Effects of a school-based health intervention and cross-sectional associations of schoolchildren's academic performance, selective attention and health-related quality of life in Port Elizabeth, South Africa

Inaugural dissertation

to

be awarded the degree of Dr. sc. med.

presented at

the Faculty of Medicine

of the University of Basel

by

Stefanie Gall

from Hunzenschwil (AG), Switzerland

Basel, 2020

Approved by the Faculty of Medicine

On application of

Faculty representative	Prof. Dr. Uwe Pühse
First supervisor	Prof. Dr. Uwe Pühse
Second supervisor	Prof. Dr. Markus Gerber
External expert	Prof. Dr. Hanlie Moss

Basel, 31.7.2020 (Date of the acceptance of the Faculty)

Dean

Prof. Dr. Primo Leo Schär

«ubuntu ngumuntu ngabantu»

«I am because we are»

Zulu proverb

I Table of contents

II List of figures

III List of tables

IV List of abbreviations

ADHD	Attention deficit hyperactivity disorder
AIDS	Acquired immunodeficiency syndrome
ANOVA	Analysis of variance
BMI	Body mass index
BMIZ	BMI-for-age z score
C2005	Curriculum 2005
CAPS	National Curriculum and Assessment Policy Statement
CG	Control group
CI	Confidence interval
CP	Concentration performance
CRF	Cardiorespiratory fitness
CVD	Cardiovascular disease
DASH	Disease activity and schoolchildren's health
DSBG	Department of Sport, Exercise and Health
E%	Percentage of errors
e.g.	Exempli gratia
EKNZ	Ethics Committee of Northwest and Central Switzerland
EoYR	End of the year results
EPG	Eggs per gram (of stool)
etc.	Et cetera
FAS	Foetal alcohol syndrome
FASD	Foetal alcohol spectrum disorder
GBD	Global burden of disease
HAKSA	Healthy active kids South Africa
HAZ	Height-for-age z score
Hb	Haemoglobin
HBSC	Health behaviour in school-aged children
HCI	Human capital index
HIV	Human immunodeficiency virus
HMS	Human Movement Science
HRQoL	Health-related quality of life
i.e.	Id est
IG	Intervention group
ISRCTN	International standard randomised control trial number
kcal	Kilocalorie
kg	Kilogram
LMICs	Low- and middle-income countries
M	Means

MANOVA	Multivariate analysis of variance
MET	Metabolic equivalent
min	Minute
ml	Millilitres
MVPA	Moderate-to-vigorous intensity physical activity
NCDs	Non-communicable diseases
NMMU	Nelson Mandela Metropolitan University
NMU	Nelson Mandela University
NRF	National Research Foundation
NTDs	Neglected tropical diseases
OBE	Outcomes based education
OR	Odds ratio
p	Probability
PA	Physical activity
PE	Physical Education
RDT	Rapid diagnostic test
SACE	South African Council for Educators
SAQA	South African Qualifications Authority
SD	Standard deviation
SES	Socio-economic status
SLP	Short learning programme
SNSF	Swiss National Science Foundation
SSAJRP	Swiss South African Joint Research Programme
STH	Soil-transmitted helminth
Swiss TPH	Swiss Tropical and Public Health Institute
T1	Baseline measurement
T2	Follow-up measurement
T3	End-line measurement
TN	Total number of characters processed
UNESCO	United Nations Educational, Scientific and Cultural Organization
VO_2max	Maximal oxygen uptake
WASH	Water, sanitation and hygiene
WAZ	Weight-for-age z score
WHO	World Health Organisation

V Acknowledgements

Little did I know back in 2014, when I joined the DASH project as a Master student, that this opportunity would turn into a 5-year journey, where I grew academically as well as personally more than I could ever have imagined. I would like to take this opportunity to say thank you to all the people that have supported and accompanied me up until this day.

"*ubuntu ngumuntu ngabantu*"-I am because we are

First and foremost, I want to express my gratitude to my supervisors. To Uwe Pühse, who encouraged me to join the DASH study as a master student in 2014 and who offered me a PhD position in the same project two years later. Uwe Pühse has given me the chance to work autonomously, realize ideas and make my own decisions while I was always able to ask him for advice regarding decisions and challenges. I am grateful for the opportunity to work in such an inspiring project and I am thankful for the trust that he has placed in me. I would also like to thank Markus Gerber for his patience, support and encouragement. Markus Gerber has helped me on more than one occasion, be it with statistical calculations, going through a first draft line by line or by showing me how to put science into words. Then I would like to say thank you to Ivan Müller, who is the heart and soul of this project. His hard work and persistence, as well as his generosity have impacted my life tremendously. I appreciate our discussions, especially the ones where we agree to disagree. Additionally, I would like to thank Harald Seelig, for not only his statistical knowledge and support but also for his patience. I valued the time he spent explaining, listening and giving advice. I appreciated our idealistic conversations as much as our pragmatic ones. Further, I would like to thank Cheryl Walter, for her advice and support, for our interesting political discussions and for sharing her passion for upliftment in disadvantaged communities. I would like to thank Rosa du Randt for her scientific input and constructive feedback as well as her advice on which running routes are the safest. Special words of thanks go to Jürg Utzinger and Peter Steinmann, I am extremely grateful to have had the opportunity to work with the both of them and to benefit from their experience in scientific writing and publishing.

Furthermore, I would like to thank the team members and research group for their great support, company and friendship. We spent countless hours during fieldwork as well as during our time off, discussing research-related and unrelated issues, overcame multiple challenges, spent time on road trips and sipping rich red wine when the sun was setting, but most importantly I had the privilege to get to know you all personally. To my research sister and good friend Nandi Joubert, who is one of the most kind yet determined people I know. To Larissa Adams, Siphesihle Nqweniso and Danielle Smith, with whom I learned that "there are many ways to kill a cat". I am grateful to have shared this journey with you. To Jan Degen who has challenged yet enriched my life in many ways. To all the master students, Dominique Bänninger, Thomas Hager, Benjamin Wegenstein, Lize van der Walt, Melanie Glover, Chantal Brügger, Nicola Hausner, Roman Aebischer, Jennifer Künzle, Jonas Schöni and Nora Degonda. To all other colleagues and students from the Nelson Mandela University, with whom I either worked at the schools, in the office or shared my coffee and lunch breaks with. Thank you to Shona Ellis for your help with literally everything, I would have been lost without you countless times.

Additionally, I would like to thank my work colleagues at the DSBG. I appreciated the coffee breaks, the swimming lessons, the beach-volleyball sessions, the spike ball rounds, and the encouragement and support. These thanks go to Johanna Beckmann, Robyn Cody, Flora Colledge, Manuel Mücke, René Schilling, Vera-Nina Loser, Varenka Strobel and Christin Lang. Furthermore, I would like to thank Eric Lichtenstein for his help with the complicated Excel script. Concerning this thesis, I would like to thank Robyn Cody and Nandi Joubert for their proofreading and grammar corrections.

I am grateful for my friends who have supported me in all ways possible. Thank you to my best friend Corinne Hasler for your continuous support, belief and encouragement, the long walks, bike rides and for visiting me in South Africa. To Kathrin Beck, Fabia Schaffer and Sophia Vögtli for the pep-talks and your friendship. To Marina Mäder whom I had the privilege to share the first authorship of my second publication. To my tolerant and supportive roommate Sheida Hadji Rasouliha, to my good friend Patricia Wernli who encouraged me over many coffees. To my anyway-friend Aislinn Oeri, thank you for always believing in me, and thank you to Niamh Oeri for helping me to find the golden thread.

Finally, I would like to extend my gratitude to my family. To my parents Urs and Eveline, and to my sister Isabella who have supported me on my educational path and have never stopped believing in me. I thank you for this and for much more!

VI Summary

Background

Globally, only one in five children achieve the recommended 60 minutes of moderate-to-vigorous intensity physical activity per day. This number is even lower in low- and middle-income countries such as South Africa, where only half of all children and adolescents achieve the global physical activity recommendation. Regular physical activity is associated with children's mental health and wellbeing, academic performance and the ability to pay attention at school. However, many South African primary schools located in disadvantaged areas, do not offer regular Physical Education classes due to a lack of facilities and equipment, insufficiently trained teachers and the school subject's low status. Furthermore, access to adequate sanitation facilities and clean water are often lacking in disadvantaged primary schools. This in turn increases the risk of soil-transmitted helminths infections. Being infected with parasitic worms such as *Ascaris lumbricoides* and *Trichuris trichiura*, may lead to symptoms such as abdominal pain, (bloody) diarrhoea and anaemia. Moreover, soil-transmitted helminth infections may lead to growth retardation, school absenteeism, impaired cognitive abilities and reduced physical fitness. Therefore, children from low resourced communities are at an increased risk of ill health which may hamper their development, wellbeing, and academic success.

Aim

This PhD project aims to investigate health indicators and the effect of a 20-week multicomponent school-based physical activity intervention. Our study sample included approximately 1000 fourth grade schoolchildren from disadvantaged primary schools in Port Elizabeth, South Africa. The specific objectives were i) to explore cross-sectional associations and possible determinants of selective attention and academic performance; ii) to investigate the associations between health-related quality of life, self-reported physical activity and cardiorespiratory fitness; iii) to evaluate the effect of a 20-week school-based physical activity intervention program on academic performance, selective attention and health-related quality of life.

Methods

The disease activity and schoolchildren's health study is a cluster-randomized controlled trial with a twice 10 week multicomponent intervention program. Eight quintile three schools were selected based on their classification (quintile 1 represents the poorest schools, while quintile 5 reflects the least poor schools), geographic location, population demographics and the number of students in the grade four classes (at least 100 children). The schools are located in and around Port Elizabeth in south-eastern South Africa. Four schools are in the areas of Kwazakhele, Motherwell, New Brighton and Zwide, which are referred to as townships (mainly inhabited by black Africans who mostly speak Xhosa). The additional four schools are in the areas of Schauderville, Helenvale, Hillcrest and Booysenspark, which are colloquially referred to as the Northern areas (mainly inhabited by coloured people whose native language is Afrikaans).

Physical fitness was assessed via the 20-m shuttle run test (VO_2max) and upper body strength was determined with the grip strength test. Self-reported physical activity was measured with the health-behaviour of school-aged children survey and health-related quality of life was assessed with the KIDSCREEN-27 questionnaire, representing wellbeing. Selective attention was assessed with the pencil and paper version of the d2-test of attention measuring concentration performance and error percentage. The averaged end-of-year school results (Maths, Life Skills, Home Language, and Additional Language) were used as an indicator of academic performance. Demographic data and socio-economic status were captured with a questionnaire. Stool samples were analysed with the Kato-Katz thick smear technique to diagnose soil-transmitted helminth infections. When soil-transmitted helminth infections were detected, children were treated with Albendazole (single dose, 400mg) after each assessment. Haemoglobin levels and anthropometric indicators were measured with standard tools.

