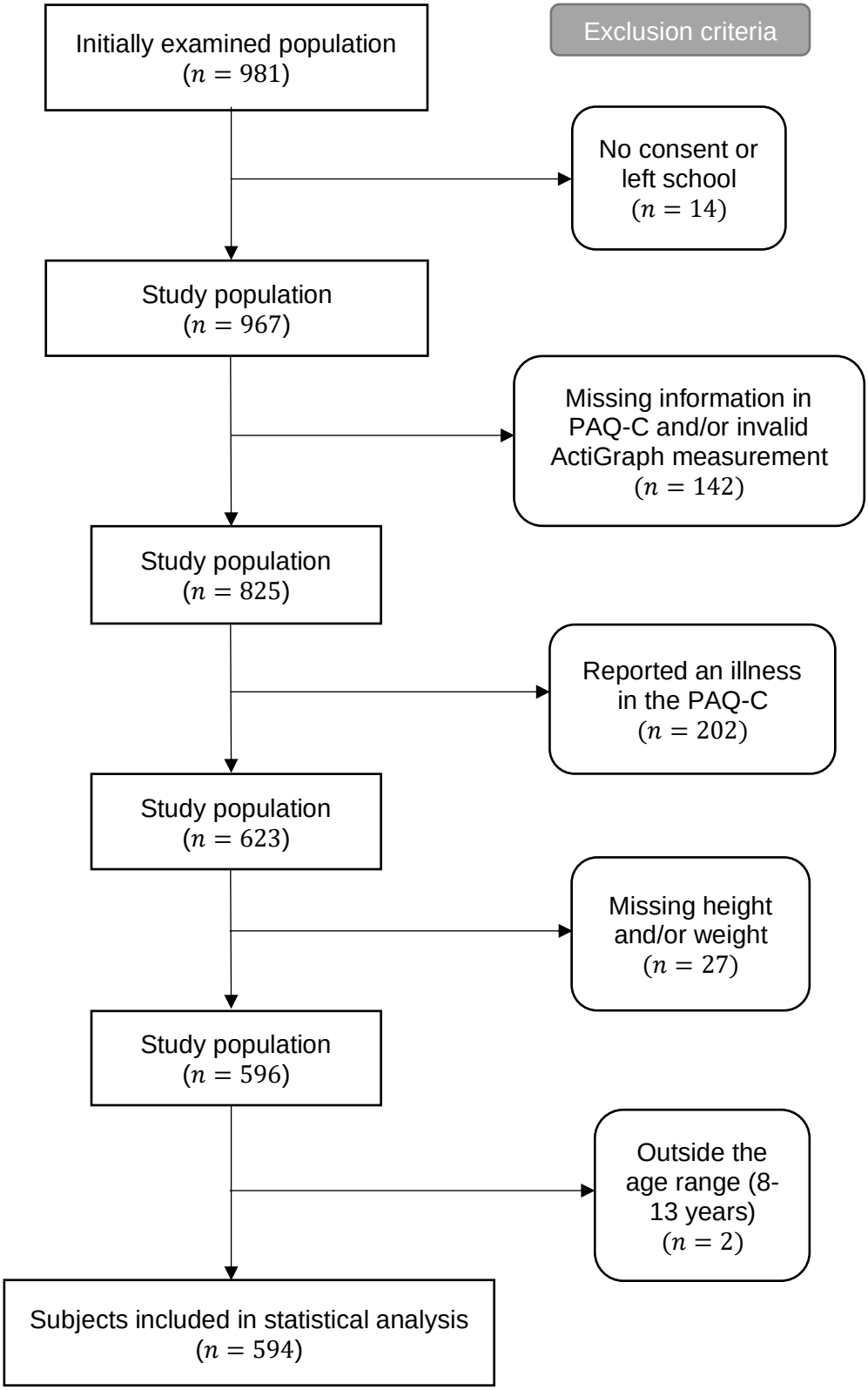

Figure 5: Process of Data Cleansing

6 Results

The findings from the statistical analyses are presented in this chapter. The analyses carried out aim to answer the following questions:

- How does the PAQ-C determine the amount of PA compared to accelerometer measurements (ActiGraph accelerometer) and how do the two methods correlate with each other in a population of South African school children from Gqeberha?
- How are both methods associated with BP, BMI, HbA1c, and BLP values, and which method performs better at explaining variability in these cardiovascular risk markers?

6.1 Descriptive Statistics

Characteristics of the overall and divided by sex study participants are presented in Table 3. The learners had an average height of 140 cm, median weight of 33.3 kg, and median BMI value of 17.15 kg/m^2. Approximately 1 in 4 participants was overweight or obese, indicating a higher proportion compared to national data (1 in 5) (Shisana et al., 2014). The usual BP among the learners amounted to 108/65.5 mmHg. On average, learners showed no signs of abnormal serum lipid and lipoprotein levels compared to normative data from Africa (Orimadegun, 2021). The mean overall HbA1c value of 5.4% was well below the 6.5% cut-off for diabetes, but higher than the 5.0% reference value from Germany and the Netherlands for children around 10 years of age (Hovestadt et al., 2021; Jansen et al., 2015).

There were significant between-sex differences among the study participants. Female learners were slightly taller and weighed more than their male counterparts. The proportion of overweight or obese individuals was higher in girls than in boys (33.2% vs. 19.5%). SBP and DBP were also higher in girls than in boys. In the BLP, girls showed higher values for TG, TC, Non-HDL, and TC/HDL. No significant sex-specific differences were found in LDL and HDL values. HbA1c concentrations also did not differ between the sexes.

Table 3: Sample Characteristics Stratified by Sex.

	All	**Boys**	**Girls**	***p*-value[a]**
Anthropometrics				
	N = 594	N = 302	N = 292	
Age (8/9/10/11/12/13)	16 / 119 / 185 / 161 / 90 / 23	5 / 57 / 84 / 82 / 59 / 15	11 / 62 / 101 / 79 / 31 / 8	**0.011***
Height (cm)	140.0 ± 8.9	139.3 ± 8.8	140.8 ± 9.0	**0.044***
Weight (kg)	33.3 (28.9 – 39.6)	32.1 (28.3 – 37.1)	35.5 (29.9 – 42.1)	**0.000****
BMI (kg/m^2)	17.2 (15.6 – 19.2)	16.7 (15.4 – 18.2)	17.8 (15.8 – 20.3)	**0.000****
Weight status (Thin/Normal/ Overweight/Obese)	20 / 419 / 90 / 65	13 / 231 / 34 / 24	7 / 188 / 56 / 41	**0.002****

Blood pressure				
	N = 585	N = 294	N = 291	
SBP (mmHg)	108.0 (99.0 - 116.0)	106.3 (98.0 - 115.5)	109.0 (99.5 - 117.0)	**0.026***
DBP (mmHg)	65.5 (60.5 - 71.5)	64.5 (59.5 - 70.0)	66.5 (61.5 - 72.5)	**0.017***
Blood lipid profile				
	N = 498	N = 250	N = 248	
TG (mmol/l)	0.77 (0.62 - 1.02)	0.71 (0.57 - 0.94)	0.86 (0.69 - 1.17)	**0.000****
TC (mmol/l)	3.74 ± 0.66	3.68 ± 0.69	3.81 ± 0.62	**0.035***
LDL (mmol/l)	2.03 ± 0.54	2.00 ± 0.56	2.06 ± 0.52	0.161
HDL (mmol/l)	1.30 ± 0.30	1.32 ± 0.32	1.28 ± 0.29	0.087
Non-HDL (mmol/l)	2.44 ± 0.57	2.36 ± 0.58	2.53 ± 0.54	**0.001****
TC/HDL (ratio)	2.9 (2.5 - 3.3)	2.8 (2.4 - 3.2)	3.0 (2.7 - 3.5)	**0.000****
Blood sugar				
	N = 506	N = 253	N = 253	
HbA1c (%)	5.4 ± 0.2	5.4 ± 0.2	5.4 ± 0.2	0.555

Annotation. Data are mean ± SD, median (IQR), or number; * $p < .05$; ** $p < .01$; [a] Between-sex differences assessed by independent two-sample t-Test, Mann-Whitney-U-Test, or Pearson's chi-squared test; Body mass index (BMI); Systolic blood pressure (SBP); Diastolic blood pressure (DBP); Triglycerides (TG); Total cholesterol (TC); Low-density lipoprotein (LDL); High-density lipoprotein (HDL); Difference between TC and HDL (Non-HDL); Ratio between TC and HDL (TC/HDL); Glycated hemoglobin (HbA1c)

More details on the outcomes of the statistical analyses of this chapter can be found in Appendix 3 (page 81).

6.2 Results for Hypothesis 1

Hypothesis 1: *The PAQ-C and accelerometer measurements of PA are associated.*

6.2.1 Descriptive Statistics About Physical Activity Measurements

PA metrics of the overall and divided by sex study participants are shown in Table 4. The mean PAQ-C score of 2.91 (±0.77) is in line with what one would expect for this age group (Marasso et al., 2021). With an overall median of 62.2, and a skewed mean of 65.2 minutes of MVPA per day, 53.5% of learners achieved the recommended minimum of 60 minutes of MVPA per day. Overall, study participants spent approximately 71.3% of their daily time in SB, 23.1% in LPA, 3.8% in MPA, and 1.5% in VPA.

Boys were more active than girls, as indicated by both questionnaire and accelerometer. Boys reported higher mean PAQ-C scores than girls (3.03 vs. 2.79) and they also spent less time engaging in SB and more time in moderate- and vigorous-intensity activities. 73% of boys achieved the WHO recommendation for PA, while only 33% of girls met the recommendation.

Table 4: Physical Activity Measurements of Study Participants Stratified by Sex.

	All (N = 594)	**Boys** (N = 302)	**Girls** (N = 292)	***p*-value[a]**
PAQ-C				
Mean score (1-5)	2.91 ± 0.77	3.03 ± 0.77	2.79 ± 0.75	**0.000****
ActiGraph				
Sedentary Time (%)	71.3 ± 4.8	70.2 ± 4.7	72.4 ± 4.7	**0.000****
Light Activity Time (%)	23.1 ± 3.5	23.3± 3.4	22.9 ± 2.6	0.230
Moderate Activity Time (%)	3.8 (2.9 – 4.7)	4.3 (3.5 – 5.2)	3.3 (2.6 – 4.0)	**0.000****
Vigorous Activity Time (%)	1.5 (1.0 – 2.2)	2.0 (1.4 – 2.8)	1.2 (0.9 – 1.6)	**0.000****
Average MVPA (min/day)	62.2 (46.6 – 79.1)	73.6 (58.1 – 92.0)	50.6 (39.6 – 64.9)	**0.000****
Total PA (min)	2574 ± 478	2701 ± 477	2443 ± 443	**0.000****
Meets PA Guidelines (Y/N)	318 / 276	221 / 81	97 / 195	**0.000****

Annotation. Data are mean ± SD, median (IQR), or number; * $p < .05$; ** $p < .01$; [a] Between-sex differences assessed by independent two-sample t-Test, Mann-Whitney-U-Test, or Pearson's chi-squared test; Physical Activity Questionnaire for Older Children (PAQ-C); Moderate- to vigorous-intensity physical activity (MVPA); Physical activity (PA); More than or equal to (Y), or less than (N) 60 minutes of moderate to vigorous physical activity per day (PA Guidelines)

6.2.2 Results of the Correlation Analysis

There were significant associations between PAQ-C scores, its individual questions, and PA metrics measured by the ActiGraph accelerometer (Table 5). However, the associations had a small effect size ($\rho = 0.09 - 0.16$).

PAQ-C scores were significantly associated with average minutes of MVPA per day ($\rho = 0.13$, $p = 0.002$). PAQ-C scores also correlated with the percentage of time spent engaging in moderate- and vigorous-intensity activities ($\rho = 0.12;\ 0.13$). However, they were not significantly associated with time spent engaging in SB or LPA. The amount of total PA also did not correlate with PAQ-C scores. Regarding the individual questions of the PAQ-C, items 3, 6, and 7 showed significant associations with ActiGraph measurements, particularly with MVPA measurements. Items 2 and 8 were not significantly correlated to any accelerometry

metric. The percentage of time spent in SB or LPA did not significantly correlate with any PAQ-C item.
Overall, it is noticeable that most of the significant correlations of PAQ-C scores and its items were found with accelerometry-derived measurements of MVPA, rather than SB, LPA, or total PA.

Table 5: Spearman Rank Correlations Between PAQ-C (items and total score) and ActiGraph Measurements of PA. (N = 594)

	Correlations (Spearman's rho)					
	Average MVPA (min/day)	Sedentary Time (%)	Light Activity Time (%)	Moderate Activity Time (%)	Vigorous Activity Time (%)	Total PA (min)
PAQ-C						
Q2 – PE	-0.009	-0.006	0.022	0.014	-0.006	-0.031
Q3 – Break	**0.122****	-0.044	-0.011	**0.093***	**0.156****	0.053
Q4 – Lunch	0.065	0.023	-0.078	0.066	**0.087***	-0.041
Q5 – After School	**0.090***	-0.066	0.052	0.077	0.065	**0.091***
Q6 – Evening	**0.143****	-0.021	-0.046	**0.126****	**0.127****	0.037
Q7 – Weekend	**0.111****	-0.025	-0.033	**0.102***	**0.103***	0.074
Q8 – 7 Days	0.041	0.009	-0.028	0.018	0.056	0.010
Total score	**0.130****	-0.031	-0.029	**0.119****	**0.134****	0.044

Annotation. * $p < .05$; ** $p < .01$; Moderate- to vigorous-intensity physical activity (MVPA); Physical activity (PA); Physical Activity Questionnaire for Older Children (PAQ-C); Question of the PAQ-C about activity: during physical education classes (Q2 – PE), at recess (Q3 – Break), at lunch (Q4 – Lunch), after school (Q5 – After School), in the evening (Q6 – Evening), on the weekend (Q7 – Weekend), frequency during the last 7 days (Q8 – 7 Days)

The association between ActiGraph-measured minutes of MVPA per day and overall PAQ-C scores is illustrated in a scatterplot (Figure 6). To give a clearer and less cluttered presentation of the association, it is additionally illustrated in a line chart where the average minutes of daily MVPA are grouped into quintiles (Figure 7).