The multidimensional physical activity intervention was implemented in four schools, whereas four schools served as control. The intervention lasted for 2x10 weeks and consisted of five parts: i) two Physical Education lessons per week, ii) weekly moving-to-music classes, iii) daily in-class physical activity breaks and iv) physical activity homework as well as v) the creation of a low-cost physical activity-friendly school environment.

Results

At baseline, the study population consisted of 1009 primary schoolchildren aged 9-12 years (501 girls, 508 boys) from 26 school classes. Cross-sectional baseline data revealed that higher academic achievement and selective attention were associated with higher shuttle run performance ($p<0.05$; $p<0.001$). Furthermore, lower selective attention and lower school grades were observed in children with soil-transmitted helminth infection ($p<0.05$; $p<0.001$). Higher self-reported physical activity was associated with health-related quality of life ($p<0.001$). The five dimensions of health-related quality of life are: physical wellbeing, psychological wellbeing, parent relations and autonomy, social support and peers and school. We found small but significant group differences across all five dimensions of health-related quality of life when comparing children with low and high self-reported physical activity ($p<0.001$). No associations were observed between cardiorespiratory fitness and health-related quality of life. The physical activity intervention had a positive effect on academic performance ($p=0.032$) by contributing to the maintenance of school grades, meaning they remained stable. Whereas in the control group a decrease was observed. No effect was found on selective attention (concentration performance; $p=0.469$; error percentage; $p=0.237$) or health-related quality of life, except for the dimension social support and peers reporting a decline after the intervention. However, the concentration performance and health-related quality of life of physically active children was higher compared to their less active peers, independent of control or intervention condition. Also, physically fit children had better concentration performance and reported better physical wellbeing.

Conclusion

The physical activity intervention was positively associated with children's academic performance. Our findings suggest that a physical activity intervention of this nature has the potential to counteract decreases in academic performance in children living in low-resourced communities. Additionally, we found that higher physical activity and positive change in physical activity were prospectively associated with better health-related quality of life. Hence, the regular implementation of Physical Education lesson, and therefore the promotion of physical activity, might have beneficial effects on children's academic performance and wellbeing. Furthermore, low physical fitness and soil-transmitted helminth infections are negatively associated with selective attention. Based on our findings, there is an urgent need to increase children's overall physical activity, to implement regular deworming, and to strengthen hygiene awareness. South African policy makers should support schools and Physical Education teachers in their effort to implement quality Physical Education lessons. Furthermore, the investment in school infrastructure such as the provision of physical activity friendly environments and sport facilities that promote physical activity and play are worthwhile. And the renovation of water and sanitation facilities are paramount for the health and wellbeing of children.

VII Zusammenfassung

Hintergrund

Weltweit erreicht nur jedes fünfte Kind die empfohlenen Bewegungszeit von mindestens 60 Minuten mittlerer Intensität pro Tag. Diese Zahl ist in Ländern mit niedrigem und mittlerem Einkommen wie Südafrika sogar noch niedriger und nur die Hälfte aller Kinder und Jugendlichen erreichen die empfohlene Bewegungszeit pro Tag. Regelmäßige körperliche Bewegung steht in engem Zusammenhang mit der mentalen Gesundheit und dem Wohlbefinden der Kinder, wie auch mit der schulischen Leistung und der Konzentrationsfähigkeit. Viele südafrikanische Grundschulen in benachteiligten Gebieten bieten jedoch aufgrund fehlender Einrichtungen und Ausrüstung, unzureichend ausgebildeter Lehrerpersonen und aufgrund des niedrigen Status des Schulfachs keinen regulären Sportunterricht an. Darüber hinaus fehlt in ärmeren Grundschulen häufig der Zugang zu angemessenen sanitären Einrichtungen und sauberem Wasser. Dies wiederum erhöht das Risiko vom Boden übertragenen Helminthen Infektionen. Eine Infektion mit parasitären Würmern wie *Ascaris lumbricoides* und *Trichuris trichiura* kann zu Symptomen wie Bauchschmerzen, (blutigem) Durchfall und Anämie führen. Darüber hinaus können durch den Boden übertragene Helminthen Infektionen zu Wachstumsverzögerungen, Fehlzeiten in der Schule, beeinträchtigten kognitiven Fähigkeiten und verminderter körperlicher Fitness führen. Daher besteht für Kinder aus ärmeren Gegenden ein erhöhtes Krankheitsrisiko, welches ihre Entwicklung, ihr Wohlbefinden und ihren schulischen Erfolg beeinträchtigen kann.

Ziel

Ziel diese PhD Projektes war, Gesundheitsindikatoren und die Wirksamkeit eines 20-wöchigen schulbasierten Bewegungsprogrammes zu untersuchen. Unsere Stichprobe enthielt ca. 1000 Schüler der vierten Klasse aus sozioökonomischen benachteiligten Grundschulen in Port Elizabeth, Südafrika. Die spezifischen Ziele waren i) die Untersuchung von Querschnittsassoziationen und möglichen Determinanten von selektiver Aufmerksamkeit und Schulerfolg; ii) die Untersuchung von Zusammenhängen zwischen gesundheitsbezogener Lebensqualität, selbstberichtete körperlicher Aktivität und kardiorespiratorischer Fitness; iii) die

Wirkung eines 20-wöchigen schulbasierten Bewegungsprogramm auf die schulische Leistung, die selektive Aufmerksamkeit und die gesundheitsbezogene Lebensqualität zu analysieren.

Methode

Die Studie «Disease, Activity and Schoolchildren's Health» ist eine randomisierte kontrollierte Clusterstudie mit einem zweimal 10-wöchigen Mehrkomponenten-Bewegungsprogramm. Acht Quintile 3 Schulen wurden anhand ihrer Klassifizierung (Quintile 1 repräsentiert die ärmsten Schulen, während Quintile 5 die am wenigsten armen Schulen widerspiegelt), ihrer geografischen Lage, der Bevölkerungsdemographie und der Anzahl der Schüler in vierten Schulstufe (mindestens 100 Kinder), ausgewählt. Die Schulen befinden sich in der Nähe von Port Elizabeth im Südosten Südafrikas. Vier Schulen befinden sich in den Gebieten Kwazakhele, Motherwell, New Brighton und Zwide, die als Townships bezeichnet werden (hauptsächlich von Schwarzafrikanern bewohnt, die vor allem Xhosa sprechen). Die anderen vier Schulen befinden sich in den Gebieten Schauderville, Helenvale, Hillcrest und Booysenspark, die umgangssprachlich als nördliche Gebiete bezeichnet werden (hauptsächlich von farbigen Menschen bewohnt, deren Muttersprache Afrikaans ist).

Die körperliche Fitness wurde über den 20-m-Shuttle-Lauftest (VO2max) ermittelt und die Oberkörperkraft mit dem Grifffestigkeitstest bestimmt. Körperliche Aktivität wurde anhand des Fragebogens: «Health-Behaviour of School-Aged Children» bestimmt und die gesundheits-bezogene Lebensqualität wurde mit dem KIDSCREEN-27-Fragebogen bewertet, der das Wohlbefinden repräsentiert. Die selektive Aufmerksamkeit wurde mit der Bleistift- und Papierversion des d2-Aufmerksamkeitstests erhoben, welcher auf Konzentrationsleistung und Fehlerprozent testet. Die gemittelten Schulergebnisse zum Jahresende (Mathematik, «LifeSkills», Muttersprache und zusätzliche Sprache) wurden als Indikator für die schulischen Leistungen verwendet. Demografische Daten und sozioökonomischer Status wurden mit einem Fragebogen erfasst. Stuhlproben wurden mit der Kato-Katz-Dickabstrich-Technik analysiert, um mögliche bodenübertragene Helminthen Infektionen zu ermitteln. Wenn Infektionen festgestellt wurden, wurden den Kindern Albendazol (Einzeldosis 400 mg) verabreicht. Hämoglobinspiegel und anthropometrische Indikatoren wurden mit Standardgeräten gemessen.

Die Bewegungsintervention wurde in vier Schulen durchgeführt, während vier Schulen als Kontrolle dienten. Die Intervention dauerte 2x10 Wochen und bestand aus fünf Teilen: i) zwei Sportstunden pro Woche, ii) eine wöchentliche Tanzen-zu-Musik Stunde, iii) tägliche Aktivpausen mit Bewegungsaufgaben, iv) Bewegungshausaufgaben sowie v) bewegungsfreundliche Infrastrukturanpassungen.

Resultate

Zu Studienbeginn bestand die Studienpopulation aus 1009 Grundschulkindern im Alter von 9 bis 12 Jahren (501 Mädchen, 508 Jungen) aus 26 Schulklassen. Querschnittsdaten zeigten, dass höhere Schulleistung und selektive Aufmerksamkeit mit einer höheren Shuttlerun-Laufleistung verbunden waren (p<0,05; p<0,001). Darüber hinaus wurden bei Kindern mit bodenübertragener Helminthen Infektion eine geringere selektive Aufmerksamkeit und niedrigere Schulnoten beobachtet (p<0,05; p<0,001). Höhere selbstberichtete körperliche Aktivität war mit gesundheitsbezogener Lebensqualität assoziiert (p<0,001). Die fünf Dimensionen der gesundheitsbezogenen Lebensqualität sind: körperliches Wohlbefinden, psychisches Wohlbefinden, Beziehungen zu Eltern und Autonomie, soziale Unterstützung und Gleichaltrige und schulisches Umfeld. Beim Vergleich von Kindern mit geringer und hoher selbstberichteter körperlicher Aktivität fanden wir kleine, aber signifikante Gruppenunterschiede in allen fünf Dimensionen der gesundheitsbezogenen Lebensqualität (p<0,001). Es wurden keine Assoziationen zwischen kardiorespiratorischer Fitness und gesundheitsbezogener Lebensqualität beobachtet. Die physische Intervention wirkte sich positiv auf die schulische Leistung aus (p = 0,032), indem sie zur Aufrechterhaltung der Schulnoten beitrug, was bedeutete, dass sie stabil blieben. Während in der Kontrollgruppe eine Abnahme beobachtet wurde. Es wurde kein Effekt auf die selektive Aufmerksamkeit (Konzentrationsleistung; p = 0,469; Fehlerprozent; p = 0,237) oder die gesundheitsbezogene Lebensqualität festgestellt, mit Ausnahme der Dimension soziale Unterstützung und Gleichaltrige, die nach der Intervention einen tieferen Wert anzeigte. Die Konzentrationsleistung und die gesundheitsbezogene Lebensqualität körperlich aktiver Kinder waren jedoch höher als bei weniger aktiven Altersgenossen, unabhängig von Kontroll- oder Interventionsgruppe. Zusätzlich wurde festgestellt, dass körperlich fitte Kinder eine bessere Konzentrationsleistung und körperliches Wohlbefinden haben.

Fazit

Die Bewegungsintervention stand im positiven Zusammenhang mit der schulischen Leistung der Kinder. Unsere Ergebnisse zeigen, dass eine solche Intervention das Potenzial hat, einem Rückgang der schulischen Noten bei Kindern in ärmeren Gegenden entgegenzuwirken. Darüber hinaus stellten wir fest, dass eine höhere körperliche Aktivität und eine positive Veränderung der körperlichen Aktivität prospektiv mit einer besseren gesundheitsbezogenen Lebensqualität verbunden waren. Daher könnte der Sportunterricht und die körperliche Aktivität positive Auswirkungen auf die schulischen Leistungen und das Wohlbefinden der Kinder haben. Darüber hinaus hängen geringe körperliche Fitness und durch den Boden übertragene Helminthen Infektionen negativ mit selektiver Aufmerksamkeit zusammen. Basierend auf unseren Erkenntnissen ist es dringend erforderlich, die allgemeine körperliche Aktivität von Kindern zu steigern, regelmäßige Entwurmung durchzuführen und das Hygienebewusstsein zu stärken. Südafrikanische Politiker sollten Schulen und Sportlehrer bei ihren Bemühungen unterstützen, qualitativ hochwertigen Sportunterricht zu erteilen. Darüber hinaus lohnen sich Investitionen in die Schulinfrastruktur wie die Bereitstellung Bewegungsfreundlicher Umgebungen und Sportanlagen, die Bewegung und Spiel fördern. Ebenso bedeutend, ist die Renovierung von Wasser- und Sanitäranlagen ist für die Gesundheit und das Wohlbefinden von Kindern.

Chapter 1 Introduction

1.1 Benefits of physical activity and physical fitness

In the 1950s a British epidemiologist named Jeremy Morris was the first researcher who discovered that physical activity was associated with coronary heart disease. Morris examined two groups of men who worked on London's double-decker busses. The first group was mostly sedentary and consisted of bus drivers who were sitting for almost the entire shift. The second group, consisting of conductors, were more active since they climbed roughly 500-750 stairs each working day. Despite the fact that all men came from similar working classes, the active group had fewer than half the number of heart attacks compared to their sedentary colleagues (Morris et al., 1953). Today, almost 70 years later, the benefits and evidence of physical activity and fitness in children, adolescents and adults, is undisputable.

First, it is important to clarify the terms physical activity and physical fitness. It is usually assumed that active people will have a higher level of physical fitness, and that the relationship is causal. In order to examine the relationship between these two concepts, it is perhaps best to start by defining them. Physical activity, physical exercise and physical fitness are often used interchangeably since they are closely related. Physical activity refers to any bodily movement produced by skeletal muscle, which requires the consumption of energy (Caspersen et al., 1985). Physical exercise, on the other hand, is a subcategory of physical activity, that is usually planned, structured and requires repetitive body movements for the purpose of maintaining or improving one or more components of physical fitness (Caspersen et al., 1985). Physical fitness can be interpreted as a measure of the capacity to perform physical activity and/or physical exercise. Physical fitness can be understood as a set of attributes an individual has or can achieve and it can be divided into health-related and skill-related. Health-related fitness includes cardiorespiratory fitness, muscular strength, muscular endurance, muscular flexibility, and body composition (Caspersen et al., 1985). Furthermore, health-related fitness is associated with lower prevalence of chronic disease and has a strong relationship with health and wellness (American College of Sports et al., 2018). Skill-related physical fitness consists of agility, coordination, balance, power, reaction time and speed (Caspersen et al., 1985). Even though a large part of the variability in physical fitness is genetically determined, in fact about 40-50 percent of aerobic fitness (Bouchard et al., 1998, Ross et al., 2019) and about 50-60 percent of

strength and muscle mass (Simoneau and Bouchard, 1995, Silventoinen et al., 2008) can be attributed to a person's genes. However genes are not the only determinant, socio-environmental factors, and particularly physical exercise, also influence physical fitness to a large extent (Martínez-Vizcaíno and Sánchez-López, 2008). Similar to the fact that genes influence our fitness and strength, evidence points towards the fact that a considerable amount of the daily physical activity level is genetically determined. More specifically, biological factors such as hormones which regulate drive and motivation, and social-environmental factors such as the presence of sidewalks, peer/parent support, illness, diseases, diet and environmental toxins influence physical activity (Lightfoot et al., 2018). However, regardless of a person's genes, hormones or social-environment, physical activity and physical fitness are powerful markers of health and physical activity should be part of our daily routine. The next section will provide an overview of the most important findings from studies that investigated the benefits of physical activity and fitness in children, adolescents and adults. These were grouped into three main categories: i) mental health, ii) cognition and iii) physical health (including the prevention of non-communicable diseases (NCDs)). The next section will, in a first step, take a closer look at the adult population and then in a second step at adolescents and children.
Mental health benefits of physical activity and physical fitness are improved mood, reduced anxiety (Ströhle, 2009) and fewer depressive symptoms (Pinto Pereira et al., 2014). Research has linked poor mental health with a higher risk of developing heart problems (Dhar and Barton, 2016) and diabetes mellitus (Holt and Mitchell, 2015). Furthermore, exercise seems to be effective in reducing and regulating stress (Klaperski, 2018), which in turn when left unmanaged, can lead to serious health problems such as coronary heart disease, inflammation and asthma (Wirtz and von Kanel, 2017, Rosenkranz et al., 2016).

Recent research supports the notion that physical activity is associated with brain health (Opel et al., 2019). In fact, a meta-analysis with an overall sample size of over 117'000 participants found that physical activity is an important modifiable risk factor for reducing the risk of Alzheimer's disease, all-cause dementia, and cognitive decline (Guure et al., 2017). Moreover, a study by Erickson et al. (2011) found that physical activity increased the size of the hippocampus in older adults, which is the part of the brain responsible for memory, learning and emotion. Equally important is the study by Ding et al. (2018) who found that older adults with a higher maximal oxygen uptake (VO_2max) score, had less deterioration of the white-matter fibres, which are associated with critical thinking and planning skills.

In terms of physical health, research shows that physical activity and fitness are associated with healthy ageing (Daskalopoulou et al., 2017), improved quality of sleep (Yang et al., 2012) and a reduced risk of falls in older people (Carter et al., 2002). Furthermore, there is a strong link between physical inactivity and major non-communicable diseases. In fact, research shows that being physically active reduces the risk of NCDs such as coronary heart disease, high blood pressure, stroke, metabolic syndrome, type II diabetes, osteoporosis, as well as breast and colon cancer significantly (Warburton et al., 2010). Moreover, insufficient levels of physical activity has been identified as one of the leading risk factors responsible for the global disease burden, with an estimated 1.4 million deaths attributed to low physical activity in 2016, an increase of 18.4% since 2006 (Vos et al., 2017).

To address the question of how much physical activity (dose-response) is needed for the prevention of NCDs, the World Health Organisation (WHO) developed global physical activity guidelines for health (WHO, 2010). According to WHO, adults aged 18-64, should accumulate at least 150 minutes of moderate-intensity aerobic physical activity or 75 minutes of vigorous-intensity aerobic physical activity weekly, or an equivalent combination. Also, muscle-strengthening activities should be performed involving major muscle groups on two or more days a week (WHO, 2010). Yet for individuals who are physically inactive or unfit, even small improvements in fitness and activity can translate into significantly lower risk of all-cause mortality and cardiovascular disease (CVD) (Warburton et al., 2006).

While the negative effects of NCDs are mainly manifested in adults, it becomes evident that the development of these conditions start much earlier in life (Hallal et al., 2006, Cook et al., 2009). It seems therefore reasonable to conclude, that the promotion of physical activity and fitness during childhood and adolescence are essential to establish healthy habits, which in turn may help prevent NCDs later in life.

Childhood and adolescence are crucial periods of life (Institute of Medicine (U.S.), 2013). The next paragraph will provide an overview of evidence from the past 20 years which demonstrate that physical activity and physical fitness are important for the development and health of children and adolescents. The findings are again grouped into three main categories: i) mental health, ii) cognition and iii) physical health (including the prevention of NCDs).

The scientific community largely agrees that physical activity and physical fitness have positive effects on overall mental health and health-related quality of life (Wu et al., 2017, Gopinath et al., 2012, Andersen et al., 2017), on the prevention or treatment of developing mental health disorders such as depression and anxiety (Korczak et al., 2017, Ströhle, 2009, Brown et al., 2013, Biddle and Asare, 2011) and on prosocial behaviour (Australian Government Department of Health, 2019). The underlying mechanisms responsible for the effects of physical activity on mental health are unclear; however, several hypotheses have been proposed (Rodriguez-Ayllon et al., 2019). On a physiological level, physical activity might enhance mental health through the release of endorphins (Dishman and O'Connor, 2009) and through the development of new neural pathways (Cotman et al., 2007). On a psychological level it might satisfy basic psychological needs such as social connectedness, self-acceptance, and purpose in life, and consequently improve overall mental health in young people (Lubans et al., 2016, Rodriguez-Ayllon et al., 2019). In line with this finding Eime et al. (2013) and Howie et al. (2010) report that sport participation increases social health through positive relationships with coaches, opportunities of social learning, making new friends, and through the development of teamwork and social skills. Furthermore, Haugen et al. (2011) found that increased levels of physical activity may be beneficial for the global self-worth in male and female adolescents by enhancing their perceptions of physical self-esteem. Physical activity has also been associated with mental toughness (Brand et al., 2016, Brand et al., 2017), a mindset which may help children who are physically active and have higher physical fitness to better cope with stress (Gerber et al., 2017, Gerber et al., 2016).