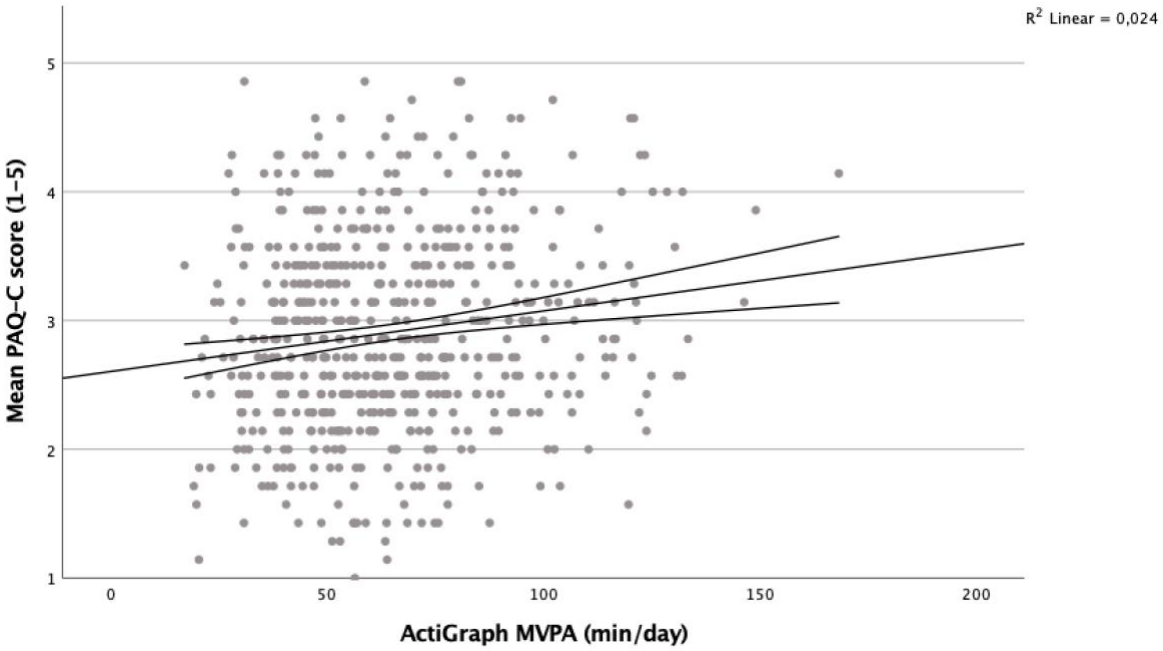

Figure 6: Scatterplot with Trend Line (and Confidence Interval) for the Relationship Between ActiGraph-measured Minutes of MVPA per Day and Mean PAQ-C Scores.

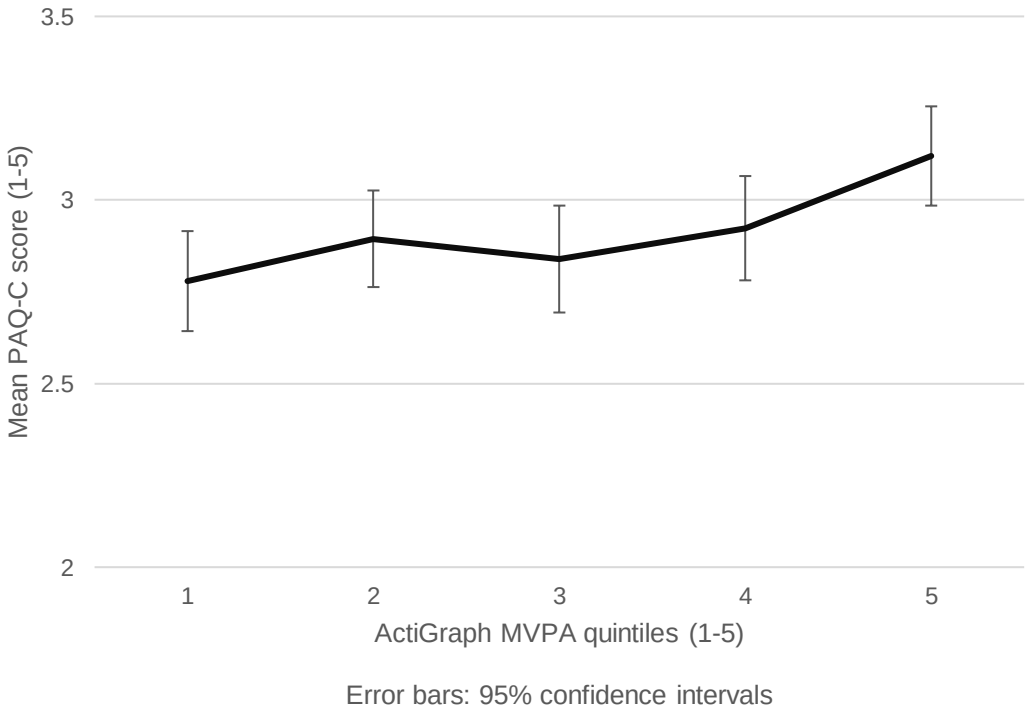

Figure 7: Line Chart for the Relationship Between ActiGraph-measured Minutes of MVPA per Day and Mean PAQ-C Scores.

6.2.3 Results of the Linear Regression Analysis

In addition to the correlation analysis, a linear regression analysis was conducted, with ActiGraph MVPA as the predictor of PAQ-C score (Table 6). Strong evidence was found that average daily MVPA, measured by ActiGraph, has a positive functional relationship with PAQ-C scores ($F(1, 592) = 14.43,\ p < 0.001$). Results showed that Actigraph MVPA significantly predicts PAQ-C scores with a regression coefficient of $\beta = 0.005$ $(95\% - CI\colon\ 0.002;\ 0.007,$ $p = 0.001)$. Thus, an increase of 10 minutes of MVPA per day was associated with an increase of 0.05 points in PAQ-C score.

The ActiGraph-measured minutes of MVPA per day explained 2.4% of the variance of PAQ-C scores $(R^2 = 0.024)$, which indicates a weak explanation ability. This weak explanatory power can also be seen in Figure 6, where the data points substantially scatter around the fitted regression line.

Table 6: Results of the Linear Regression Model with ActiGraph MVPA as the Predictor of PAQ-C Scores.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,154[a]	0.024	0.022	0.7582252

a. Predictors: (Constant), ActiGraph MVPA (min/day)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	8.294	1	8.294	14.427	,000[b]
	Residual	340.344	592	0.575		
	Total	348.638	593			

a. Dependent Variable: PAQ-C score (1-5)

b. Predictors: (Constant), ActiGraph MVPA (min/day)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	2.604	0.086		30.121	0.000	2.435	2.774
	ActiGraph MVPA (min/day)	0.005	0.001	0.154	3.798	0.000	0.002	0.007

a. Dependent Variable: PAQ-C score (1-5)

Annotation. Moderate- to vigorous-intensity physical activity (MVPA); Physical Activity Questionnaire for Older Children (PAQ-C)

More details on the outcomes of the statistical analyses of this chapter can be found in Appendix 4 (page 83).

6.3 Results for Hypothesis 2

Hypothesis 2: *Selected CRMs are associated with PAQ-C scores and accelerometer measurements of PA.*

6.3.1 Results of the Correlation Analysis

There were significant associations between selected CRMs and PA metrics measured by PAQ-C and ActiGraph (Table 7). These associations had a small to medium effect size ($|r| = 0.09 - 0.27$). PAQ-C scores were inversely correlated with BMI, SBP, and DBP. ActiGraph MVPA correlated inversely with BMI, SBP, TG, Non-HDL, and the TC/HDL ratio. The time spent engaging in SB, as measured by ActiGraph, was positively associated with TC, LDL, Non-HDL, and the TC/HDL ratio. The strongest association was found between BMI and ActiGraph MVPA ($r = -0.27$). It is graphically presented in Figure 8. HDL and HbA1c did not correlate with PAQ-C score, ActiGraph MVPA, or time spent in SB.

Table 7: Pearson Correlations Between Cardiovascular Risk Markers and Physical Activity Measurements.

		Correlations (Pearson Correlation)		
		PAQ-C score (1-5)	ActiGraph MVPA (min/day)	Sedentary Time (%)
BMI (kg/m^2)	N = 594	**-0.109****	**-0.266****	0.059
SBP (mmHg)	N = 585	**-0.120****	**-0.084***	0.013
DBP (mmHg)	N = 585	**-0.092***	-0.076	0.010
TC (mmol/l)	N = 498	0.061	-0.050	**0.111***
LDL (mmol/l)	N = 492	0.033	-0.047	**0.116***
HDL (mmol/l)	N = 498	0.072	0.087	-0.018
TG (mmol/l)	N = 498	0.037	**-0.116***	0.056
Non-HDL (mmol/l)	N = 498	0.033	**-0.104***	**0.138****
TC/HDL (ratio)	N = 498	-0.022	**-0.128****	**0.100***
HbA1c (%)	N = 506	0.031	0.034	-0.033

Annotation. * $p < .05$; ** $p < .01$; Physical Activity Questionnaire for Older Children (PAQ-C); Moderate- to vigorous-intensity physical activity (MVPA); Body mass index (BMI); Systolic blood pressure (SBP); Diastolic blood pressure (DBP); Total cholesterol (TC); Low-density lipoprotein (LDL); High-density lipoprotein (HDL); Triglycerides (TG); Difference between TC and HDL (Non-HDL); Ratio between TC and HDL (TC/HDL); Glycated hemoglobin (HbA1c)

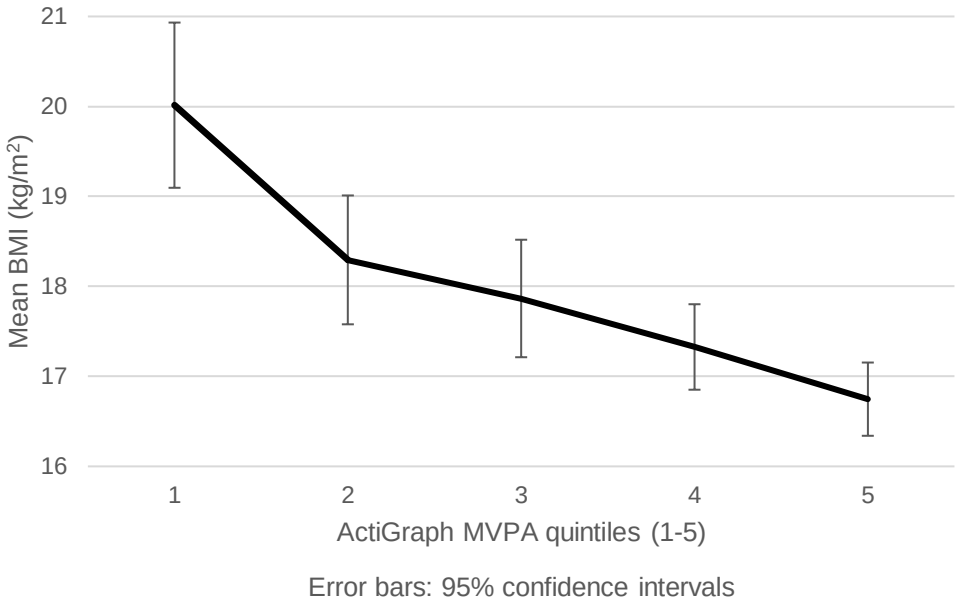

Figure 8: Line Chart for the Relationship Between BMI and Daily Minutes of MVPA Measured by ActiGraph.

6.3.2 Results of the Partial Correlation Analysis

The partial correlation analysis was conducted to account for the influence of different control variables. Table 8 and Table 9 show the adjusted correlations between selected CRMs and PA levels measured by PAQ-C and ActiGraph. After adjusting for sex, age, height, and weight, PAQ-C scores only correlated significantly with SBP. The effect size of this association was small $(partial\, r = -0.09,\ p = 0.035)$. ActiGraph MVPA remained significantly and inversely associated with BMI after controlling for sex and age (Table 9), and the strength of the relationship was weak to medium $(partial\, r = -0.20,\ p < 0.001)$. The time spent with SB remained positively correlated with TC, LDL, and Non-HDL after controlling for sex, age, height, and weight. The strength of these associations was weak $(partial\, r = 0.10 - 0.13)$.

Table 8: Partial Correlations Between Cardiovascular Risk Markers (Without Body Mass Index) and Physical Activity Measurements.

		Partial Correlations Control variables: Sex, age, height, weight		
		PAQ-C score (1-5)	ActiGraph MVPA (min/day)	Sedentary Time (%)
SBP (mmHg)	N = 579	**-0.088***	0.013	-0.036
DBP (mmHg)	N = 579	-0.064	0.006	-0.015
TC (mmol/l)	N = 492	0.078	-0.005	**0.104***
LDL (mmol/l)	N = 486	0.047	-0.013	**0.129****
HDL (mmol/l)	N = 492	0.049	0.028	0.002

TG (mmol/l)	N = 492	0.085	0.005	-0.024
Non-HDL (mmol/l)	N = 492	0.065	-0.021	**0.121****
TC/HDL (ratio)	N = 492	0.021	-0.018	0.075
HbA1c (%)	N = 506	0.038	0.047	-0.041

Annotation. * $p < .05$; ** $p < .01$; Physical Activity Questionnaire for Older Children (PAQ-C); Moderate- to vigorous-intensity physical activity (MVPA); Systolic blood pressure (SBP); Diastolic blood pressure (DBP); Total cholesterol (TC); Low-density lipoprotein (LDL); High-density lipoprotein (HDL); Triglycerides (TG); Difference between TC and HDL (Non-HDL); Ratio between TC and HDL (TC/HDL); Glycated hemoglobin (HbA1c)

Table 9: Partial Correlations Between Body Mass Index and Physical Activity Measurements.

		Partial Correlations Control variables: Sex, age		
		PAQ-C score (1-5)	ActiGraph MVPA (min/day)	Sedentary Time (%)
BMI (kg/m^2)	N = 590	-0.077	**-0.200****	-0.013

Annotation. * $p < .05$; ** $p < .01$; Physical Activity Questionnaire for Older Children (PAQ-C); Moderate- to vigorous-intensity physical activity (MVPA); Body mass index (BMI)

More details (i.e., exact significances) on the outcomes of the statistical analyses of this chapter can be found in Appendix 5 (page 86).

6.4 Results for Hypothesis 3

Hypothesis 3: *Accelerometer-measured minutes of MVPA per day are better able to explain variability within BP, BMI, HbA1c, and BLP parameters than PAQ-C scores.*

6.4.1 Results of the Multivariable Linear Regression Models (ANCOVAs)

Results of the ANCOVAs showed that while controlling for confounders, PAQ-C scores significantly predicted SBP ($\beta = -1.53,\ 95\% - CI: -2.91; -0.14,\ p = 0.031$) and ActiGraph-measured minutes of MVPA significantly predicted BMI ($\beta = -0.03,\ 95\% - CI: -0.05; -0.02,\ p = 0.001$) (Table 10 and Table 11). The other selected CRMs were not significantly affected by PAQ-C scores or ActiGraph MVPA. The proportions of variance of CRMs explained by PAQ-C scores and ActiGraph MVPA were very small or negligible ($\eta_p^2 = 0.00 - 0.04$). The greatest explanatory power was found between ActiGraph MVPA and BMI, where the effect size was still small to medium however ($\eta_p^2 = 0.04$). Although the effect sizes were small, PAQ-C scores explained a greater proportion of variance for SBP, DBP, TC, LDL, HDL, TG, and Non-HDL compared to ActiGraph MVPA. On the other hand, ActiGraph MVPA explained a greater portion of variance for BMI and HbA1c.