A vast majority of studies agree that there is a relationship between cognition, physical activity and physical fitness in children and adolescents (Tomporowski et al., 2015, Tomporowski et al., 2008, Donnelly et al., 2016, Sibley and Etnier, 2003, Doherty and Forés Miravalles, 2019). Especially executive function (inhibition, working memory, and cognitive flexibility), attention and academic performance seem to benefit from physical activity and physical fitness (de Greeff et al., 2018), which in turn lay the foundation for learning, academic gains and thus future success. Possible explanations are proposed by Donnelly et al. (2016) who suggest that physical activity has an indirect effect on academic performance through a pathway of executive functions. The direct effect of physical activity on this higher-order cognitive function has been attributed to morphological changes (i.e., angiogenesis, neurogenesis, and synaptogenesis) in brain regions that are important for learning (Hillman et al., 2008). The promotion of physical activity in early childhood may also help to develop motor skills (Zeng et al., 2017) and cross-sectional studies show a reciprocal relationship between physical activity and motor development (Fisher et al., 2005, Williams et al., 2008). Basic motor competencies are the prerequisites for children's active participation in sports culture and play, therefore, a major role for an active lifestyle in future (Herrmann et al., 2019).

In terms of physical health, research indicated that physical activity is associated with sleep. Lang et al. (2016) reported that adolescents with higher subjective and objective physical activity levels are more likely to experience good quality of sleep. And in line with this finding, Nixon et al. (2009) describe that children who were physically active during the day, fall asleep more rapidly compared to their sedentary peers. In turn insufficient sleep and sleep disruption are associated with a wide range of behavioural, cognitive and mood impairments, including hyperactivity, reduced school grades and depression (O'Brien, 2011). Furthermore, physical activity is associated with stronger bones (Gabel et al., 2017), particularly activities which apply large forces rapidly, such as jumping, appear to benefit the bone mineralisation and structure in children and adolescence, which in turn has the potential to prevent osteoporosis later in life (Gunter et al., 2012). Additionally, research suggests that children who engage in higher levels of physical activity during childhood have lower resting blood pressures (Cesa et al., 2014), higher cardiovascular health (Andersen et al., 2006) and more favourable indicators of arterial stiffness (Haapala et al., 2017). Furthermore, physical activity helps keep weight stable (Janssen and Leblanc, 2010), improves metabolic disorders, such as hypertension, dyslipidaemia and impaired glucose tolerance (Maffeis and Castellani, 2007) and therefore, physical activity prevents NCDs.

Considering these benefits, the WHO recommends that children and youth aged 5-17 years should accumulate at least 60 minutes of moderate-to-vigorous intensity physical activity (MVPA) daily. They further state, that most of the daily physical activity should be aerobic and that activities which strengthen muscle and bones should be incorporated at least three times per week (WHO, 2010).

1.2 Global physical activity levels in youth

Despite the benefits summarised in the previous paragraphs, physical activity levels in youth are declining worldwide. In a study incorporating 1.6 million school-going adolescents (11 to 17 years old) from 146 countries, 81% of the students did not reach the minimum recommendation of 60 minutes of MVPA per day (Guthold et al., 2020). Similar results were found, in the Global Matrix 3.0 Physical Activity Report Card, a study including 49 countries where common indicators were graded in order to harmonize available data. The average global grade for physical activity was given grade D, equivalent to 21 % to 40 % of children achieving the recommended 60 minutes of MVPA daily (Aubert et al., 2018). These numbers are alarming given the fact that physical inactivity has negative consequences on physical, mental, social and cognitive health outcomes (Janssen and Leblanc, 2010, Poitras et al., 2016, Kremer et al., 2014, McMahon et al., 2017), is associated with lower physical fitness (Blair et al., 2001) and lower physical activity levels later in life (Telama et al., 2005). Figure 1.2 depicts the worldwide physical inactivity trend for school-going girls aged 11-17 years and Figure 1.3 depicts the trend correspondingly for school-going boys.

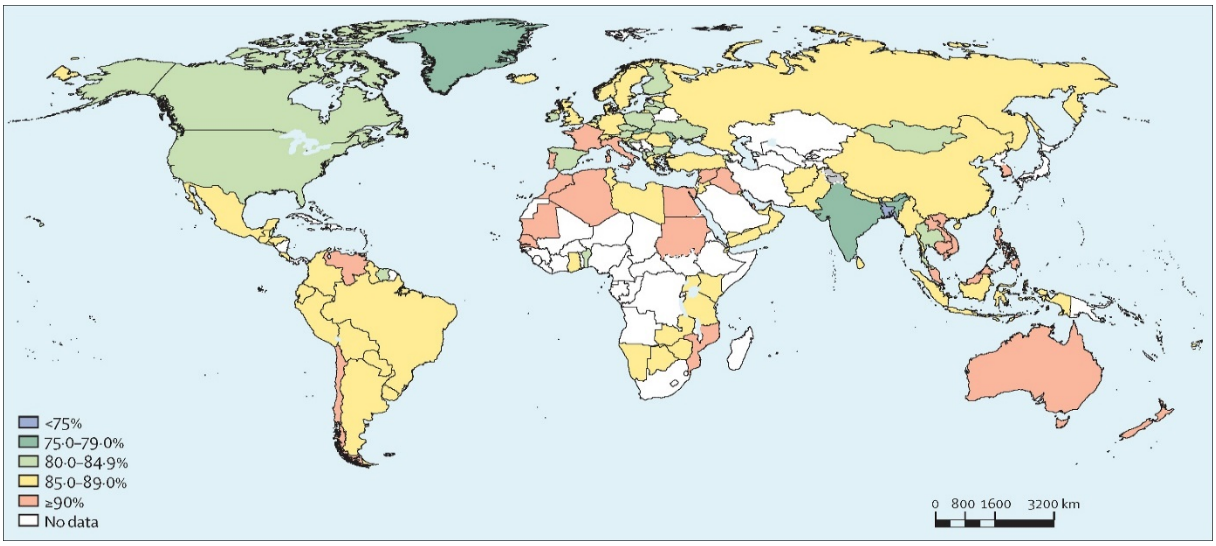


Figure 1.1 Prevalence of insufficient physical activity among school-going girls aged 11–17 years, 2016 (Guthold et al. 2019)

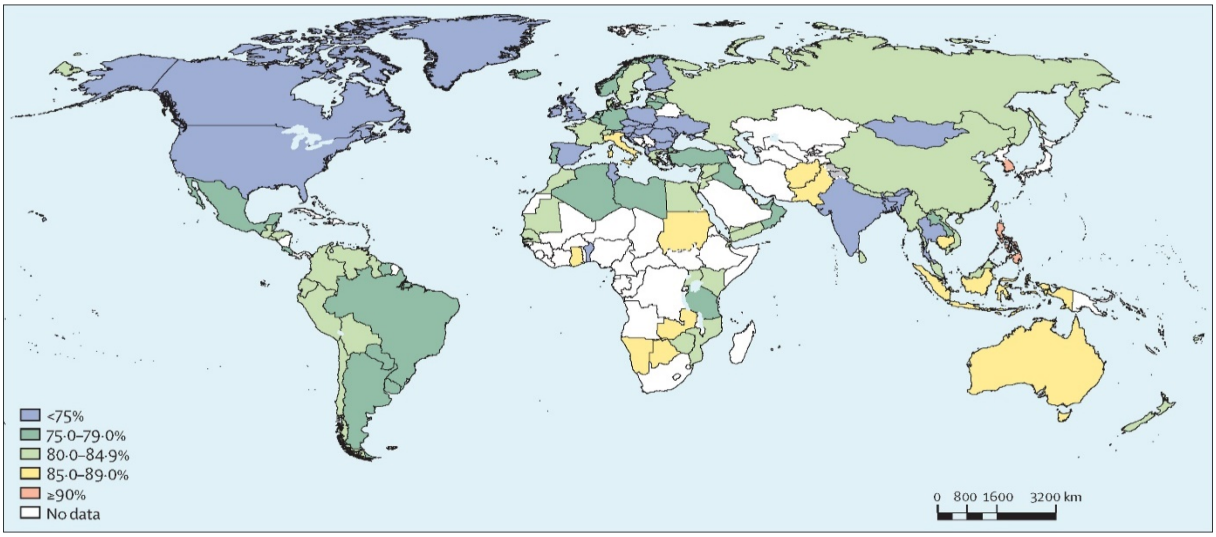


Figure 1.2 Prevalence of insufficient physical activity among school-going boys aged 11–17 years, 2016 (Guthold et al. 2019)

1.3 Physical inactivity and health burden in South Africa

In South Africa approximately 50% of children and adolescents are considered insufficiently active (Draper et al., 2018). Furthermore, researchers have estimated that among South Africans older than 15 years, about 30% of ischemic heart disease, 27% of colorectal carcinoma, 22% of ischemic stroke, 20% of type II diabetes and 17% of breast cancer are the result of physical inactivity (Joubert et al., 2007). A recent longitudinal study, including 3'273 urban South African Adolescents born between April and June 1990 in Soweto and in Johannesburg, found that only 18% of male and 0% of the female participants (aged 12 to 17) met the WHO recommendation of 60 minutes of moderate-vigorous intensity physical activity per day (Hanson et al., 2019). Moreover, South Africa has moved towards a disease profile similar to Western countries. Which means that many school-aged children are overweight or obese and increasing proportions of deaths among adults are attributed to chronic diseases of lifestyle (Steyn and Damasceno, 2006, Kipping et al., 2008). These modifiable risk factors pose a significant challenge for the health care system of South Africa. One way of addressing physical inactivity is through school-based interventions and the strengthening of Physical Education at schools.

1.4 The promotion of physical activity and fitness at school

The single most important channel to address physical inactivity in youth is through school. The subject Physical Education is the only setting where all children, especially those from low socio-economic status families, have access to moderate-to-vigorous intensity physical activity and learn important fundamental movement skills that may provide the foundation for a lifetime of physical activity (Lubans et al., 2010, Hills et al., 2015). Schools have therefore an immense responsibility, not only to provide children with the opportunity to meet the daily physical activity recommendations, but to cultivate physical literacy. Physical literacy, as defined by Whitehead (2006) can be described as "the motivation, confidence, physical competence, knowledge and understanding to maintain physical activity throughout life, and refers to the skills needed to obtain, understand and use information to make good decisions for health". The promotion of physical literacy at school and through the subject Physical Education might be especially important for children living in disadvantaged areas, since opportunities for physical activity outside the school environment are lacking (Walter, 2011).

Research on the promotion of physical activity and fitness at school shows that children who spent more time participating in physical activities showed higher levels of physical fitness and also better academic performance (Van Dusen et al., 2011). Le Masurier and Corbin (2006) further demonstrated that Physical Education programmes enable students to participate in a variety of physical activities by providing them with the opportunity to learn motor skills, such as throwing, catching, dribbling, bouncing, running, rolling, jumping and balancing. Similarly, Herrmann et al. (2015) and Bailey et al. (2006) state that Physical Education and sport promote the development of a broad range of basic movement and motor skills that are likely to encourage learners to be physically active. However, Haerens et al. (2011) argue that Physical Education can only promote an active lifestyle if the activities provided are considered enjoyable, personally relevant and interesting, so as to impact children's and adolescent's intrinsic motivation to engage in physical activities outside school. This view is supported by the self-determination theory of Deci and Ryan (2000). Their theory states that students are more likely to engage in activities outside of school, when activities are perceived as inherently meaningful, interesting and enjoyable, or when activities hold personal relevance (Haerens et al., 2011, Haerens et al., 2010). Therefore, Physical Education teachers should be motivated, trained and competent in providing learners with opportunities that enhance intrinsic motivation. However, Physical Education teachers do not always have the right training, experience, or motivation depending on the available resources and policies in the country. This is especially the case in lower socio-economic areas where access to facilities and equipment is limited. Furthermore, parents, teachers, principals and politicians perceive the subject Physical Education as low status and less important than "academic" subjects (UNESCO, 2014). The reason for the low status of the subject is multifaceted. One the one hand, past negative experiences as a Physical Education student might influence the perception of the subject negatively. Furthermore, there is a general lack of understanding of the importance of physical literacy (Lago-Ballesteros et al., 2019). On the other hand, the government does not see Physical Education as priority, and therefore not enough time and budget is allocated to Physical Education. Consequently, Physical Education is often marginalised, allocated to untrained teachers and even neglected within the school curriculum (UNESCO, 2014).

1.5 Physical Education in the school curriculum

The world-wide survey of school Physical Education, including data from 232 countries (Africa 43, Asia 23, Europe 57, Latin America 23, Middle East 14, North America 61 and Oceania 11), stated that 97% of countries include Physical Education in their general education system. This means, there are either legal requirements or it is part of general practice for both girls and boys to attend Physical Education in at least one stage of compulsory schooling (UNESCO, 2014). Unfortunately, the actual implementation of the subject Physical Education does not meet legal obligations (Du Toit et al., 2007). In 29% of these countries, Physical Education is not being implemented in accordance with the school curriculum. This is partly due to the fact that 54% of countries perceive Physical Education as a low status subject .This is equally true for both northern and southern hemisphere countries. (UNESCO, 2014).

1.6 Physical Education in South Africa

The perception of Physical Education as a low status subject holds especially true for low- and middle-income countries, such as South Africa. The subject Physical Education has lost its stand-alone status after the democratic government was elected in 1994 and was only reinstated in the National Curriculum after an absence of more than 10 years (South African Department of Basic Education, 2011a). Physical Education is now part of a multidimensional learning area called Life Skills for grades R-6 and Life Orientation for grades 7-12. For the foundation phase (grade R-3), the subject Life Skills is being taught six hours per week and consists of the four learning areas: Beginning Knowledge, Creative Arts, Physical Education and Personal and Social Wellbeing. Thereof, Physical Education is allocated two hours per week. For the intermediate phase (grades 4-6) Life Skills has been allocated four hours per week, with only one hour dedicated to Physical Education. Life Orientation for the senior phase (grade 7-12) is allocated two hours per week, of which one is given to Physical Education (South African Department of Basic Education, 2011a). The South African Curriculum, in comparison to most other countries worldwide, allocates little time to Physical Education (Pühse and Gerber, 2005), with 58 minutes per week in primary school (range 30-120 minutes) and 63 minutes in high school (range 30-120 minutes) (UNESCO, 2014). This deficiency of Physical Education is further aggravated by the fact that a number of schools do not follow the National Curriculum and Assessment Policy Statement (CAPS) (Du Toit et al., 2007). Reddy et al. (2003) report in their study that only every second South African child had Physical Education classes on their timetable. However, since South Africa consists of both advantaged and disadvantaged schools and communities, the lack of Physical Education implementation holds particularly true for the latter (Du Toit et al., 2007). Historically disadvantaged schools face multiple challenges in the implementation of Physical Education such as inadequate or non-existing recreation and sports facilities and sports equipment, large class sizes of up to 60 learners per class and underqualified Physical Education teaching staff (Van Deventer, 2009, Stroebel et al., 2016). The state and status of the subject Physical Education can, on the one hand, be attributed to the political history of South Africa (Du Toit et al., 2007) and, on the other hand, to the fact that South Africa is listed as a country with an emerging economy. Emerging economies are defined as rapidly growing and volatile, where potential for growth is accompanied by substantial risks in terms of political, economic and social perils (Hoskisson et al., 2000). With regards to education, the challenges that countries with emerging economies face, are more typical of a regression, ranging from dropout rates, teacher shortages to insufficient funds (Damon et al., 2016). In the next paragraph we will take a closer look at South Africa and the challenges the country faces in light of historical, political as well as economic reasons.

1.7 South Africa: economic and political challenges

South Africa is one of the most developed countries in Sub-Saharan Africa, with an estimated population of 58.78 million. The unemployment rate was 29.1% in the third quarter of 2019 and youth aged between 15-24 years are the most vulnerable in the South African labour market as the unemployment rate among this age group was 55.2% in the first quarter of 2019 (Statistics South Statistics South Africa, 2019). According to the World Bank's human capital index, South Africa ranks 126 out of 157 countries, behind Malawi and eSwatini, formally known as Swaziland (World Bank, 2019). The human Capital Index measures the knowledge, skills, and health that people gain throughout their lives, which enables them to realize their full potential as productive members of society. The human capital index of South Africa is 0.41, which means that a child born in South Africa will only have a 41% chance of being productive as an adult.

South Africa's education system foresees 13 years of school, including grade R. A child who starts school at six can expect to complete 9.3 years of schooling by the age of 18. However, when years of schooling are adjusted for quality of learning, this is only equivalent to 5.1 years, which is a learning gap of 4.2 years, as displayed in figure 1.4 (World Bank, 2019).

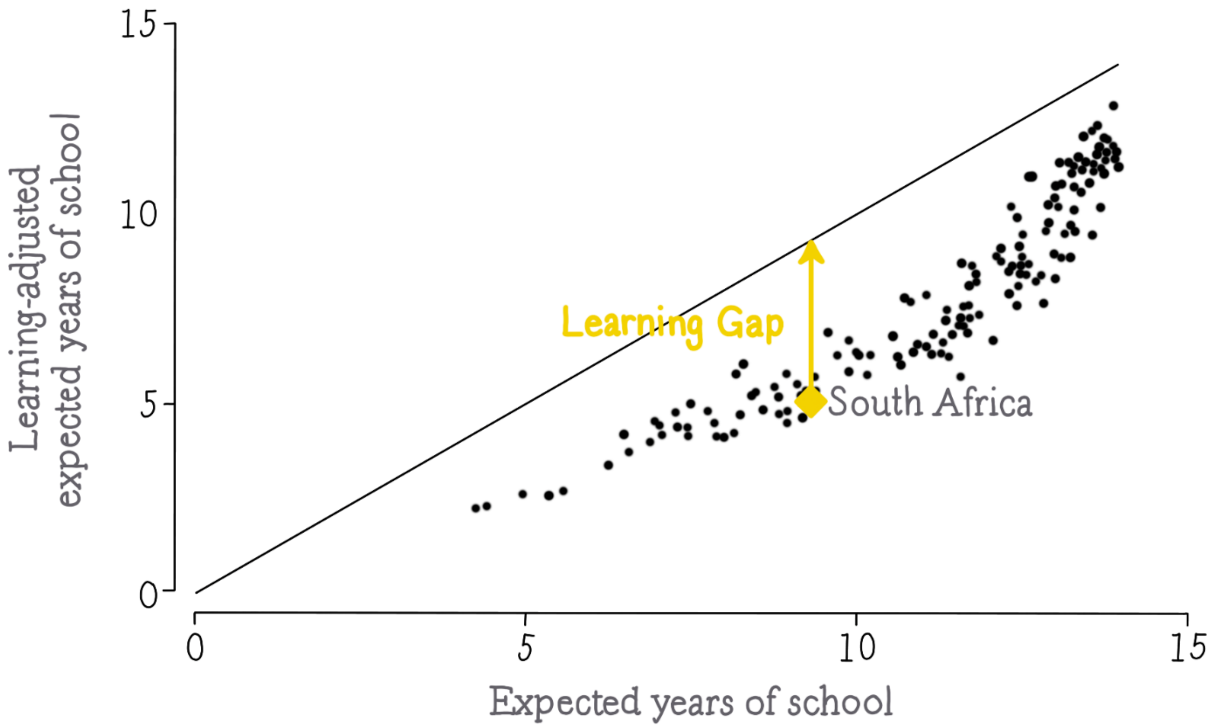


Figure 1.3 Learning Gap (adapted from World Bank, 2019)

The challenges in the education sector in South Africa are neither singular nor simple, but they are the legacy of the Apartheid system, which divided the country into two nations:

> *… the one black, the other white … [the latter] is relatively prosperous and has ready access to a developed economy, physical, educational, communication and other infrastructure… The second, and larger, nation of South Africa is black and poor, [and] lives under conditions of a grossly underdeveloped infrastructure…* (Mbeki, 1998)

The metaphor still holds true today, two decades after the end of Apartheid, where South Africa has not one, but two education systems. The first system, consisting of mainly former white and Indian schools, is well resourced and entails a small but growing private sector. The first system ensures that most children acquire competences that are comparable to those of middle-class children anywhere in the world. The second school system, is less than adequate, yet it enrols the vast majority of the working-class and children from lower socio-economic settings (Fleisch, 2008). In an effort to eliminate inequalities between the 'two systems', the present government allocates funds to public schools, based on their socio-economic status. These funds barely cover the basic staff salaries. Therefore, most schools supplement the government grant with school fees paid by parents, fundraising events and donations. Once more, since there is no limit to the amount of fees that schools can demand, socioeconomically disadvantaged children will not be able to attend the well-equipped and well-functioning schools (Kanjee and Chudgar, 2009).