The regression models also showed that weight had the greatest impact on SBP, DBP, HbA1c, HDL, Non-HDL, and TC/HDL compared to the other predictor variables in the models, as indicated by partial eta squared.

Table 10: Results of the Multivariable Linear Regression Model with Systolic Blood Pressure as Dependent Variable. (N = 585)

Tests of Between-Subjects Effects

Dependent Variable:	SBP					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected model	10346,894[a]	6	1724.482	10.408	0.000	0.098
Intercept	18081.777	1	18081.777	109.127	0.000	0.159
PAQ-C score	777.960	1	777.960	4.695	0.031	0.008
ActiGraph MVPA	45.644	1	45.644	0.275	0.600	0.000
Height	164.752	1	164.752	0.994	0.319	0.002
Weight	5126.976	1	5126.976	30.942	0.000	0.051
Age	110.334	1	110.334	0.666	0.415	0.001
Sex	171.242	1	171.242	1.033	0.310	0.002
Error	95771.204	578	165.694			
Total	7029823.750	585				
Corrected Total	106118.098	584				

a. R Squared = ,098 (Adjusted R Squared = ,088)

Parameter Estimates

Dependent Variable:	SBP						
Parameter	B	Std. Error	t	Sig.	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Intercept	106.954	10.146	10.542	0.000	87.027	126.882	0.161
PAQ-C score	-1.525	0.704	-2.167	0.031	-2.907	-0.143	0.008
ActiGraph MVPA	0.013	0.024	0.525	0.600	-0.035	0.061	0.000
Height	-0.095	0.095	-0.997	0.319	-0.281	0.092	0.002
Weight	0.401	0.072	5.563	0.000	0.259	0.542	0.051
Age	0.477	0.584	0.816	0.415	-0.671	1.624	0.001
[Sex=male]	-1.252	1.232	-1.017	0.310	-3.671	1.167	0.002
[Sex=female]	0[a]						

a. This parameter is set to zero because it is redundant.

Annotation. Systolic blood pressure (SBP); Physical Activity Questionnaire for Older Children (PAQ-C); Moderate- to vigorous-intensity physical activity (MVPA); Body mass index (BMI)

Table 11: Results of the Multivariable Linear Regression Model with Body Mass Index as Dependent Variable. (N = 594)

Tests of Between-Subjects Effects

Dependent Variable:	BMI					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected model	876,145[a]	4	219.036	16.926	0.000	0.103
Intercept	1362.129	1	1362.129	105.257	0.000	0.152
PAQ-C score	26.774	1	26.774	2.069	0.151	0.004
ActiGraph MVPA	297.902	1	297.902	23.020	0.000	0.038
Age	187.416	1	187.416	14.482	0.000	0.024
Sex	76.022	1	76.022	5.875	0.016	0.010
Error	7622.257	589	12.941			
Total	202072.020	594				
Corrected Total	8498.402	593				

a. R Squared = ,103 (Adjusted R Squared = ,097)

Bootstrap for Parameter Estimates

Dependent Variable:	BMI					
Parameter	B	Bootstrap[a]				
		Bias	Std. Error	Sig. (2-tailed)	BCa 95% Confidence Interval	
					Lower	Upper
Intercept	16.253	-0.045	1.463	0.001	13.569	18.952
PAQ-C score	-0.282	0.007	0.216	0.186	-0.715	0.159
ActiGraph MVPA	-0.032	-5.365E-05	0.006	0.001	-0.045	-0.020
Age	0.490	0.002	0.128	0.001	0.241	0.733
[Sex=male]	-0.816	0.005	0.339	0.019	-1.467	-0.121
[Sex=female]	0	0	0			

a. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Annotation. Body mass index (BMI); Physical Activity Questionnaire for Older Children (PAQ-C); Moderate- to vigorous-intensity physical activity (MVPA); Body mass index (BMI)

The results of the ANCOVAs with DBP, HbA1c, TC, LDL, HDL, TG, Non-HDL, and TC/HDL as dependent variable can be found in Appendix 6 (page 88).

7 Discussion

In this chapter, the results and findings are discussed in consideration of the hypotheses made and the questions to be answered. Different assumptions are made in an approach to understand the relationships between ActiGraph-measurements, PAQ-C scores, and CRMs in the study population.

Key findings

PAQ-C scores were positively associated with ActiGraph-measured MVPA, but not with SB, LPA, or total PA. Self-reported activity levels at recess, in the evenings, and over the weekends seem to be better indicators of accelerometer-measured MVPA than self-reported activity levels at other time periods of the week. ActiGraph MVPA was inversely associated with BMI, and higher levels of SB were related to increasing TC, LDL, and Non-HDL concentrations. PAQ-C scores correlated inversely with SBP. The proportions of variance of CRMs explained by PAQ-C scores and ActiGraph-measured MVPA were very small or even negligible. Excess weight seems to play a particularly important role in CVD risk due to its association with other CRMs.

7.1 Hypothesis 1

The PAQ-C and accelerometer measurements of PA are associated.

- *PAQ-C scores are positively correlated with ActiGraph measurements of MVPA and total PA. They are inversely correlated with ActiGraph measurements of SB.*
- *PAQ-C item scores are positively correlated with ActiGraph measurements of MVPA and total PA. They are inversely correlated with ActiGraph measurements of SB.*

7.1.1 PAQ-C Total Scores and ActiGraph Measurements

As expected, PAQ-C scores correlated significantly with ActiGraph-measured MVPA levels. Thus, children rating themselves as more physically active in the PAQ-C tended to achieve higher levels of MVPA measured by accelerometer. However, the overall numbers indicate that the strength of the relationship between the two PA measurement methods is small. Based on the low correlation coefficient and the weak explanatory power, it can be argued that a lack of agreement between PAQ-C scores and the ActiGraph as methods for assessing PA levels in pediatric populations has been found. There is a great deal of uncertainty when attempting to derive children's objective MVPA levels from their PAQ-C scores, and vice versa.

These findings are in line with the results from other studies questioning the convergent validity of the PAQ-C (Benítez-Porres et al., 2016; Ben Jemaa et al., 2018; Chan et al., 2019). The extensive 2021 meta-analysis by Marasso and colleagues identified a moderate pooled correlation coefficient of $r = 0.34$ between the PAQ-C and accelerometer measurements, while also reporting wide correlation variability in the studies included. The low correlation coefficient of $r = 0.14$ observed in this master's thesis is significantly lower than $r = 0.34$ and

contributes to the notion that the PAQ-C and accelerometers have an inconsistent agreement for measuring MVPA (the initial $\rho = 0.13$ Spearman coefficient from the correlation analysis was converted into an estimated Pearson correlation coefficient of $r = 0.14$ by using the formula $r = 2\sin(\rho\frac{\pi}{6})$ (Rupinski & Dunlap, 1996)). In order to fulfill qualitative standards of a PA questionnaire, it has been proposed that the PAQ-C should achieve a correlation coefficient of $r \geq 0.50$ with accelerometer-measured MVPA (Terwee et al., 2010). However, Ham and colleagues pointed out that the association between the two methods is likely not to exceed moderate strength (Ham et al., 2007), and because children's ability to recall PA time is limited, it has been recommended to regard moderate correlation coefficients to resemble high validity for the PAQ-C (Biddle et al., 2011).

Further, the findings showed that despite PAQ-C scores correlating significantly with accelerometer-measured MVPA levels, they were not associated with total minutes of PA, the time spent in LPA, or the time spent engaging in SB. A significant inverse association between PAQ-C scores and the time spent engaging in SB, as reported by Voss et al. in 2017, was therefore not confirmed by the results of this study. This demonstrates that PAQ-C scores contain information about PA spent in moderate or vigorous intensity, but no clear picture can be drawn from the scores for estimating the time spent in other PA intensities. However, since the goal of the PAQ-C is to estimate MVPA levels, associations with other PA intensities (i.e., SB and LPA) would only be a bonus and should not be considered a necessity.

Differences between self-reported PA levels using the PAQ-C and accelerometer-measured PA can be interpreted as children's difficulties in assessing their own PA habits. It has been observed that memory errors play an important role particularly when dealing with children (Sirard & Pate, 2001). Another factor potentially contributing to discrepancies is the social desirability bias, whereby study participants report higher PA levels in order to be viewed favorably by others. Moreover, differences might stem from the ActiGraph not being able to capture water activities such as swimming or from failing to accurately measure activities with little upper body movement such as cycling. Previous studies have also pointed out that the PAQ-C and accelerometry do not actually measure the same construct (Ham et al., 2007). Accelerometers measure exact duration, frequency, and intensity of body movement, while the PAQ-C can provide information about self-perceived PA engagement, activity types, and the weekly distribution of PA. Therefore, the PAQ-C can be seen as a method to assess PA behaviors (i.e., type and timing of PA) rather than absolute PA (Marasso et al., 2021). Furthermore, the PAQ-C inquires the subjective frequency spent in PA, which is a different unit of measure compared to accelerometry (Benítez-Porres et al., 2016).

Simultaneous use of PAQ-C and accelerometer could allow for both a qualitative and quantitative assessment of PA, which provides for a more comprehensive study of the relationship between self-perceived and actual PA. One advantage of the PAQ-C over accelerometers is its ability to determine at what time periods of the week children are active and what types of activities they are engaged in (item 1, activity checklist). In light of this context, it could be recommended to use the PAQ-C for obtaining information about the type and the time framing of PA to get an estimate of children's habitual PA, while accelerometers could deliver data about the quantification of PA. This way, customized PA recommendations

can be made. For example, if a child reports many hours of playing handball per week (PAQ-C), but the accelerometer reveals low levels of MVPA, then it could be advised to increase engagement during handball training and games.

7.1.2 PAQ-C Item Scores and ActiGraph Measurements

Regarding the individual PAQ-C questions (2 – 8), the scores of items 3, 6, and 7 were associated with all ActiGraph-measurements of MVPA. Items 3, 6, and 7 cover the PA behavior at recess, in the evenings, and over the weekends. It appears that these three questions provide particularly good self-reported indicators of MVPA levels compared to the other four questions. Therefore, it could be argued that the self-reported PA behavior at recess, in the evenings, and over the weekends is more indicative of general MVPA levels than self-reported PA behavior at other time periods of the week. Items 2, 4, and 8 did not show an association with accelerometer-measured MVPA levels. They enquire the PA behavior at lunch, during PE, and the frequency of PA during the seven days prior to filling out the questionnaire. Self-reported PA behavior right after school (item 5) correlated weakly with daily minutes of MVPA, but not with the percentage of time spent engaging in moderate or vigorous PA.
These findings seem plausible since recess, evenings, and especially weekends are fairly large time windows of the week when much time can be spent engaging in PA. Therefore, children reporting higher levels of PA for these time periods likely accumulate more MVPA detectable by ActiGraph. Children who are members of a sports club presumably accumulate a lot of MVPA in the evenings, during training sessions, and over the weekends, during competitions. Lunch time, PE classes, and the time right after school represent shorter time windows where a limited amount of PA can be accumulated. Therefore, a child reporting high levels of PA during (e.g.) PE classes might still achieve low levels of ActiGraph-measured MVPA if it engages in SB all weekend.
Like overall PAQ-C scores, none of the PAQ-C items were associated with the time spent in SB or LPA.

Significant correlation coefficients between accelerometer-measured MVPA and the scores of items 3, 6, and 7 have previously been found in other studies (Benítez-Porres et al., 2016; Venetsanou et al., 2020; Voss et al., 2017). However, these studies have additionally found associations with other items, which were not verified in this master's thesis. Item 9, which asks about the weekly distribution and frequency of PA, has consistently been shown to correlate with accelerometry-derived MVPA. Unfortunately, this item was omitted from the questionnaire for the study participants of this master's thesis. Possibly, the inclusion of item 9 could have resulted in a stronger association between PAQ-C scores and ActiGraph MVPA.

7.2 Hypothesis 2

Selected CRMs are associated with PAQ-C scores and accelerometer measurements of PA.

- *PAQ-C scores and accelerometer measured minutes of MVPA per day are inversely associated with SBP, DBP, BMI, HbA1c, TC, TG, LDL, Non-HDL, and TC/HDL.*
- *PAQ-C scores and accelerometer measured minutes of MVPA per day are positively associated with HDL.*
- *The time spent engaging in SB is positively associated with SBP, DBP, BMI, HbA1c, TC, TG, LDL, Non-HDL, and TC/HDL.*
- *The time spent engaging in SB is inversely associated with HDL.*

There were significant associations between selected CRMs and PA measured by ActiGraph and PAQ-C. However, the strength of those associations was mostly weak, and the two PA assessment methods were inconsistent in detecting relationships with CRMs. Independent of sex and age, ActiGraph-measured MVPA, but not PAQ-C scores, was inversely related to BMI. With a correlation coefficient of $partial\, r = -0.20$, indicating a relationship of low to moderate effect size, this was the strongest association between a CRM and children's PA levels found in this study. Further, while adjusting for sex, age, height, and weight, PAQ-C scores were inversely and weakly associated with SBP. Spending more time engaging in SB was weakly related to increasing TC, LDL, and Non-HDL concentrations. DBP, TG, HDL, TC/HDL, and HbA1c were not associated with PAQ-C scores, ActiGraph MVPA, or the time spent engaging in SB.

Without controlling for confounders, PAQ-C scores were, in addition to SBP, related to BMI and DBP. SB was additionally associated with TC/HDL, and significant inverse correlations were also found between ActiGraph MVPA and SBP, TG, Non-HDL, and TC/HDL. All these associations became statistically insignificant after adjusting for the influence of confounders. The following discussion focuses on the associations that remained significant after controlling.

7.2.1 Body Mass Index and Physical Activity

Consistent with the current state of research, the findings showed that the more time children spend in MVPA each day, the lower their BMI. Increasing MVPA by 15 minutes per day was associated with a substantial BMI reduction of approximately -0.5 points (Table 11). However, as discussed in "Relationship Between Physical Activity and BMI", reverse causality cannot be ruled out; it is not clear whether increased MVPA was the reason for lower BMI or if individuals with higher BMI had difficulties performing MVPA. Nonetheless, it has been shown that it is likely that higher MVPA levels indeed cause a reduction of excess weight (Ness et al., 2007).

The significant association between accelerometer-measured MVPA and BMI found in this study demonstrates that PA, particularly MVPA, can be a crucial contributor to weight control already at young age. Overweight and obesity have serious health consequences and their

prevalence among children has become a growing concern, particularly in African regions (de Onis et al., 2010). The results of this study support the notion that encouraging PA in children plays a decisive role in lifelong obesity prevention. This is not as simple as it might seem, since the promotion of PA requires consideration of cultural, environmental, and financial aspects. PA should be well integrated into children's daily life. Schools and communities should provide a setting that encourages a physically active life such that PA patterns can be established for later in adulthood (M. Goran et al., 1999). The fact that in South Africa, PE lost its existence as a stand-alone school subject in 1997 and is now taught as part of the learning area "Life Orientation" seems to be a step in the wrong direction (Stroebel et al., 2016); PE classes must give way to other subjects within "Life Orientation", which signals a reduced importance of PE. Schools have been identified as key settings for promoting PA among children and adolescents (World Health Organization, 2004). For instance, it has been shown that appealing outdoor school environments can increase students' PA levels by increasing PA participation during breaks (Haug et al., 2010).