1.8 South African history and its consequences on Physical Education

The situation pertaining to Physical Education differed significantly even before Apartheid. In first system schools (with predominantly white children), Physical Education established itself as an indispensable part of education and was taught gender specific (Stroebel et al., 2016). Schools pertaining to the second system, predominantly black children, were mostly missionary run and education was neither free nor compulsory. Sports equipment and sport facilities were available in first-system schools, partly funded by the government and partly by school fees. However, very little equipment, if any, was supplied to schools located in lower socio-economic areas (Archer and Bouillon, 1982). The Bantu Education Act of 1953, a segregation law which legalised several aspects of the Apartheid system, issued that schools with mostly black African children, were removed from missionary bodies and placed under the Department of Native Affairs. Even though Physical Education was included in the school curriculum of these schools, there was a considerable shortage of teachers, classrooms and sports facilities (Christie and Collins, 1990). Whereas in more affluent schools, Physical Education was viewed as an instrument to further the ideological agenda of the Apartheid government and was compulsory with two periods allocated for grades 1 to 12 (Rajput and van Deventer, 2010, Stroebel et al., 2016). After the first democratic election in 1994 and the transition into a democracy, South Africa's government launched several reconstruction, reconciliation and development programs. These programmes had the aim to restore justice and mobilise resources toward the final eradication of Apartheid and the building of a democratic, non-racial and non-sexist future. In the immediate aftermath of the election, the school syllabuses were thoroughly revised and the racially offensive and outdated content was removed (Jansen, 1999). However, Physical Education was starting to be perceived as a low-status subject due to the belief that participation in physical activity was taking time away from more important subjects such as Maths or English. Furthermore, Physical Education was seen as non-examinable and was therefore excluded as a stand-alone subject in 1994 (Du Toit et al., 2007). Prior to 1994 more than 120 national teacher training colleges offered courses in Physical Education training, but after losing its stand-alone status, teacher training colleges and higher education institutions, gradually stopped offering specialised Physical Education teacher training (Rajput and van

Deventer, 2010). As a result, at schools Physical Education was mostly taught by non-specialist teachers, who rotated the unpopular task regularly, which in turn had a detrimental effect on the status and practice of Physical Education. In 1997, the minister of education, Sibusiso Bengu, announced that from 1998 a new school curriculum will be implemented, namely the curriculum 2005 (C2005) (Jansen, 1999). C2005, which was regarded as the master plan to eradicate the inequalities of the Apartheid education system, comprised of a completely new philosophy which was based on outcomes based education (OBE). The new philosophy focused on pupil-centred education rather than teacher-led classroom engagement, competences rather than pass or fail, outcomes rather than aims and objectives and assessment criteria. With the new C2005, school subjects were replaced with learning areas, which led to the dawn of a new learning area called Life Orientation (Stroebel et al., 2016). This drastic shift marginalised the former stand-alone subject Physical Education to one of eight Learning Outcomes within the learning area Life Orientation. One period a week was allocated to Life Orientation, in which the eighth outcome, was Human Movement and Development (Van Deventer, 2009, Stroebel et al., 2019). C2005 and OBE was critiqued substantially, as teachers and schools were not prepared to take on the new demands C2005 posed. Teachers found the implementation of OBE difficult due to the large class sizes and because they regarded the assessment methods difficult and problematic. Therefore, a review process was commissioned by the Department of Education in 2000, which led to a revision of C2005, called Revised National Curriculum Statement (R-NCS) and was introduced in 2004 (Pudi, 2006). Further revisions of the curriculum followed in 2009, resulting in the National Curriculum and Assessment Policy Statement (CAPS). CAPS was implemented in 2011 and is still in use today (South African Department of Basic Education, 2011a). The CAPS committee developed a new curriculum for each subject including the study areas known as Life Skills (taught in the Foundation Phase from grade 1-3, and in the Intermediate Phase from grade 4-6) and Life Orientation (taught in the senior phase, consisting of grade 7-12). The purpose of the subject Life Skills/Life Orientation is to equip learners with knowledge, skills and values that assist them to achieve their full physical, intellectual, personal, emotional and social potential. The subject Life Skills aims to develop learners through three different, but interrelated study areas, that is, Personal and Social Well-being, Physical Education and Creative Arts. The subject Life Orientation focuses on the development of self-in-society and contains the following five topics: i) development of the self in society, ii) health, social and environmental responsibility, iii) constitutional rights and responsibilities, iv) Physical

Education and v) world of work. At the school level, Physical Education specialists were largely no longer appointed, but instead, generalist teachers, who had neither knowledge nor understanding of Physical Education, were required to teach the subject Life Skills. A repercussion of the restructuring was that the Life Skills/Life Orientation teachers had to become masters of a multi-faceted subject almost overnight. The teachers had to demonstrate knowledge in Social and Natural Science (Beginning Knowledge), Psychology and Sociology (Personal and Social Wellbeing), the Fine Arts (Creative Arts), Human Movement Science (Physical Education), without proper training (Stroebel et al., 2019). According to a study by Prinsloo et al. (2007) being considered a qualified Life Orientation teacher can range from being a teacher in one of the former subjects such as Guidance, Religion Studies or Physical Education; attending a three-day Human Immunodeficiency Virus (HIV) and Acquired Immunodeficiency Syndrome (AIDS) course; or attending a two-hour Life Orientation workshop. Knowledge around HIV and AIDS is a relevant topic for a Life Orientation teacher, especially since South Africa is the world’s worst-affected country. In fact, in 2017 approximately 7.9 million people, or in other words 13.9%, of all ages were living with HIV. Even more drastic are the numbers when looking at the age range 15 to 49 years, where the HIV prevalence was 20.6%, with 26.3% being women and 14.8% being men. Even though, the participation in a three-day HIV and AIDS course is highly relevant for a Life Orientation teacher, it will however not equip the teacher with skills relating to the other four topics such as for example Physical Education. Underlining this notion, Deventer (2012) and Stroebel et al. (2017) found that 58% of the Life Orientation teachers in Western Cape Schools, and more than two thirds of in-service Foundation Phase Life Skills teachers at primary schools in the Free State Province, were not qualified to teach Physical Education. In summary, every second Life Skills and Life Orientation teacher is not properly trained to teach Physical Education. The curriculum reform has so far been unable to provide in service and pre-service teachers with the needed tools and skills to implement quality Physical Education (Stroebel et al., 2019). As a result, students are deprived of quality Physical Education which lays the foundation for health and wellbeing and for an active lifestyle later in life.

Even though, the status of Physical Education and problems pertaining to implementation in South Africa are comparable to other countries worldwide, there are unique challenges that need to be overcome. As previously mentioned, South Africa consists of both advantaged and disadvantaged school communities, deriving from mainly two different social backgrounds. The next paragraph will provide an overview of challenges within these disadvantaged settings.

1.9 South Africa: challenges in disadvantaged settings

The present study was conducted in townships in the Nelson Mandela Bay Municipality, in the Eastern Province of South Africa. A Township refers to an underdeveloped and segregated urban area where racial groups classified as non-white were forcefully relocated during Apartheid. Most townships were developed on the periphery of towns and cities and were lacking basic services such as clean water, electricity, sewerage and road infrastructure, this holds partly still true today (du Plessis, 2013). Challenges that are common within townships are high unemployment rates, overcrowding, violence, poverty, the lack of services, such as health care, sanitation, electricity, physical security, and high quality academic and physical education. On the one hand, these socio-economic problems directly influence children's psychological and physiological development and wellbeing (Lu et al., 2016). And on the other hand, they influence the school setting in terms of the teaching and learning environment to the detriment of children's education (Zulu *et al.*, 2004). Even though, South Africa has experienced steady economic growth, addressing inequalities has been a challenge since 1994 (McIntyre and Gilson, 2002). The circumstances and challenges surrounding learners, teachers and school settings will subsequently be discussed in further detail.

1.9.1 Challenges related to children

Children living in disadvantaged neighbourhoods experience less social support, watch more TV and have fewer places to engage in physical activity and play. They are exposed to more crime, more family turmoil and violence (Evans, 2004). Being exposed to stressors such as shootings, violence, neglect or hunger (Maringira and Gibson, 2019) has been linked to damaging the self-regulatory capacities in children (Blair and Raver, 2012, Blair, 2010). Self-regulation entails tasks such as, listen to the teacher and act accordingly as well as waiting their turn and pay attention in class essentially of his or her own accord (Rimm-Kaufman and Pianta, 2000). Research has shown that self-regulation provides the basis for a broad range of developmental competences (Blair and Razza, 2007). These in turn are highly relevant for school readiness and academic achievement (Valiente et al., 2008). Equally important are health-related problems caused by the lack of essential services such as clean water, insufficient hygiene, inadequate sanitation and access to health care. The aforementioned conditions are associated with protozoa and soil-transmitted helminths infections (Strunz et al., 2014, Speich et al., 2016). These infections can lead to anaemia, growth retardation, diarrhoea and abdominal pain (Utzinger et al., 2012) and may result in a greater risk of illness and school absenteeism (Farah et al., 2004).

Furthermore, economic hardship limits parents' ability to provide a supportive and safe learning environment (Ferguson et al., 2001) and lowers the probability that children have access to cognitively stimulating resources such as books and toys (Riley et al., 2014). Additionally, financial instability increases distress among parents, which negatively affects the quality of parent-child interactions (Conger and Donnellan, 2007). Correspondingly, economic hardship and stressful life events increase the risk of substance abuse such as excessive alcohol consumption. A study by Malia et al. (2008) found that women who face economic hardship and are exposed to severe, chronic stressors have an elevated risk of psychosocial distress and problem drinking (Mulia et al., 2008). A study by Watt et al. (2014) showed that women living in townships were found to use alcohol as a way of dealing with stress, irrespective of pregnancy. This behvior is harmful for unborn children, since drinking during pregnancy may cause foetal alcohol syndrome (FAS), a condition under the broader umbrella of foetal alcohol spectrum disorder (FASD). The syndrome can manifest in birth defects such as brain damage, physical and mental impairments and stunted growth. FAS affects more children in South Africa than anywhere else in the world, which is 14 times the global average which is and occurrence of 7.7 per 1000 children (Chudley, 2017, Williams et al., 2015). With these challenges in mind it becomes evident that children will bring their health, family and community difficulties with them into the classroom.

1.9.2 Challenges related to Physical Education teachers and school setting

School settings within disadvantaged communities experience unique challenges affecting teaching, learning and Physical Education in various ways. Schools that are not private nor located in affluent areas, often face a lack of funds. Even though the government allocates money to public schools, the majority is used for salaries and municipal services (De Waal, 2004). With the lack of funds, there are usually a lack of appropriate and sufficient instructional equipment and sporting facilities. This in turn limits the range of Physical Education content that can be taught and makes lessons dependant on favourable weather conditions (De Waal, 2004). Furthermore, Physical Education instructional time is regularly limited due to the marginalisation of the subject on the school's timetable, in favour of prioritising 'more important', examinable subjects, such as Mathematics and Sciences. Moreover, large gaps in the student-teacher ratio with classes up to sixty or seventy children make teaching Physical Education extremely difficult (Rajput and van Deventer, 2010).