In contrast to ActiGraph MVPA, children's self-reported PA levels were not significantly related to BMI. Thus, learners who considered themselves as more active, did not exhibit lower BMI values. This situation underlines the fact that there exist differences between self-reported and accelerometer-measured PA levels and that they are inconsistent in detecting relationships with CRMs. More consistent associations with BMI for objectively measured PA than for self-reported PA have previously been reported and were attributed to self-report bias (Wanner et al., 2017).

Unexpectedly, the time spent in SB was also not associated with BMI in this study. This finding indicates that in order to lose weight, children should focus on being physically active with moderate to vigorous intensity, rather than trying to minimize the time they spend in SB. Wanner and colleagues obtained similar results in their study from 2017. They found that objectively measured PA was associated with BMI regardless of sedentary time, and that SB did not appear to be associated with overweight and obesity (Wanner et al., 2017). Katzmarzyk et al. also found that sedentary time was not related to obesity independent of MVPA. They emphasize that children should be encouraged to spend time in MVPA and VPA to promote a healthy body weight (Katzmarzyk et al., 2015). The lack of effect of SB on BMI may be explained by the fact that there is markedly less inter-child variation in SB than in other PA intensities (Talarico & Janssen, 2018). In the study population of this master's thesis, there was only a 25% difference between the time spent in SB at the 5^{th} versus 95^{th} percentile, while the corresponding value for MVPA was 277%.

7.2.2 Blood Lipid Profile and Physical Activity

However, the time spent engaging in SB does appear to influence BLPs. Independent of age, sex, height, and weight, higher levels of SB were associated with increased concentrations of TC, LDL, and Non-HDL. LDL and Non-HDL are of particular importance, since they represent the "bad" and harmful cholesterol which contributes to an increased risk of heart disease and developing atherosclerosis (Abdullah et al., 2018). Reducing LDL and Non-HDL concentrations is the main therapeutic goal for the risk-reduction of CVD (Toth et al., 2013).

The results of this study indicate that LDL and Non-HDL concentrations can be lowered by reducing the amount of time spent engaging in SB. These findings are consistent with results from other studies that observed positive associations between sedentary time and TC, LDL, and Non-HDL concentrations (Celis-Morales et al., 2012; Crichton & Alkerwi, 2015; Väistö et al., 2014).

In contrast to SB, ActiGraph MVPA and PAQ-C scores were not associated to any BLP parameter after adjusting for the influence of control variables. Regarding LDL and Non-HDL concentrations, it has been reported that the time spent engaging in SB is more robustly related to the "bad" cholesterol than time spent in MVPA, explaining the findings of this study (Celis-Morales et al., 2012). Furthermore, as mentioned in "Relationship Between Physical Activity and Blood Lipid Profile Parameters", it has been claimed that PA does not seem to significantly lower LDL and TC, independent of weight changes (Ahmed et al., 2012). However, higher levels of MVPA might still reduce CVD risk by increasing LDL particle size (Kraus et al., 2002). Unfortunately, particle sizes were not measured in this study.
The effect of MVPA on HDL and TG has been shown to be more promising and to occur even in the absence of weight loss (Carroll & Dudfield, 2004). However, a significant positive association between MVPA and HDL, and an inverse association between MVPA and TG, as has been observed in many previous studies, was unexpectedly not found in this study (Dancy et al., 2008; Ekelund et al., 2012). Although most studies have observed significant associations between MVPA and HDL and TG concentrations, data from the European Youth Heart Study also revealed non-significant relationships between the variables (Ekelund et al., 2007).
A significant effect of MVPA levels on the TC/HDL ratio also remained absent, contradicting the findings of Twisk and colleagues (Twisk et al., 2000).

Regarding the differences between SB and MVPA for their influence on BLP, it has been hypothesized that PA and SB have independent effects on lipoprotein metabolism, with PA more strongly affecting HDL, rather than LDL and Non-HDL, and SB affecting LDL and Non-HDL, rather than HDL (Aadland et al., 2013).

7.2.3 Blood Pressure and Physical Activity

In this study, DBP was not related to PAQ-C scores, ActiGraph MVPA, or the time spent engaging in SB. SBP was weakly and inversely associated with self-reported PA levels (PAQ-C scores), but not with ActiGraph MVPA levels or SB. A 1-point increase in PAQ-C score was associated with a reduction of SBP by -1.53 mmHg (Table 10).
These findings again demonstrate how different outcomes regarding the relationships between CRMs and PA can be obtained by using different PA measurement methods. Research has not shown that subjective PA measurements are more likely to identify a significant association with BP than objective PA measurements. On the contrary, failure to identify a significant association is believed to stem from estimating PA subjectively, rather than objectively (Lazarou et al., 2009). However, even studies using objective measurement methods have not always been able to find a relationship between PA and BP (Brage et al., 2004; Craig et al., 1996; Klesges et al., 1990). On the other hand, there are cross-sectional studies with large

sample sizes and objectively measured PA that did observe a significant inverse association (Andersen et al., 2011; Leary et al., 2008; Owen et al., 2010). The inconsistency of the findings on the relationship between PA and BP among children and adolescents may be explained by varying durations of PA measurement, a lack of consistency in methodology, and wide ranges of age groups included in the studies (Knowles et al., 2013). They may also stem from the influence of childhood adiposity. The strong association between excess weight and elevated BP among children and adolescents is well established (Din-Dzietham et al., 2007; Falkner et al., 2006; Sorof et al., 2004). Not adequately accounting for the mediating role of excess weight can lead to misinterpretations of the relationship between MVPA and BP. In one study for instance, it has been shown that adjusting the association for BMI was not sufficient; a significant relationship between MVPA and BP was observed, but, after more thorough evaluation, it was found that the association was only significant for children in the highest adiposity tertile. Furthermore, the study found that higher MVPA levels led to lower SBP and DBP only by decreases in waist circumference and sum of skinfolds (Lucena Filho et al., 2021). The effect of body composition on BP was also observable in this master's thesis; when not accounting for the influence of body weight and height, PAQ-C scores were, additionally to SBP, associated with DBP and ActiGraph MVPA was associated with SBP.
Another aspect that has been the subject of debate is the importance of total PA versus MVPA for the effect on BP. The findings of one study by Leary and colleagues suggest that the total amount of PA is of greater importance, while Hay and colleagues emphasize that VPA has a greater effect than LPA and MPA (Hay et al., 2012; Leary et al., 2008). It is sometimes also argued that PA effects BP only in children and adolescents with elevated BP (Baranowski et al., 1992).
Ultimately, since a clear association between PA and BP has been established in adults, a relationship in childhood and adolescents is highly plausible (Diaz & Shimbo, 2013). According to the findings of this study, an inverse association between MVPA and SBP in children exists, and it was identified by self-reported PA levels. This knowledge is valuable considering the great impact of elevated BP on CVD risk, and it contributes to the notion that MVPA should be encouraged as a means of preventing hypertension in childhood and adolescence (Asia Pacific Cohort Studies Collaboration, 2003).

The findings of this study showed no association between SB and BP. Previous studies have also often failed to demonstrate a relationship between SB and BP and it has been found that SB has a different effect on BP than PA (Ekelund et al., 2006, 2012; Hancox et al., 2004). A systematic review found that self-reported, but not accelerometer-measured time spent in SB was associated with BP (P. H. Lee & Wong, 2015). Similarly, another study found that accelerometer-measured SB did not correlate with BP, while children's parental-reported TV viewing and screen time was significantly associated with BP, demonstrating a lack of agreement between objectively and subjectively assessing SB (Martinez-Gomez et al., 2009).

7.2.4 Glycated Hemoglobin and Physical Activity

HbA1c was not associated with PAQ-C scores, ActiGraph MVPA levels, or time spent engaging in SB. As discussed in "Relationship Between Physical Activity and Glycated Hemoglobin", the favorable effects of PA on HbA1c have primarily been detected in studies

with participants diagnosed with high levels of HbA1c. Overall, the children of this study did not exhibit high levels of HbA1c, which might explain the lack of association between PA levels and HbA1c concentrations. The findings corroborate the results obtained by Jansen et al. and Hovestadt et al. (Hovestadt et al., 2021; Jansen et al., 2015). It seems that HbA1c concentrations are relatively unaffected by PA and SB in children and adolescents without diabetes. Furthermore, it has been claimed that PA has a greater influence on HbA1c in adulthood than in childhood. Therefore, interventions to lower HbA1c concentrations in children and adolescents should not be based on the same principles as interventions for adults (Hovestadt et al., 2021).

7.2.5 Meeting Guidelines on Physical Activity and Sedentary Behaviors

Overall, the magnitude of the associations between selected CRMs, MVPA and SB was small. However, SB significantly affected BLP parameters and increasing MVPA was related to reductions in BMI and SBP. The importance of PA in terms of cardiovascular health can also be observed when comparing learners meeting the WHO guidelines on PA and SB with learners who do not meet them (Appendix 7: Meeting Versus Not Meeting WHO Guidelines). Children accumulating at least 60 minutes of MVPA per day had lower SBP and DBP, and they also showed a favorable TC/HDL ratio and lower concentrations in TG and Non-HDL. 36.6% of learners not meeting the guidelines were overweight or obese, while only 17.0% were overweight or obese in the group of learners being sufficiently physically active (Figure 9). Furthermore, study participants engaging in less than 60 minutes of MVPA per day were four times as likely to be obese compared to their sufficiently active counterpart.

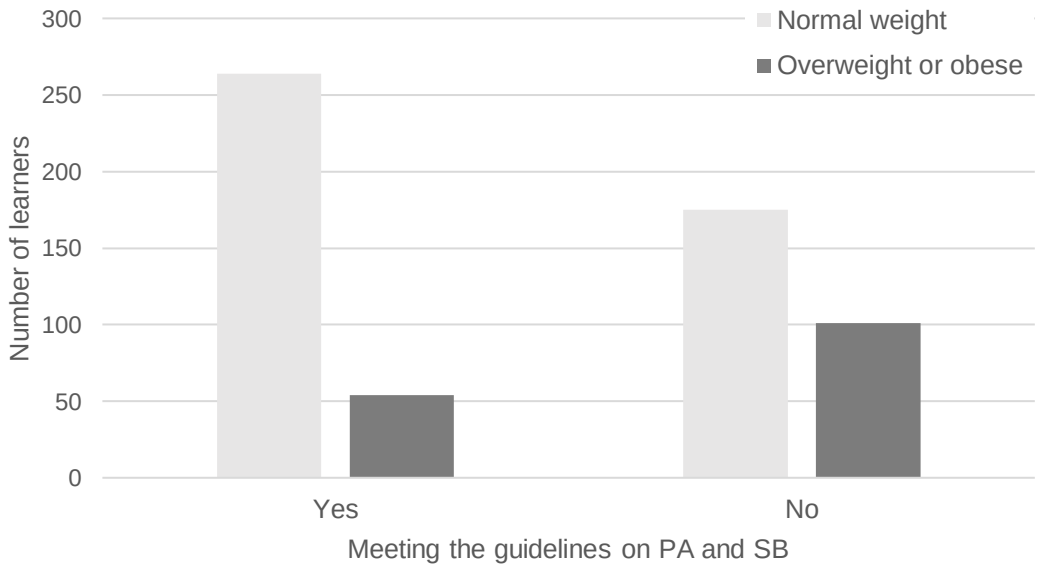

Figure 9: Bar Chart for the Number of Normal Weight versus Overweight or Obese Learners Separated by Meeting versus Not Meeting the WHO Guidelines on PA and SB

7.3 Hypothesis 3

- *Accelerometer-measured minutes of MVPA per day are better able to explain variability within BP, BMI, HbA1c, and BLP parameters than PAQ-C scores.*

ANCOVAs were conducted to further investigate the effect of PA on the selected CRMs and to compare the ability of ActiGraph MVPA and PAQ-C scores to explain variance of the CRMs. In comparison, PAQ-C scores explained a greater proportion of variance for SBP, DBP, TC, LDL, HDL, TG, and Non-HDL, while ActiGraph MVPA explained a greater proportion only for BMI and HbA1c. Therefore, the hypothesis was not confirmed.
However, the proportions of variance of CRMs explained by PAQ-C scores and ActiGraph-measured MVPA were very small or even negligible, indicating again that even the significant relationships were not very substantive. In the selected CRMs, the variance associated with PAQ-C scores did not exceed 0.8% and the variance associated with ActiGraph did not exceed 3.8%. Although PAQ-C scores were better able to explain variability for more parameters than ActiGraph MVPA, it is difficult to argue that the PAQ-C is actually the superior method for predicting those parameters. That is because for one, except for the association with SBP, PAQ-C scores were not significantly associated with the CRMs, and secondly, the effect sizes were very small. Therefore, it is difficult to refute that a substantial part of the ability to explain variance occurred due to random variations in the data. Furthermore, even though not significant, PAQ-C scores identified positive correlations with TC, LDL, TG, Non-HDL, TC/HDL, and HbA1c, indicating that increasing MVPA would result in deteriorated BLPs and HbA1c concentrations. These results are counterintuitive and do not seem to reflect the true state of relationship between PA and BLP and HbA1c based on the current state of literature. Therefore, the ability of PAQ-C scores to explain variance in these CRMs loses meaningfulness. The ActiGraph on the other hand, at least detected inverse (but also not significant) associations with TC, LDL, Non-HDL, and TC/HDL, indicating the identification of a more plausible relationship between PA and BLP parameters.
Finally, it can be claimed that neither of the two MVPA measurement methods is better than the other regarding the ability to explain variability in the selected CRMs and that the only considerable proportion of variance of a CRM was explained by ActiGraph MVPA (3.8% for BMI).

7.3.1 The Influence of Excess Weight on Cardiovascular Health

The ANCOVAs also revealed that overall, children's weight had the most important effect on the CRMs. Therefore, a partial correlation analysis for BMI was additionally conducted (Appendix 8: Partial Correlation Analysis for BMI) and it showed that BMI was significantly associated with SBP, DBP, LDL, HDL, TG, Non-HDL, and TC/HDL, even after adjusting for the influence of sex, age, PAQ-C score, ActiGraph MVPA, and time spent engaging in SB. Moreover, BMI was a great indicator of body fat percentage in this study population (Appendix 9: Relationship Between Body Mass Index and Body Fat Percentage).

Further analyses revealed that in contrast to BMI, BLP parameters, BP, and HbA1c were largely not associated with each other. These findings accentuate the role of BMI among the selected CRMs and proves that its effect on CVD risk is multifactorial; losing excess weight itself independently reduces CVD risk, and on top of that, lowering BMI results in reduced BP and favorable BLPs which has additional beneficial effects on CVD risk. The findings corroborate the current understanding that excess weight is related to BP and blood lipid concentrations in children and adolescents (Boyd et al., 2005; Jiang et al., 1995). Higher BMI values are associated with elevated BP values and an increased risk for dyslipidemia (Chorin et al., 2015; Expert Panel on Integrated Guidelines for Cardiovascular Health and Risk Reduction in Children and Adolescents, 2011).

The interconnection between BMI and BP, cholesterol, and also blood glucose among the general population in relation to the impact on CVD risk was examined in more detail by Lu and colleagues (Lu et al., 2014). They found that 46% of excess risk for coronary heart disease and 76% of excess risk for stroke due to high BMI were mediated by BP, cholesterol, and blood glucose. BP turned out to be the most important mediator, accounting for a third of the excess risk for coronary heart disease and two-thirds for stroke. Thus, reducing only high BP (e.g., by medication) may already take over a significant proportion of the impact of high BMI on CVD risk. However, the study authors emphasize that the largest benefits for reducing CVD risk can be expected by losing excess weight. This is because of the combined favorable effects of reduced BP, cholesterol, and blood glucose originating from lowered BMI.

There are various physiological mechanisms by which the influence of excess weight in form of body fat on CVD risk and CRMs can be explained. Adipose tissue does not only store energy, instead it is an active tissue for cellular reactions and metabolic homeostasis. Adipose tissue can release many hormones, proinflammatory cytokines, and proteins that effect various physiological processes and can contribute to endothelial dysfunction (Unamuno et al., 2018). Endothelial dysfunction is associated with atherosclerosis, dyslipidemia, hypertension, insulin resistance, and thus an increased risk of CVD (Poirier et al., 2006). Moreover, obesity is associated with elevated leptin levels, which causes sodium retention, vasoconstriction, and increased BP (Bravo et al., 2006). Adipocyte tissue is a key driver of renin-angiotensin-aldosterone system activation, which is one of the most important BP regulating systems of the body (Cabandugama et al., 2017). As proposed by Cercato and Fonseca, Figure 10 provides an overview of further factors and processes related to obesity that influence CVD risk (Cercato & Fonseca, 2019).

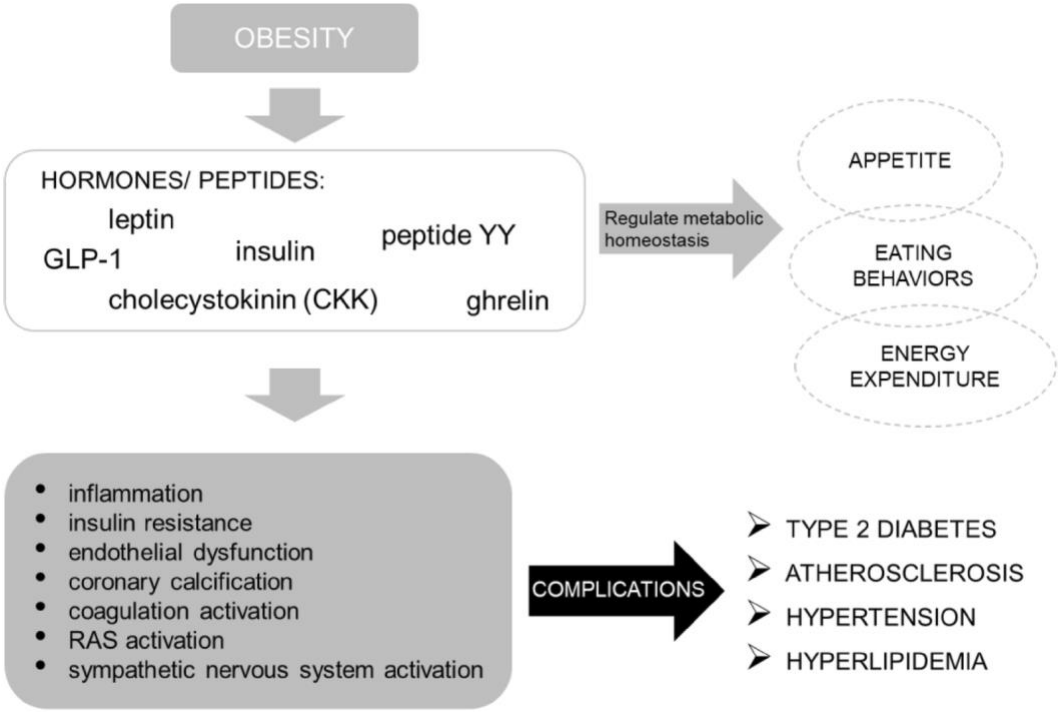

Figure 10: Relationship Between Obesity and Cardiovascular Risk.
Annotation: glucagon-like peptide 1 (GLP-1); renin angiotensin system (RAS)

8 Study Limitations and Strengths

The relatively large sample size of N = 594 can be seen as a strength of this study, since it provides a representative data pool. The distribution of sex was equal across the study population. However, the study sample consisted only of children and adolescents from disadvantaged neighborhoods of Gqeberha in South Africa and may not be representative of children and adolescents living in other regions and under different circumstances. Caution is advised when general overarching statements and assumptions are made. Furthermore, the data of this master's thesis was cross-sectional, which means that causality cannot be unconditionally inferred because temporality is not known.
The methods and measurements for data collection in this study were all standardized and performed by a trained research team which minimized bias and ensured quality.

PA was assessed over the period of one week, but since PA is highly variable in children, the measure comprised of one week may not fully reflect learners' true PA levels. The study setting could have motivated children to be more active during the measurement period and falsify the results. Furthermore, the time of the year data collection took place could have affected the results, since it has been shown that PA varies with season and weather conditions (Tucker & Gilliland, 2007). Sex-related differences in the relationship between self-reported and accelerometer-measured PA were not investigated. This could be done in a next step and might provide interesting results considering the differences in self-perception of PA between boys and girls (Crocker et al., 2000).

The accelerometer measurements also entailed known limitations. As mentioned, the ActiGraph was unable to accurately measure activities with little upper body movement such as cycling or weight training, since it was worn around the hip. In addition, the device had to be removed for activities in the water (e.g., swimming) and might have therefore underestimated activity levels. These limitations could be overcome in the future, for example by combining different methods such as accelerometry and heart rate monitors, or by developing waterproof devices. Another limitation is that the estimation of activity and sedentary time would have yielded different results, if alternate cut-points to define SB, LPA, MPA, and VPA would have been used. Furthermore, it has been shown that study participants with poorer health are less compliant with wearing accelerometers, which might cause them to be excluded for the analyses due to insufficient wear time (P. H. Lee et al., 2013).

Limitations of the PAQ-C included recall errors, social desirability effect, and difficulties understanding the questions. Also, more than 25% of study participants reported that an illness had prevented them from engaging in usual PA and were therefore not included in the analysis. In this study, the PAQ-C was adapted from its original design; Questions 1 and 9 were omitted from the questionnaire, which facilitated completing the questions, but also meant that valuable information was not collected. Question 1 is the only question of the PAQ-C requesting participants to specify which type of physical activities they performed and question 9 assesses the daily frequency of PA and was consistently shown to be associated with accelerometer measured MVPA.

The study of cardiovascular health also came with limitations. First, cardiovascular health is a complex and multidimensional construct that needs to be assessed from a broad perspective. In this study, the impact of children's dietary habits was not addressed, which is something that future research should take into account if possible. For example, it has been found that watching TV, which is one of the most common sedentary behaviors, is associated with an unhealthy diet (Wiecha et al., 2006). Thus, the relationship between SB and TC, LDL, and Non-HDL may partially be explained by diet.
Further, BP can vary greatly due to the effect of biological and diurnal factors (Pickering et al., 2005). BP readings can also be unreliable if children move during the measurement and since the participants were experiencing an unfamiliar situation, BP values may have increased slightly. Errors were minimized by repeating BP measurements three times and by directing children to remain seated for approximately 5 minutes prior to measuring.

9 Conclusion and Outlook

The aim of this master's thesis was to compare self-reported with accelerometer-measured PA and to investigate its association with different CRMs among school children from South Africa.

Self-reported (PAQ-C) and accelerometer-measured (ActiGraph) MVPA levels were significantly associated. However, the strength of the relationship was weak, and caution should be used when comparing studies using the PAQ-C with studies using accelerometry as methods for assessing PA in pediatric populations. The PAQ-C should not be used to replace objective PA measurement methods in research settings. The questionnaire seems to be a valid method for assessing children's PA behavior rather than absolute PA levels.

Some questions of the PAQ-C appeared to better estimate MVPA than other questions. Questions 3, 6, and 7 asked for recess, evening, and weekend PA levels, and they were more closely related to accelerometer-measured MVPA than questions 2, 4, 5, and 8.

PA and SB were found to affect learners' cardiovascular health, which was reflected in the CRMs. This finding demonstrates that already in childhood, PA has a preventive effect against the risk of CVD. Higher levels of MVPA were associated with reduced SBP and BMI, as identified by PAQ-C and ActiGraph respectively. Lower concentrations of TC, LDL, and Non-HDL were measured in study participants engaging less in SB. Children accumulating at least 60 minutes of MVPA per day, thus meeting the WHO guidelines on PA and SB, showed favorable values in BMI, BP, and BLP, compared to those not meeting the guidelines. Based on these findings, this master's thesis supports the recommendation for children and adolescents to spend more time in MVPA and less in SB, in order to reduce CVD risk. Establishing a physically active lifestyle in youth increases the chance of remaining active later in life when the consequences of CVD become more serious for health. PA is an independent factor that has been shown to be preventive against CVD mortality, but it also reduces CVD risk by influencing CRMs (e.g., BMI, BP, or BLP) (Blair et al., 1995).

The results of this study also showed that the magnitude of the impact of PA on the selected CRMs was limited and that the influence of excess weight was more crucial. This subsequently demonstrates the meaningfulness of the inverse association between MVPA levels and BMI, detected by Actigraph accelerometer in this study. By accumulating more MVPA, children and adolescents can lose excess weight and prevent the direct and associated negative effects of obesity on CVD risk. Self-reported MVPA levels (PAQ-C) did not correlate with BMI. Hence, the important relationship between MVPA and BMI would not have been detected if PA was assessed only with the PAQ-C, emphasizing the importance of comparing objective and subjective measurement methods "head-to-head". Moreover, the PA assessment by accelerometer provided estimates of the time children spent in SB, which the PAQ-C is unable to do. On the other hand, ActiGraph measurements did not detect an association between MVPA and BP, while PAQ-C scores correlated inversely with SBP. The inconsistency in detecting associations with health outcomes between the questionnaire and the accelerometer may explain why previous publications have obtained diverging findings on associations of PA with health outcomes.

In conclusion, accelerometer measurements identified more and stronger associations between PA and CRMs than PAQ-C scores. Thus, measuring PA by accelerometer allowed for a more accurate CVD risk estimation than by PAQ-C. However, accelerometer technology is not always feasible due to high costs and the time-consuming administration. The PAQ-C on the other hand, does not require a large budget or specialized staff, which makes it more practical for large-scale studies. Since at present, no definitive conclusions can be drawn about the convergent validity of the PAQ-C compared to accelerometers, it is important for future research to consider the implications that chosen PA measurement methods entail. If possible, accelerometers and the PAQ-C should be used concurrently to obtain the most comprehensive assessment of PA.

Given that for many large-scale studies self-reported PA data is the only affordable option, it is crucial to understand how to interpret this data and how it relates to accelerometer-measured PA. Future research should not focus on finding a "correct" method for assessing PA but rather acknowledge that each method provides unique information on physical movement and behavior. That being said, self-report methods should still be as accurate and reliable as possible. Studying and comparing subjective and objective methods for assessing PA remains important for future research. A promising and cost-effective approach to enhance the utility of self-report measures is calibrating the output against objectively measured PA data. A simple calibration equation that converts raw PAQ-C scores into time spent in MVPA can be a valid alternative to provide accurate estimates of MVPA. For instance, by applying the formula "Daily % MVPA = 14.56 – (sex * 0.98) – (0.84 * age) + (1.01 * PAQ)" by Saint-Maurice et al., the strength of the association between self-reported and ActiGraph-measured MVPA increased from $\rho = 0.13$ to $\rho = 0.21$ in the participants of this study (data not shown) (Saint-Maurice et al., 2014). Another possibility to improve the PAQ-C that could be implemented in the future is an online form of the questionnaire via internet or software application, and to allow filling out the questionnaire over the course of the week. This would shorten the duration between performing and writing down the activity and would therefore reduce recall time.
An aspect that was not investigated in this study but would be worth looking at is the type of activities that are most effective in promoting PA in children and adolescents. Furthermore, there is much time for play over the weekends, thus it would also be interesting to know what activities children engage in over the weekends and how those relate to overall PA levels.

Future research should also continue to investigate the impact of PA on cardiovascular health in children and adolescents using longitudinal study designs to analyze cause-effect relationships and long-term trends. Evidence-based data on this matter can offer the opportunity to raise public awareness and justify the need for further engagement in promoting PA. It is important thereby to keep in mind that associations between PA and health outcomes may vary depending on the PA assessment method chosen.

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Appendix

Appendix 1: Official Version of the Physical Activity Questionnaire for Older Children

Source: Kowalski, K. C., Crocker, P. R. E., & Donen, R. M. (2004). *The Physical Activity Questionnaire for Older Children (PAQ-C) and Adolescents (PAQ-A) Manual*. College of Kinesiology. University of Saskatchewan.

Physical Activity Questionnaire (Elementary School)

Name:_____ Age:_____

Sex: M_____ F_____ Grade:_____

Teacher:_____

We are trying to find out about your level of physical activity from ***the last 7 days*** (in the last week). This includes sports or dance that make you sweat or make your legs feel tired, or games that make you breathe hard, like tag, skipping, running, climbing, and others.

Remember:

1. There are no right and wrong answers — this is not a test.
2. Please answer all the questions as honestly and accurately as you can — this is very important.

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1. Physical activity in your spare time: Have you done any of the following activities in the past 7 days (last week)? If yes, how many times? (Mark only one circle per row.)