It is also important to mention, that after the extensive post-Apartheid curriculum reform discussed above, teachers report that they feel incompetent to teach Physical Education since they had not been trained for the realities of disadvantaged school settings (Rajput and van Deventer, 2010). Moreover, a study evaluating a large sample of South African teachers working in public schools concluded, that the combination of difficulties experienced by teachers in disadvantaged communities lead to considerably higher stress levels compared with teachers facing a less challenging work environment. Consequently, teachers in disadvantaged communities have a higher risk for stress-related physical illnesses, such as hypertension, heart disease, emotional distress, and substance abuse (Peltzer et al., 2009). Furthermore, teachers in disadvantaged settings find it difficult to teach Physical Education to a diverse and complex group of learners. The diversity does not only include varying academic levels, but significant differences in practical physical abilities, as well as major health-related physical fitness and motor proficiency disparities between learners from the same grade (Barnard and McCaughtry, 2007, De Waal, 2004). Furthermore, violence negatively effects the teaching and learning environment. In the KwaZulu Natal Province, up to 75 % of learners indicated that they felt school is not a safe setting, 76 % indicated that they have witnessed a physical attack on a fellow learner and 38 % witnessed an attack on a teacher (Zulu et al., 2004). Given such statistics, it is not surprising that teachers in similar settings reported spending up to half of class time teaching conflict resolution, cooperation, self-control and bullying (McCaughtry et al., 2006).

It is evident that schools located in disadvantaged communities face a myriad of challenges that shape how Physical Education is taught and therefore negatively affects the physical activity participation of learners from disadvantaged communities. Given that children from these communities present with the lowest physical activity levels and have fewer opportunities to be active within their community and school setting (Walter, 2011), they are at high risk for all the dangers of an inactive lifestyle, affecting their personal health and development, their academic achievement and their social and emotional wellbeing. This demonstrates the need to support schools and teachers in providing adequate Physical Education and offer increasing opportunities for in-school physical activity participation (McVeigh et al., 2004).

1.10 School-based health interventions

Schools are the ideal setting to promote physical activity and a healthy lifestyle. Children spend about 40% of their wake time at school (Fox et al., 2004) which make it one of the most important places where all children, especially those from low-resourced areas, have access to physical activity and active play (Hills et al., 2015). There is considerable evidence from middle- and high-income countries that multi-component school-based health interventions promote physical activity and cardiorespiratory fitness (Kriemler et al., 2011, Dobbins et al., 2013). However, there is a paucity of research within lower income countries such as South Africa (Heath et al., 2012). The authors of the Healthy Active Kids Report South Africa (Uys et al., 2016) conclude that there is an urgent need for evidence and for the evaluation of existing interventions concerning children's physical activity, wellbeing and health.

1.11 Scope of this thesis within the DASH project

This Dissertation is embedded in a much larger project entitled: *Disease Activity and Schoolchildren's Health* (DASH) and was funded by the Swiss National Science Foundation (SNSF) within the context of the Swiss South African Joint Research Programme (SSAJRP).

The project investigated multiple health markers, including: cardiorespiratory fitness, upper body strength, self-reported physical activity, academic achievement, selective attention, health-related quality of life, school burnout, soil-transmitted helminth infections, body composition, haemoglobin levels, anaemia, glucose levels, blood pressure and nutritional status. Furthermore, children's socio-economic status was assessed.

These assessments were conducted before, during and after the introduction of setting-specific interventions focusing on a physical education as well as a health hygiene education programme, deworming and a nutritional supplement. Moreover, the association between the measured risk factor variables for non-communicable diseases (including: cardiorespiratory fitness, body composition, anaemia, glucose levels and blood pressure) and the implemented lifestyle interventions among Grade four schoolchildren in Port Elizabeth, South Africa, were investigated (Müller, 2019). Including all assessed health indicators would go beyond the scope of this dissertation. Therefore, a special focus is placed on physical activity, physical fitness (cardiorespiratory fitness and upper-body strength), cognition (academic achievement, selective attention) and wellbeing (health-related quality of life). Furthermore, the following variables were included: soil-transmitted helminth infections, body composition and socio-economic status.

It is hypothesised that by promoting a setting-specific physical activity programme and that deworming can positively influence the health and wellbeing, as well as learning outcomes of children. Intensive research in a socio-economically disadvantaged part of Port Elizabeth, South Africa, offers a unique chance to investigate the impact of physical activity and fitness on children's psychosocial health and cognitive performance within a low socio-economic setting.

1.12 Aims

This PhD project aimed to explore the effects of a 20-week multi-component school-based physical activity intervention and cross-sectional associations of academic performance, selective attention and health-related quality of life, among primary schoolchildren from socio-economically deprived neighbourhoods in Port Elizabeth, South Africa.

1.13 Objectives

- Objective 1: To explore cross-sectional associations and possible determinants of selective attention and academic performance.
- Objective 2: To investigate cross-sectional associations between health-related quality of life, self-reported physical activity and cardiorespiratory fitness.
- Objective 3: To evaluate the effect of a 20-week school-based physical activity intervention program on academic performance, selective attention and health-related quality of life.

1.14 Outline and hypotheses

Publication 1: Study protocol

The first publication of this thesis is the study protocol. This paper describes the rationale for the umbrella study DASH, the methods used, the assessed parameters and the description of the study population within the specific setting in Port Elizabeth, South Africa.

Publication 2: Possible determinants of selective attention and academic achievement

The second publication explores determinants of cognition (selective attention and academic achievement) cross-sectionally, in 1009 primary schoolchildren.

We hypothesised that higher cardiorespiratory fitness and muscular strength are associated with higher selective attention and academic achievement. Furthermore, we hypothesised that children who are non-stunted, helminth infection-free and food secure have a better selective attention and higher school grades compared to their stunted, infected or food insecure peers.

Publication 3: Associations between physical activity and health-related quality of life

The third publication examines the cross-sectional relationship between self-reported physical activity, physical fitness and health-related quality of life among 1009 schoolchildren from disadvantaged neighbourhoods in Port Elizabeth, South Africa.

We hypothesised that higher self-reported physical activity and higher cardiorespiratory fitness are associated with higher health-related quality of life.

Publication 4: Effect of physical activity intervention on cognitive outcomes

The fourth publication evaluates the effect of a 20-week physical activity intervention on selective attention and academic achievement in disadvantaged primary school children from Port Elizabeth, South Africa.

We hypothesised that the physical activity intervention programme has a positive effect on selective attention and academic achievement.

Publication 5: Effect of a physical activity intervention on health-related quality of life

The fifth publication evaluates the effect of a 20-week physical activity intervention on health-related quality of life in disadvantaged primary school children in Port Elizabeth, South Africa.

We hypothesised that the physical activity intervention programme has a positive effect on health-related quality of life.

1.15 Study area and population

The study population consisted of 1009 Grade 4 schoolchildren (501 girls, 508 boys) from eight primary schools located in the Nelson Mandela Bay District, South Africa. Figure 1.6 illustrates on the one hand the geographic location of the eight DASH schools, and on the other hand it shows the social tapestry of the Nelson Mandela Bay. All schools are located in historically black African areas, also known as townships, and coloured areas, also referred to as the Northern areas, around Port Elizabeth, in the Eastern Cape province of South Africa. Up until today the Nelson Mandel Bay area remains the most racially segregated city in South Africa (Statistics South Africa, 2016).

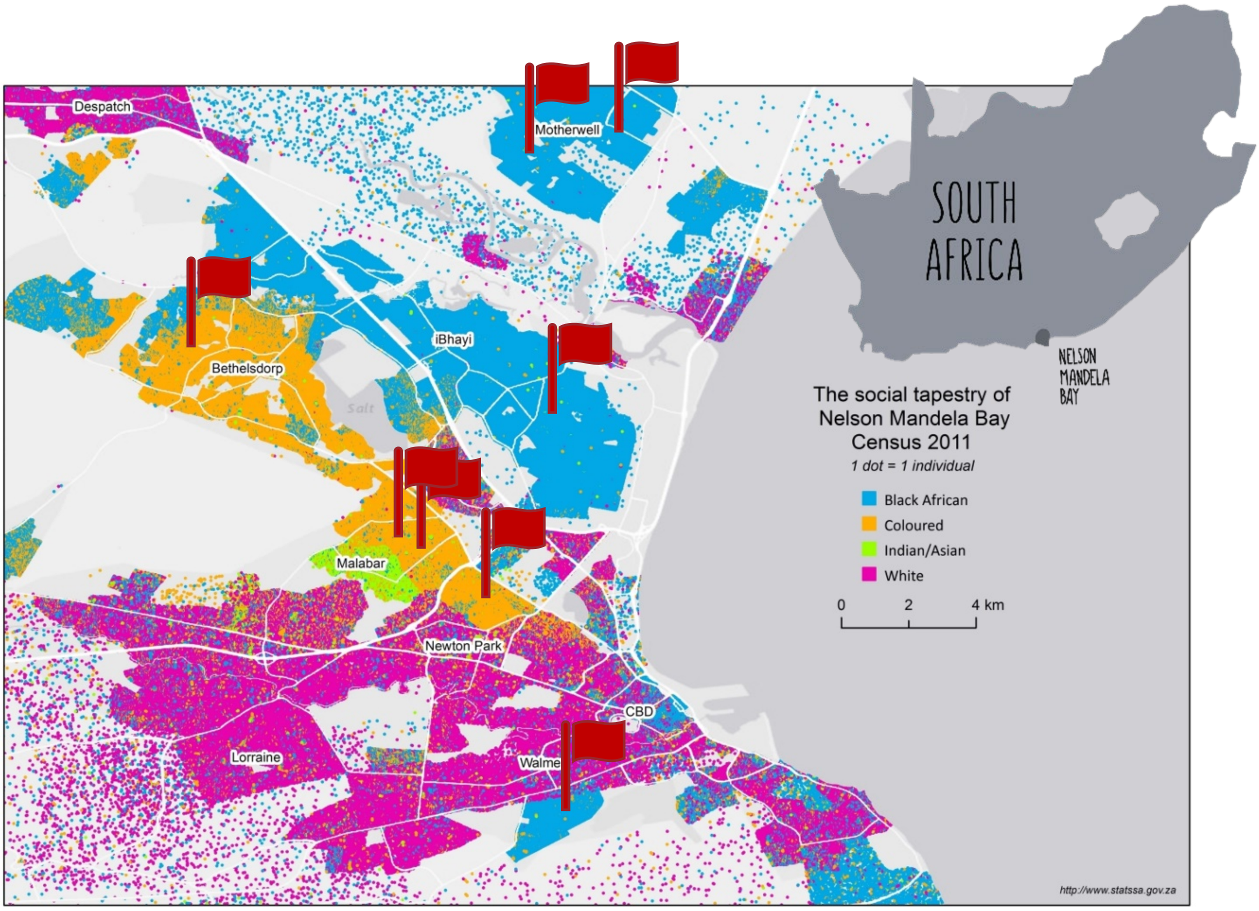


Figure 1.4 Geographic location of the eight project schools. Adapted from Statistics South Africa (2016)