	No	1-2	3-4	5-6	7 times or more
Skipping	❍	❍	❍	❍	❍
Rowing/canoeing	❍	❍	❍	❍	❍
In-line skating	❍	❍	❍	❍	❍
Tag	❍	❍	❍	❍	❍
Walking for exercise	❍	❍	❍	❍	❍
Bicycling	❍	❍	❍	❍	❍
Jogging or running	❍	❍	❍	❍	❍
Aerobics	❍	❍	❍	❍	❍
Swimming	❍	❍	❍	❍	❍
Baseball, softball	❍	❍	❍	❍	❍
Dance	❍	❍	❍	❍	❍
Football	❍	❍	❍	❍	❍
Badminton	❍	❍	❍	❍	❍
Skateboarding	❍	❍	❍	❍	❍
Soccer	❍	❍	❍	❍	❍
Street hockey	❍	❍	❍	❍	❍
Volleyball	❍	❍	❍	❍	❍
Floor hockey	❍	❍	❍	❍	❍
Basketball	❍	❍	❍	❍	❍
Ice skating	❍	❍	❍	❍	❍
Cross-country skiing	❍	❍	❍	❍	❍
Ice hockey/ringette	❍	❍	❍	❍	❍
Other:					
_____	❍	❍	❍	❍	❍
_____	❍	❍	❍	❍	❍

8

2. In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)? (Check one only.)

I don't do PE ..... ❍
Hardly ever ..... ❍
Sometimes ..... ❍
Quite often ..... ❍
Always ..... ❍

3. In the last 7 days, what did you do most of the time *at recess*? (Check one only.)

Sat down (talking, reading, doing schoolwork)..... ❍
Stood around or walked around ..... ❍
Ran or played a little bit ..... ❍
Ran around and played quite a bit ..... ❍
Ran and played hard most of the time ..... ❍

4. In the last 7 days, what did you normally do *at lunch* (besides eating lunch)? (Check one only.)

Sat down (talking, reading, doing schoolwork)..... ❍
Stood around or walked around ..... ❍
Ran or played a little bit ..... ❍
Ran around and played quite a bit ..... ❍
Ran and played hard most of the time ..... ❍

5. In the last 7 days, on how many days *right after school*, did you do sports, dance, or play games in which you were very active? (Check one only.)

None ..... ❍
1 time last week ..... ❍
2 or 3 times last week ..... ❍
4 times last week ..... ❍
5 times last week ..... ❍

6. In the last 7 days, on how many *evenings* did you do sports, dance, or play games in which you were very active? (Check one only.)

None ..... ❍
1 time last week ..... ❍
2 or 3 times last week ..... ❍
4 or 5 last week ..... ❍
6 or 7 times last week ..... ❍

7. *On the last weekend*, how many times did you do sports, dance, or play games in which you were very active? (Check one only.)

None ..... ❍
1 time ..... ❍
2 — 3 times ..... ❍
4 — 5 times ..... ❍
6 or more times ..... ❍

8. Which *one* of the following describes you best for the last 7 days? Read *all five* statements before deciding on the *one* answer that describes you.

A. All or most of my free time was spent doing things that involve little physical effort ..... ❍

B. I sometimes (1 — 2 times last week) did physical things in my free time (e.g. played sports, went running, swimming, bike riding, did aerobics) ..... ❍

C. I often (3 — 4 times last week) did physical things in my free time ..... ❍

D. I quite often (5 — 6 times last week) did physical things in my free time ..... ❍

E. I very often (7 or more times last week) did physical things in my free time ..... ❍

9. Mark how often you did physical activity (like playing sports, games, doing dance, or any other physical activity) for each day last week.

	None	Little bit	Medium	Often	Very often
Monday	❍	❍	❍	❍	❍
Tuesday	❍	❍	❍	❍	❍
Wednesday	❍	❍	❍	❍	❍
Thursday	❍	❍	❍	❍	❍
Friday	❍	❍	❍	❍	❍
Saturday	❍	❍	❍	❍	❍
Sunday	❍	❍	❍	❍	❍

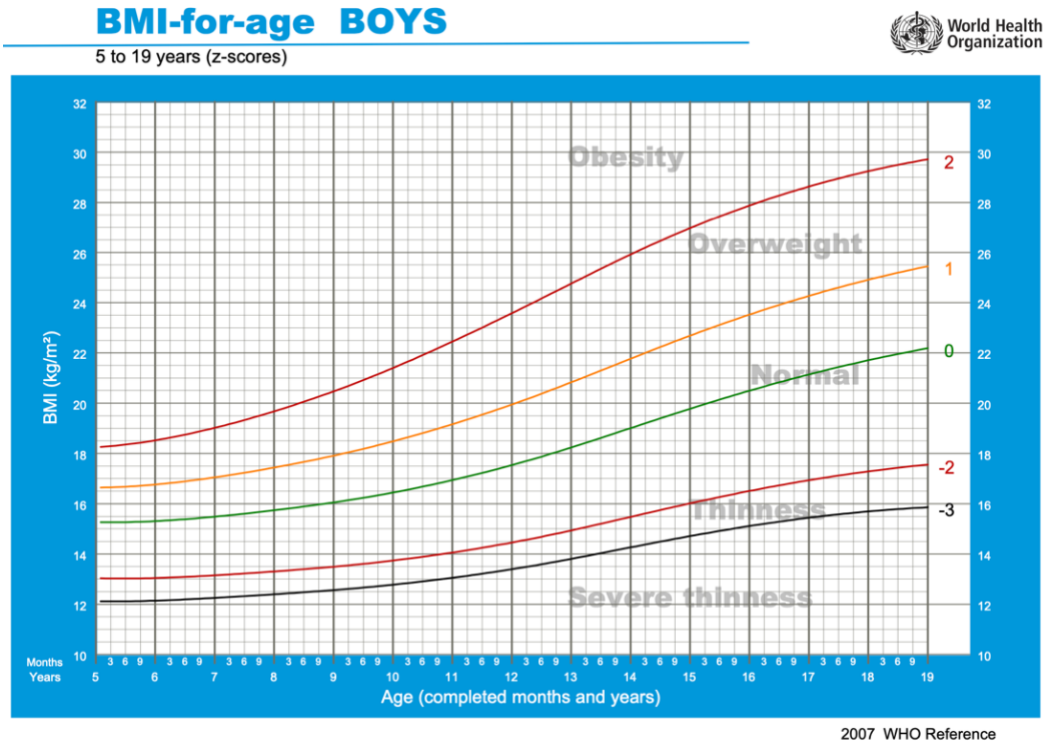
10. Were you sick last week, or did anything prevent you from doing your normal physical activities? (Check one.)

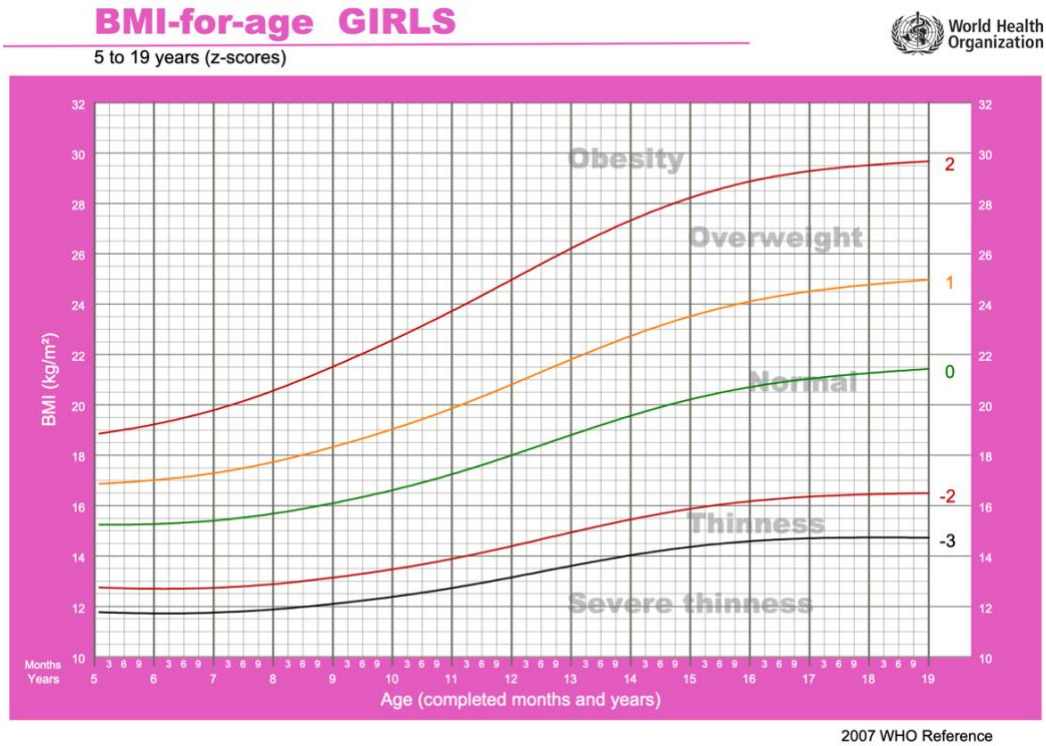
Yes ..... ❍
No ..... ❍

If Yes, what prevented you? _____

Appendix 2: Gender Separate Charts for BMI-for-age Categorizations

Source: World Health Organization (2007). BMI-for-age (5-19 years). Retrieved November 9, 2021, from https://www.who.int/tools/growth-reference-data-for-5to19-years/indicators/bmi-for-age





Appendix 3: Details on the Outcomes of the Statistical Analyses for Chapter 6.1

Independent two-sample t-Test, Mann-Whitney-U-Test, and Pearson's chi-squared test for identifying differences between boys and girls

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Height (cm)	Equal variances assumed	,214	,644	-2,022	592	,044	-1.47436383	.7291295970	-2.90635924	-.042368420
	Equal variances not assumed			-2,021	590,384	,044	-1.47436383	.7293582492	-2.90681634	-.041911320
TC (mmol/l)	Equal variances assumed	1,833	,176	-2,112	496	,035	-.124252903	.0588308200	-.239841244	-.008664562
	Equal variances not assumed			-2,113	490,644	,035	-.124252903	.0588041964	-.239792020	-.008713786
LDL (mmol/l)	Equal variances assumed	1,304	,254	-1,404	490	,161	-.067971247	.0484144181	-.163096725	.0271542312
	Equal variances not assumed			-1,404	487,915	,161	-.067971247	.0483999264	-.163069258	.0271267640
HDL (mmol/l)	Equal variances assumed	,326	,568	1,715	496	,087	.0461935484	.0269333892	-.006724051	.0991111480
	Equal variances not assumed			1,716	491,817	,087	.0461935484	.0269225279	-.006703812	.0990909086
NonHDL (mmol/l)	Equal variances assumed	,601	,439	-3,377	496	,001	-.170446452	.0504724800	-.269612675	-.071280229
	Equal variances not assumed			-3,378	494,044	,001	-.170446452	.0504580709	-.269585324	-.071307579
HbA1c (%)	Equal variances assumed	,667	,415	,591	504	,555	,000123	,000207	-,000285	,000530
	Equal variances not assumed			,591	497,927	,555	,000123	,000207	-,000285	,000530

Weight (kg) across Sex

Independent-Samples Mann-Whitney U Test Summary

Total N	594
Mann-Whitney U	53352,500
Wilcoxon W	96130,500
Test Statistic	53352,500
Standard Error	2091,007
Standardized Test Statistic	4,429
Asymptotic Sig.(2-sided test)	,000

BMI (kg/m2) across Sex

Independent-Samples Mann-Whitney U Test Summary

Total N	594
Mann-Whitney U	53312,000
Wilcoxon W	96090,000
Test Statistic	53312,000
Standard Error	2090,830
Standardized Test Statistic	4,410
Asymptotic Sig.(2-sided test)	,000

SBP (mmHg) across Sex

Independent-Samples Mann-Whitney U Test Summary

Total N	585
Mann-Whitney U	47322,500
Wilcoxon W	89808,500
Test Statistic	47322,500
Standard Error	2043,764
Standardized Test Statistic	2,224
Asymptotic Sig.(2-sided test)	,026

DBP (mmHg) across Sex

Independent-Samples Mann-Whitney U Test Summary

Total N	585
Mann-Whitney U	47635,000
Wilcoxon W	90121,000
Test Statistic	47635,000
Standard Error	2043,552
Standardized Test Statistic	2,377
Asymptotic Sig.(2-sided test)	,017

TG (mmol/l) across Sex

Independent-Samples Mann-Whitney U Test Summary

Total N	498
Mann-Whitney U	40159,500
Wilcoxon W	71035,500
Test Statistic	40159,500
Standard Error	1604,947
Standardized Test Statistic	5,707
Asymptotic Sig.(2-sided test)	,000

TC/HDL (ratio) across Sex

Independent-Samples Mann-Whitney U Test Summary

Total N	498
Mann-Whitney U	37151,500
Wilcoxon W	68027,500
Test Statistic	37151,500
Standard Error	1603,341
Standardized Test Statistic	3,837
Asymptotic Sig.(2-sided test)	,000

Sex * age

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	14,756[a]	5	,011
Likelihood Ratio	14,990	5	,010
Linear-by-Linear Association	10,739	1	,001
N of Valid Cases	594		

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 7,87.

Sex * weight status

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	15,148[a]	3	,002
Likelihood Ratio	15,275	3	,002
Linear-by-Linear Association	13,662	1	,000
N of Valid Cases	594		

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 9,83.

Appendix 4: Details on the Outcomes of the Statistical Analyses for Chapter 6.2

Independent two-sample t-Test, Mann-Whitney-U-Test, and Pearson's chi-squared test for identifying differences between boys and girls

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
PAQ-C score (1-5)	Equal variances assumed	,903	,342	3,735	592	,000	.232507355	.062254100	.110241594	.354773116
	Equal variances not assumed			3,736	591,922	,000	.232507355	.062230725	.110287469	.354727240
Sedentary Time (%)	Equal variances assumed	,024	,877	-5,811	592	,000	-2,23733	,38503	-2,99352	-1,48114
	Equal variances not assumed			-5,812	591,795	,000	-2,23733	,38493	-2,99333	-1,48133
Light Activity Time (%)	Equal variances assumed	,205	,651	1,203	592	,229	,34378	,28569	-,21732	,90487
	Equal variances not assumed			1,202	588,806	,230	,34378	,28588	-,21770	,90525
Total PA (min)	Equal variances assumed	1,693	,194	6,828	592	,000	258.093256	37.7973335	183.860077	332.326435
	Equal variances not assumed			6,837	591,054	,000	258.093256	37.7504074	183.951995	332.234516

ActiGraph MVPA (min/day) across Sex

Independent-Samples Mann-Whitney U Test Summary

Total N	594
Mann-Whitney U	20333,500
Wilcoxon W	63111,500
Test Statistic	20333,500
Standard Error	2091,041
Standardized Test Statistic	-11,362
Asymptotic Sig.(2-sided test)	,000

Moderate Activity Time (%) across Sex

Independent-Samples Mann-Whitney U Test Summary

Total N	594
Mann-Whitney U	23065,500
Wilcoxon W	65843,500
Test Statistic	23065,500
Standard Error	2091,024
Standardized Test Statistic	-10,056
Asymptotic Sig.(2-sided test)	,000

Sex * Meeting WHO guideline

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	95,298[a]	1	,000		
Continuity Correction[b]	93,698	1	,000		
Likelihood Ratio	98,017	1	,000		
Fisher's Exact Test				,000	,000
Linear-by-Linear Association	95,137	1	,000		
N of Valid Cases	594				

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 135,68.

b. Computed only for a 2x2 table

Vigorous Activity Time (%) across Sex

Independent-Samples Mann-Whitney U Test Summary

Total N	594
Mann-Whitney U	21988,000
Wilcoxon W	64766,000
Test Statistic	21988,000
Standard Error	2091,015
Standardized Test Statistic	-10,571
Asymptotic Sig.(2-sided test)	,000

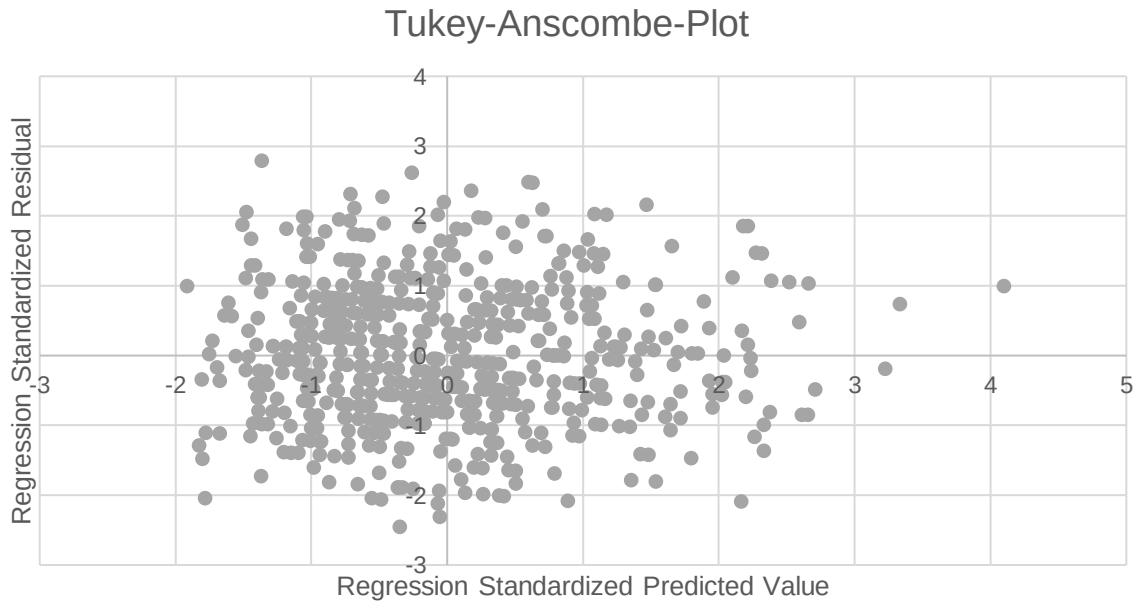
Spearman Rank Correlations Between PAQ-C (items and total score) and ActiGraph Measurements of PA. (N = 594)

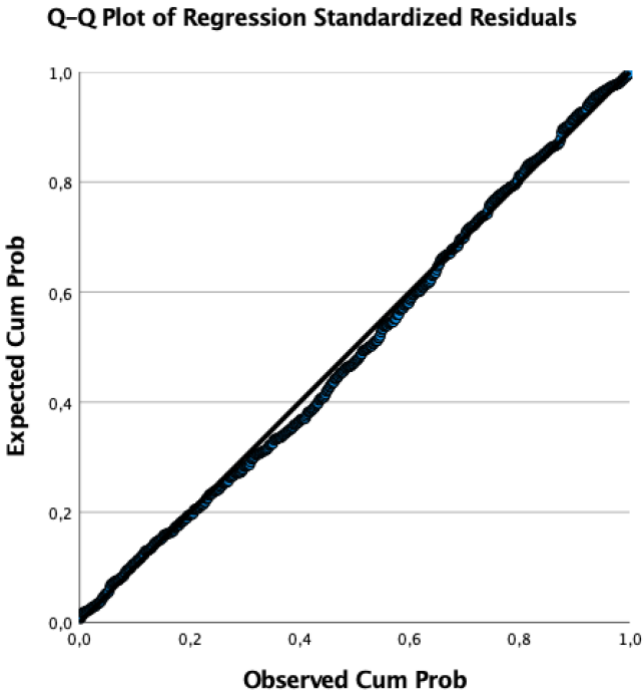
		Correlations					
PAQ-C		Average MVPA (min/day)	Sedentary Time (%)	Light Activity Time (%)	Moderate Activity Time (%)	Vigorous Activity Time (%)	Total PA (min)
Q2 - PE	Correlation Coefficient	-0.009	-0.006	0.022	0.014	-0.006	-0.031
	Sig. (2-tailed)	0.830	0.875	0.586	0.737	0.885	0.446
Q3 - Break	Correlation Coefficient	0.122	-0.044	-0.011	0.093	0.156	0.053
	Sig. (2-tailed)	0.003	0.281	0.780	0.024	0.000	0.196
Q4 - Lunch	Correlation Coefficient	0.065	0.023	-0.078	0.066	0.087	-0.041
	Sig. (2-tailed)	0.115	0.570	0.057	0.109	0.035	0.315
Q5 – After School	Correlation Coefficient	0.090	-0.066	0.052	0.077	0.065	0.091
	Sig. (2-tailed)	0.028	0.109	0.206	0.060	0.115	0.027

Q6 - Evening	Correlation Coefficient	0.143	-0.021	-0.046	0.126	0.127	0.037
	Sig. (2-tailed)	0.000	0.606	0.259	0.002	0.002	0.363
Q7 - Weekend	Correlation Coefficient	0.111	-0.025	-0.033	0.102	0.103	0.074
	Sig. (2-tailed)	0.007	0.539	0.416	0.012	0.012	0.071
Q8 – 7 Days	Correlation Coefficient	0.041	0.009	-0.028	0.018	0.056	0.010
	Sig. (2-tailed)	0.322	0.828	0.500	0.658	0.175	0.806
Total score	Correlation Coefficient	0.130	-0.031	-0.029	0.119	0.134	0.044
	Sig. (2-tailed)	0.002	0.454	0.477	0.004	0.001	0.285

Annotation. Moderate- to vigorous-intensity physical activity (MVPA); Physical activity (PA); Physical Activity Questionnaire for Older Children (PAQ-C); Question of the PAQ-C about activity: during physical education classes (Q2 – PE), at recess (Q3 – Break), at lunch (Q4 – Lunch), after school (Q5 – After School), in the evening (Q6 – Evening), on the weekend (Q7 – Weekend), frequency during the last 7 days (Q8 – 7 Days)

Tukey-Anscombe-Plot and Q-Q Plot from the Simple Linear Regression Model with ActiGraph MVPA as the Predictor of PAQ-C Scores





Appendix 5: Details on the Outcomes of the Statistical Analyses for Chapter 6.3

Pearson Correlations Between Cardiovascular Risk Markers and Physical Activity Measurements.

Correlations				
		PAQ-C score (1-5)	ActiGraph MVPA (min/day)	Sedentary Time (%)
BMI (kg/m^2)	Pearson Correlation	-0.109	-0.266	0.059
	Sig. (2-tailed)	0.008	0.000	0.148
	N	594	594	594
SBP (mmHg)	Pearson Correlation	-0.120	-0.084	0.013
	Sig. (2-tailed)	0.004	0.043	0.757
	N	585	585	585
DBP (mmHg)	Pearson Correlation	-0.092	-0.076	0.010
	Sig. (2-tailed)	0.025	0.067	0.807
	N	585	585	585
TC (mmol/l)	Pearson Correlation	0.061	-0.050	0.111
	Sig. (2-tailed)	0.171	0.268	0.013
	N	498	498	498
LDL (mmol/l)	Pearson Correlation	0.033	-0.047	0.116
	Sig. (2-tailed)	0.462	0.300	0.010
	N	492	492	492

HDL (mmol/l)	Pearson Correlation	0.072	0.087	-0.018
	Sig. (2-tailed)	0.106	0.052	0.694
	N	498	498	498
TG (mmol/l)	Pearson Correlation	0.037	-0.116	0.056
	Sig. (2-tailed)	0.406	0.010	0.216
	N	498	498	498
Non-HDL (mmol/l)	Pearson Correlation	0.033	-0.104	0.138
	Sig. (2-tailed)	0.467	0.021	0.002
	N	498	498	498
TC/HDL (ratio)	Pearson Correlation	-0.022	-0.128	0.100
	Sig. (2-tailed)	0.632	0.004	0.025
	N	498	498	498
HbA1c (%)	Pearson Correlation	0.031	0.034	-0.033
	Sig. (2-tailed)	0.489	0.443	0.454
	N	506	506	506

Annotation. Physical Activity Questionnaire for Older Children (PAQ-C); Moderate- to vigorous-intensity physical activity (MVPA); Body mass index (BMI); Systolic blood pressure (SBP); Diastolic blood pressure (DBP); Total cholesterol (TC); Low-density lipoprotein (LDL); High-density lipoprotein (HDL); Triglycerides (TG); Difference between TC and HDL (Non-HDL); Ratio between TC and HDL (TC/HDL); Glycated hemoglobin (HbA1c)

Partial Correlations Between Cardiovascular Risk Markers (Without Body Mass Index) and Physical Activity Measurements.

Partial Correlations
Control variables: Sex, age, height, weight

		PAQ-C score (1-5)	ActiGraph MVPA (min/day)	Sedentary Time (%)
SBP (mmHg)	Correlation	-0.088	0.013	-0.036
	Significance (2-tailed)	0.035	0.763	0.380
	df	579	579	579
DBP (mmHg)	Correlation	-0.064	0.006	-0.015
	Significance (2-tailed)	0.126	0.893	0.710
	df	579	579	579
TC (mmol/l)	Correlation	0.078	-0.005	0.104
	Significance (2-tailed)	0.083	0.910	0.020
	df	492	492	492
LDL (mmol/l)	Correlation	0.047	-0.013	0.129
	Significance (2-tailed)	0.302	0.775	0.004
	df	486	486	486
HDL (mmol/l)	Correlation	0.049	0.028	0.002
	Significance (2-tailed)	0.276	0.540	0.969
	df	492	492	492
TG (mmol/l)	Correlation	0.085	0.005	-0.024
	Significance (2-tailed)	0.060	0.918	0.588
	df	492	492	492
Non-HDL (mmol/l)	Correlation	0.065	-0.021	0.121
	Significance (2-tailed)	0.147	0.645	0.007

	df	492	492	492
TC/HDL (ratio)	Correlation	0.021	-0.018	0.075
	Significance (2-tailed)	0.640	0.693	0.094
	df	492	492	492
HbA1c (%)	Correlation	0.038	0.047	-0.041
	Significance (2-tailed)	0.399	0.297	0.359
	df	500	500	500

Annotation. Physical Activity Questionnaire for Older Children (PAQ-C); Moderate- to vigorous-intensity physical activity (MVPA); Systolic blood pressure (SBP); Diastolic blood pressure (DBP); Total cholesterol (TC); Low-density lipoprotein (LDL); High-density lipoprotein (HDL); Triglycerides (TG); Difference between TC and HDL (Non-HDL); Ratio between TC and HDL (TC/HDL); Glycated hemoglobin (HbA1c)

Partial Correlations Between Body Mass Index and Physical Activity Measurements.

Partial Correlations
Control variables: Sex, age

		PAQ-C score (1-5)	ActiGraph MVPA (min/day)	Sedentary Time (%)
BMI (kg/m^2)	Correlation	-0.077	-0.200	-0.013
	Significance (2-tailed)	0.062	0.000	0.747
	df	590	590	590

Annotation. Physical Activity Questionnaire for Older Children (PAQ-C); Moderate- to vigorous-intensity physical activity (MVPA); Body mass index (BMI)

Appendix 6: Details on the Outcomes of the Statistical Analyses for Chapter 6.4

Results of the Multivariable Linear Regression Model with Diastolic Blood Pressure as Dependent Variable. (N = 594)

Tests of Between-Subjects Effects

Dependent Variable:	DBP					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected model	5338,449[a]	6	889.742	7.426	0.000	0.072
Intercept	10443.833	1	10443.833	87.162	0.000	0.131
PAQ-C score	293.603	1	293.603	2.450	0.118	0.004
ActiGraph MVPA	10.525	1	10.525	0.088	0.767	0.000
Age	3.710	1	3.710	0.031	0.860	0.000
Height	563.142	1	563.142	4.700	0.031	0.008
Weight	3853.003	1	3853.003	32.156	0.000	0.053
Sex	41.248	1	41.248	0.344	0.558	0.001
Error	69256.549	578	119.821			
Total	2724970.000	585				
Corrected Total	74594.998	584				

a. R Squared = ,072 (Adjusted R Squared = ,062)

Results of the Multivariable Linear Regression Model with Glycated Hemoglobin as Dependent Variable. (N = 506)

Tests of Between-Subjects Effects

Dependent Variable:	HbA1c (%)					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5,037E-5[a]	6	8.395E-06	1.556	0.158	0.018
Intercept	0.004	1	0.004	758.120	0.000	0.603
PAQ-C score	2.862E-06	1	2.862E-06	0.530	0.467	0.001
ActiGraph MVPA	4.145E-06	1	4.145E-06	0.768	0.381	0.002
Age	1.226E-05	1	1.226E-05	2.273	0.132	0.005
Height	8.072E-06	1	8.072E-06	1.496	0.222	0.003
Weight	2.591E-05	1	2.591E-05	4.801	0.029	0.010
Sex	5.388E-08	1	5.388E-08	0.010	0.920	0.000
Error	0.003	499	5.396E-06			
Total	1.494	506				
Corrected Total	0.003	505				

a. R Squared = ,018 (Adjusted R Squared = ,007)

Results of the Multivariable Linear Regression Model with Total Cholesterol as Dependent Variable. (N = 498)

Tests of Between-Subjects Effects

Dependent Variable:	TC					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3,851[a]	6	0.642	1.488	0.180	0.018
Intercept	24.146	1	24.146	55.978	0.000	0.102
PAQ-C score	1.320	1	1.320	3.061	0.081	0.006
ActiGraph MVPA	0.020	1	0.020	0.047	0.829	0.000
Age	0.069	1	0.069	0.161	0.689	0.000
Height	0.247	1	0.247	0.573	0.450	0.001
Weight	0.214	1	0.214	0.497	0.481	0.001
Sex	1.451	1	1.451	3.364	0.067	0.007
Error	211.795	491	0.431			
Total	7197.263	498				
Corrected Total	215.646	497				

a. R Squared = ,018 (Adjusted R Squared = ,006)

Results of the Multivariable Linear Regression Model with Low-Density Lipoprotein as Dependent Variable. (N = 492)

Tests of Between-Subjects Effects

Dependent Variable:	LDL					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2,977[a]	6	0.496	1.733	0.111	0.021
Intercept	12.823	1	12.823	44.786	0.000	0.085
PAQ-C score	0.326	1	0.326	1.137	0.287	0.002
ActiGraph MVPA	0.028	1	0.028	0.097	0.755	0.000
Age	0.147	1	0.147	0.515	0.473	0.001
Height	0.979	1	0.979	3.419	0.065	0.007
Weight	0.828	1	0.828	2.894	0.090	0.006
Sex	0.246	1	0.246	0.858	0.355	0.002

Error	138.859	485	0.286
Total	2169.969	492	
Corrected Total	141.836	491	

a. R Squared = ,021 (Adjusted R Squared = ,009)

Results of the Multivariable Linear Regression Model with High-Density Lipoprotein as Dependent Variable. (N = 498)

Tests of Between-Subjects Effects

Dependent Variable:	HDL					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1,526[a]	6	0.254	2.869	0.009	0.034
Intercept	1.228	1	1.228	13.855	0.000	0.027
PAQ-C score	0.108	1	0.108	1.218	0.270	0.002
ActiGraph MVPA	0.025	1	0.025	0.286	0.593	0.001
Age	0.013	1	0.013	0.146	0.703	0.000
Height	0.239	1	0.239	2.694	0.101	0.005
Weight	0.923	1	0.923	10.413	0.001	0.021
Sex	0.036	1	0.036	0.411	0.522	0.001
Error	43.534	491	0.089			
Total	885.381	498				
Corrected Total	45.060	497				

a. R Squared = ,034 (Adjusted R Squared = ,022)

Results of the Multivariable Linear Regression Model with Triglycerides as Dependent Variable. (N = 498)

Tests of Between-Subjects Effects

Dependent Variable:	TG					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	14,609[a]	6	2.435	7.222	0.000	0.081
Intercept	0.064	1	0.064	0.191	0.662	0.000
PAQ-C score	1.063	1	1.063	3.153	0.076	0.006
ActiGraph MVPA	0.003	1	0.003	0.010	0.921	0.000
Age	0.685	1	0.685	2.033	0.155	0.004
Height	0.102	1	0.102	0.304	0.582	0.001
Weight	0.826	1	0.826	2.450	0.118	0.005
Sex	6.166	1	6.166	18.288	0.000	0.036
Error	165.535	491	0.337			
Total	620.384	498				
Corrected Total	180.144	497				

a. R Squared = ,081 (Adjusted R Squared = ,070)

Results of the Multivariable Linear Regression Model with Non-High-Density Lipoprotein as Dependent Variable. (N = 498)

Tests of Between-Subjects Effects

Dependent Variable:	Non-HDL					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	6,651[a]	6	1.108	3.528	0.002	0.041
Intercept	14.472	1	14.472	46.058	0.000	0.086
PAQ-C score	0.670	1	0.670	2.131	0.145	0.004
ActiGraph MVPA	0.092	1	0.092	0.291	0.590	0.001
Age	0.023	1	0.023	0.073	0.788	0.000
Height	0.968	1	0.968	3.080	0.080	0.006
Weight	2.028	1	2.028	6.456	0.011	0.013
Sex	1.944	1	1.944	6.186	0.013	0.012
Error	154.275	491	0.314			
Total	3138.569	498				
Corrected Total	160.926	497				

a. R Squared = ,041 (Adjusted R Squared = ,030)

Results of the Multivariable Linear Regression Model with the Ratio Between Total Cholesterol and High-Density Lipoprotein as Dependent Variable. (N = 498)

Tests of Between-Subjects Effects

Dependent Variable:	TC/HDL					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	16,494[a]	6	2.749	6.915	0.000	0.078
Intercept	23.278	1	23.278	58.558	0.000	0.107
PAQ-C score	0.059	1	0.059	0.148	0.701	0.000
ActiGraph MVPA	0.054	1	0.054	0.136	0.712	0.000
Age	0.125	1	0.125	0.316	0.574	0.001
Height	2.054	1	2.054	5.167	0.023	0.010
Weight	10.041	1	10.041	25.260	0.000	0.049
Sex	1.784	1	1.784	4.487	0.035	0.009
Error	195.184	491	0.398			
Total	4647.000	498				
Corrected Total	211.678	497				

a. R Squared = ,078 (Adjusted R Squared = ,067)

Appendix 7: Meeting Versus Not Meeting WHO Guidelines

Differences in Physical Activity and Cardiovascular Risk Markers Between Study Participants Meeting WHO Physical Activity Guidelines and Those Who Do Not

	Meet the recommended 60 min/day of MVPA		
	No	**Yes**	***p*-value[a]**
Body composition (N = 594)			
BMI (kg/m^2)	17.8 (16.0 – 20.8)	16.6 (15.4 – 18.3)	**0.000****
Overweight or obese (%)	65.2	34.8	**0.000****
Physical activity (N = 594)			
Sedentary Time (%)	74.0 ± 3.8	68.8 ± 4.3	**0.000****
ActiGraph MVPA (min/day)	45.6 (38.1 – 52.1)	77.5 (68.6 – 93.6)	**0.000****
PAQ-C score (1-5)	2.8 ± 0.8	3.0 ± 0.8	**0.016***
Blood pressure (N = 585)			
SBP (mmHg)	110.0 (99.5 – 118.5)	106.5 (98.5 – 114.0)	**0.008****
DBP (mmHg)	67 (61.5 – 72.5)	65 (59.5 – 70.0)	**0.009****
Blood lipid profile (N = 498)			
TC (mmol/l)	3.81 ± 0.67	3.69 ± 0.64	0.056
LDL (mmol/l)	2.07 ± 0.57	1.99 ± 0.51	0.101
HDL (mmol/l)	1.28 ± 0.29	1.32 ± 0.31	0.165
TG (mmol/l)	0.82 (0.65 – 1.15)	0.74 (0.58 – 0.96)	**0.001****
Non-HDL (mmol/l)	2.53 ± 0.60	2.38 ± 0.53	**0.003****
TC/HDL (ratio)	3.0 (2.6 – 3.5)	2.8 (2.5 – 3.2)	**0.001****
Blood sugar (N = 506)			
HbA1c (%)	5.4 ± 0.2	5.4 ± 0.2	0.566

Annotation. Data are mean ± SD, median (IQR), or proportion; * $p < .05$; ** $p < .01$; [a] Between-sex differences assessed by independent two-sample t-Test, Mann-Whitney-U-Test, or Pearson's chi-squared test; Moderate- to vigorous-intensity physical activity (MVPA); Body mass index (BMI); Physical Activity Questionnaire for Older Children (PAQ-C); Systolic blood pressure (SBP); Diastolic blood pressure (DBP); Triglycerides (TG); Total cholesterol (TC); Low-density lipoprotein (LDL); High-density lipoprotein (HDL); Difference between TC and HDL (Non-HDL); Ratio between TC and HDL (TC/HDL); Glycated hemoglobin (HbA1c)

Risk Estimate for Being Obese when Meeting Versus Not Meeting WHO Physical Activity Guidelines

Risk Estimate	Value	95% Confidence Interval	
		Lower	Upper
Odds Ratio for "Meeting recommendation" (No / Yes)	4.074	2.258	7.350
For cohort "Obese" = Yes	3.529	2.055	6.060
For cohort "Obese" = No	0.866	0.815	0.920
N of Valid Cases	594		

Appendix 8: Partial Correlation Analysis for BMI

Partial Correlations Between Body Mass Index and Other Selected Cardiovascular Risk Markers

Partial Correlations

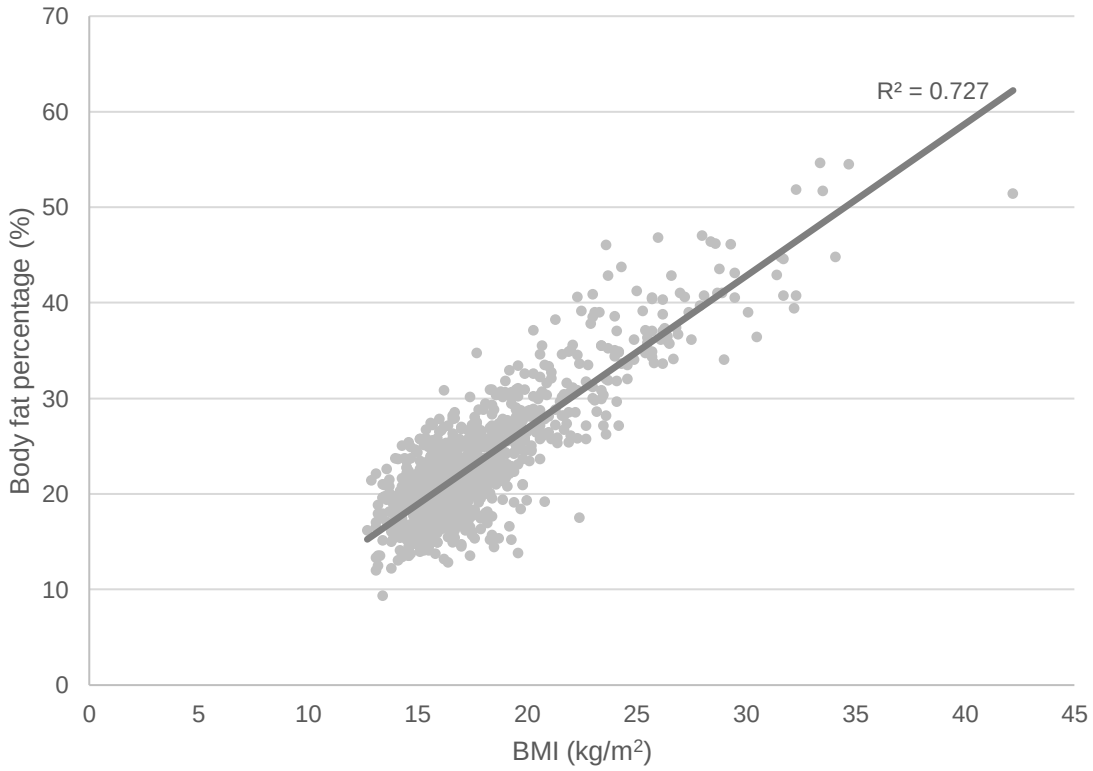
Control variables: Sex, age, ActiGraph MVPA, PAQ-C scores, sedentary time

		BMI (kg/m^2)
SBP (mmHg)	N = 578	**0.241****
DBP (mmHg)	N = 578	**0.230****
TC (mmol/l)	N = 491	0.063
LDL (mmol/l)	N = 485	**0.100***
HDL (mmol/l)	N = 491	**-0.132****
TG (mmol/l)	N = 491	**0.092***
Non-HDL (mmol/l)	N = 491	**0.144****
TC/HDL (ratio)	N = 491	**0.236****
HbA1c (%)	N = 499	0.084

Annotation. * $p < .05$; ** $p < .01$; Moderate- to vigorous-intensity physical activity (MVPA); Physical Activity Questionnaire for Older Children (PAQ-C); Systolic blood pressure (SBP); Diastolic blood pressure (DBP); Triglycerides (TG); Total cholesterol (TC); Low-density lipoprotein (LDL); High-density lipoprotein (HDL); Difference between TC and HDL (Non-HDL); Ratio between TC and HDL (TC/HDL); Glycated hemoglobin (HbA1c)

Appendix 9: Relationship Between Body Mass Index and Body Fat Percentage

Scatterplot with Trend Line and Coefficient of Determination for the Relationship Between Body Mass Index (BMI) and Body Fat Percentage



Annotation. Body fat percentage was measured as part of the *KaziBantu* data collection during baseline assessment in early 2019. It was measured by using a single-frequency, 8-electrode bio impedance analyzer system (Tanita MC-580; Tanita Corp., Tokyo, Japan).

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Department of Sport, Exercise and Health

Comparison of Objectively and Subjectively Measured Physical Activity and Its Association With Cardiovascular Risk Markers in South African School Children

Felix Guntlisbergen
Supervisor: Patricia Arnaiz Jimenez

1 | Background

Cardiovascular diseases (CVDs) are the leading cause of death worldwide, accounting for one third of all global deaths (WHO, 2021). CVD prevention strategies should begin in early life since the onset of CVD is known to begin in childhood (Berenson et al., 1998). The risk of CVD can be substantially reduced by focusing on lifestyle modifications. In particular, physical activity (PA) has received a lot of attention due to its beneficial effects on reducing the risk of CVD (Ahmed et al., 2012). An accurate and valid assessment of PA is required for studying its impact on health. Two commonly used assessment methods are questionnaires and motion sensors. However, the agreement between these methods is still a subject of discussion (Marasso et al., 2021). This master's thesis aims to compare self-reported (questionnaire) PA with accelerometer-measured (motion sensor) PA and to investigate its association with different cardiovascular risk markers (CRMs) in school children from South Africa.

2 | Method

Cross-sectional data of 594 (302 boys, 292 girls) South African school children between the ages of 8 – 13 years was included in the analysis. The data was collected as part of the *KaziBantu* project. PA was assessed subjectively using the Physical Activity Questionnaire for Older Children (PAQ-C) and objectively using ActiGraph wGT3X-BT accelerometers. Selected CRMs consisted of body mass index (BMI), blood pressure (BP), blood lipid profile (BLP), and glycated hemoglobin (HbA1c). Body height and weight was measured by stadiometer and digital weighing scale. Resting BP was measured with the Omron M6 AC blood pressure monitor. The Alere Afinion AS 100 Analyzer was used to determine the BLP and HbA1c concentrations.

3 | Results

PAQ-C scores and accelerometer-measured minutes of moderate- to vigorous-intensity physical activity (MVPA) were positively associated (= 0.13, p = 0.002) (Figure 1). 2.4% (R^2 = 0.024) of the variance of PAQ-C scores was explained by accelerometer-measured MVPA.

Fig. 1: Relationship between self-reported (PAQ-C scores) and accelerometer-measured (ActiGraph MVPA) physical activity levels

MVPA was inversely associated with BMI (partial r = -0.20, p < 0.001) (Figure 2), and sedentary behavior (SB) correlated positively with total cholesterol (TC), low-density lipoprotein (LDL), and non-high-density lipoprotein (Non-HDL) (partial r = 0.10 (TC); 0.13 (LDL); 0.12 (Non-HDL), p = 0.020 (TC); 0.004 (LDL); 0.007 (Non-HDL)). PAQ-C scores were inversely associated with systolic BP (partial r = -0.088, p = 0.035). Overall, the proportions of variance of individual CRMs explained by PAQ-C scores and ActiGraph MVPA were very small or negligible ($\frac{2}{p}$ = 0.00 – 0.04).

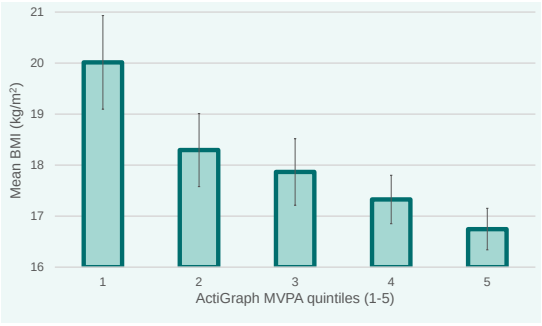

Fig. 2: Mean BMI separated by children's activity levels (ActiGraph MVPA, 5 = highest activity level)

4 | Conclusions

- The accordance between self-reported and accelerometer-measured physical activity levels was not satisfactory
- Physical activity can have a preventive effect against cardiovascular disease as early as childhood
- The relationship between BMI and MVPA was the most significant
- Excess weight plays an important role in cardiovascular disease risk
- Measuring physical activity by ActiGraph accelerometer allowed for a more accurate cardiovascular disease risk estimation than by PAQ-C

KaziBantu
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Literature

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