Chapter 2 Methodology of the DASH study

2.1 Disease, activity and schoolchildren's health (DASH) in Port Elizabeth, South Africa: a study protocol

Peiling Yap[1,2]*, Ivan Müller[1,2,3]*, Cheryl Walter[4], Harald Seelig[3], Markus Gerber[3], Peter Steinmann[1,2], Bruce P. Damons[6], Danielle Smith[4], Stefanie Gall[3], Dominique Bänninger[3], Thomas Hager[3], Nan S. N. Htun[1,2], Liana Steenkamp[5], Annelie Gresse[5], Nicole Probst-Hensch[1,2], Jürg Utzinger[1,2], Rosa Du Randt[4] and Uwe Pühse[3]

Affiliations

[1] Department of Epidemiology and Public Health, Swiss Tropical and Public Health Institute, P.O. Box, CH-4002 Basel, Switzerland

[2] University of Basel, P.O. Box, CH-4001 Basel, Switzerland

[3] Department of Sport, Exercise and Health, University of Basel, St. Jakobsturm, Birsstrasse 320B, CH-4056 Basel, Switzerland

[4] Department of Human Movement Science, Nelson Mandela Metropolitan University, P.O. Box 77000, Port Elizabeth 6031, South Africa

[5] Department of Dietetics, Nelson Mandela Metropolitan University, P.O. Box 77000, Port Elizabeth 6031, South Africa

[6] Sapphire Road Primary School, P.O. Box Booysens Park, Port Elizabeth 6059, South Africa

*These two authors contributed equally to the work presented here

This study protocol has been published in **BMC Public Health** 2015

2.2 Abstract

Background: An in-depth epidemiological investigation on intestinal parasite infections in an impoverished area of Port Elizabeth, South Africa provides a unique opportunity for research on its impact on children's physical fitness, cognitive performance and psychosocial health. Additionally, we will screen risk factors for the development of diabetes and hypertension in adulthood.

Methods/Design: A 2-year longitudinal cohort study will be conducted, consisting of three cross-sectional surveys (baseline and two follow-ups), in eight historically black and coloured (mixed race) primary schools located in different townships in Port Elizabeth, South Africa. Approximately 1000 Grade 4 primary schoolchildren, aged 8 to 12 years, will be enrolled and followed. At each survey, disease status, anthropometry and levels of physical fitness, cognitive performance and psychosocial health will be assessed. After each survey, individuals diagnosed with parasitic worm infections will be treated with anthelminthic drugs, while children with other infections will be referred to local clinics. Based on baseline results, interventions will be tailored to the local settings, embedded within the study and implemented in half of the schools, while the remaining schools will serve as controls. Implementation of the interventions will take place over two 8-week periods. The effect of interventions will be determined with predefined health parameters.

Discussion: This study will shed new light on the health burden incurred by children in deprived urban settings of South Africa and provide guidance for specific health interventions. Challenges foreseen in the conduct of this study include: (i) difficulty in obtaining written informed consent from parents/guardians; (ii) administration of questionnaires in schools where three languages are spoken (Afrikaans, Xhosa and English); (iii) challenges in grasping concepts of psychosocial health among schoolchildren using a questionnaire; and (iv) loss to follow-up due to the study setting where illiteracy, mobility and violence are common. Finally, designing the health interventions together with local principals and teachers will allow all concerned with the research to bolster a sense of community ownership and sustained use of the interventions after the study has ceased.

Trial registration: Controlled-trials.com; identifier: ISRCTN68411960 (date assigned: 14 February 2014).

Keywords: Anthropometry, Cognitive performance, Diabetes, Health interventions, Intestinal parasite infections, Physical fitness, Physical activity, Psychosocial health, South Africa.

2.3 Background

As traditional lifestyle and diet change alongside socioeconomic developments, countries are starting to experience a double burden of communicable and non-communicable diseases in the face of weak health systems (Boutayeb, 2006, Santosa et al., 2014). Many countries still struggle to meet the existing challenges stemming from infectious diseases, such as malaria and intestinal parasite infections. Meanwhile, non-communicable diseases, such as diabetes, cardiovascular diseases, obesity-related conditions and cancers, impose a growing burden on them (Marshall, 2004). This phenomenon has been recognised by the global health community and must be addressed in the new era of the sustainable development goals (SDGs), particularly "to ensure healthy lives and promote well-being for all at all ages" (Affairs, 2014), while the unfinished agenda of the communicable diseases during the millennium development goal (MDG) era must be accelerated.

In South Africa, investigations of physical activity patterns of primary schoolchildren attending schools in disadvantaged neighbourhoods have confirmed that physical activity levels are insufficient (Walter, 2011). These school environments are usually not conducive for the promotion of physical activity due to inadequate sport and recreation facilities, a lack of qualified teachers and an irregular physical education program. In 2010, Kimani-Murage et al. (Kimani-Murage et al., 2010) reported that in a low-income South African setting, the co-prevalence of early stunting and adolescent obesity in girls is a result of increasing levels of physical inactivity. This observation was particularly prevalent among black girls, who were found to have the highest rates of physical inactivity (Walter et al., 2011). As physical inactivity during childhood can lead to poor health outcomes in adulthood (Tian et al., 2015), there is a pressing need to promote physical activity among school-aged children in disadvantaged communities in order to prevent obesity-related conditions and other non-communicable diseases. Additionally, infectious diseases that are intimately connected with poverty may also occur in disadvantaged South African schools (Draper et al., 2010). These infections can have a negative impact on children's nutritional status, cognitive abilities and physical fitness (Hürlimann et al., 2014, Yap et al., 2014). Such a dual burden of disease can put children at a high risk of compromised health, poor subjective well-being, hampering their growth and economic perspectives.

In particular, it is hypothesized that, first, intestinal parasite infections have a negative influence on the physical fitness, cognitive performance, nutritional status and psychosocial health of school-aged children in deprived urban South Africa. Second, the development of setting-specific health interventions can decrease the incidence of parasitic infections and insulin resistance as well as elevated blood pressure, and thereby the risk of developing non-communicable conditions later in life, such as diabetes and hypertension (Figure 2.1).

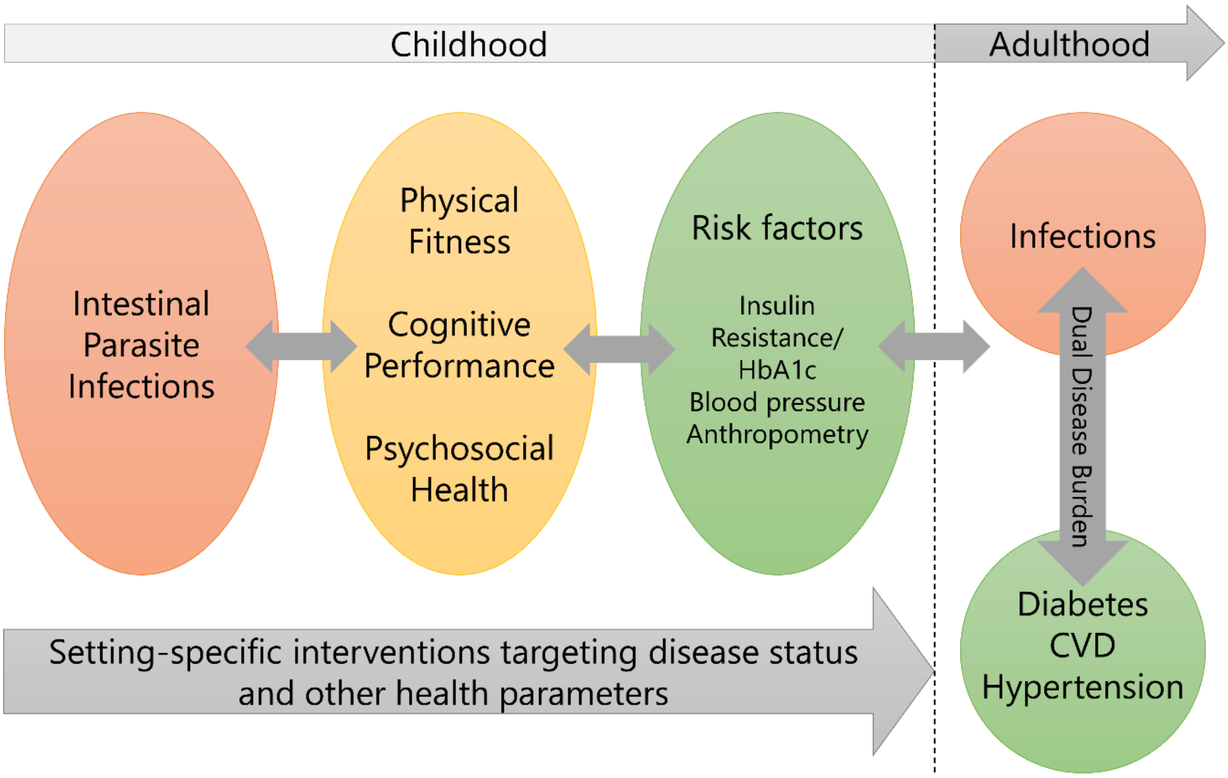


Figure 2.1 A conceptual framework for the DASH study

An in-depth epidemiological study on intestinal parasite infections in an impoverished part of Port Elizabeth, South Africa, will provide a unique opportunity for research on its impact on children's physical fitness, cognitive performance and psychosocial health. In addition, a search for risk factors for the development of diabetes and hypertension in adulthood seems justified. From this research, an evidence-base will be created to design setting-specific health interventions. The purpose of this article is to present the detailed protocol of the proposed study.

2.4 Goal and objectives

The goal of this project is to survey the distribution of selected intestinal parasite infections and risk factors for non-communicable conditions, and assess their impact on schoolchildren's health over time in the face of tailored interventions in eight townships of Port Elizabeth, South Africa before, during and after the introduction of setting-specific interventions. We will pursue two specific objectives:

to conduct a longitudinal study assessing the prevalence of intestinal parasites, risk factors for diabetes and hypertension, anthropometry and the level of physical fitness, cognitive performance and psychosocial health among schoolchildren; and

to design setting-specific interventions and assess their effect on the measured health parameters.

2.5 Methods/Design

Study area

The study will be conducted in historically black and coloured (mixed race) government primary schools from various areas in Port Elizabeth in the south-east part of South Africa (Figure 2.2).

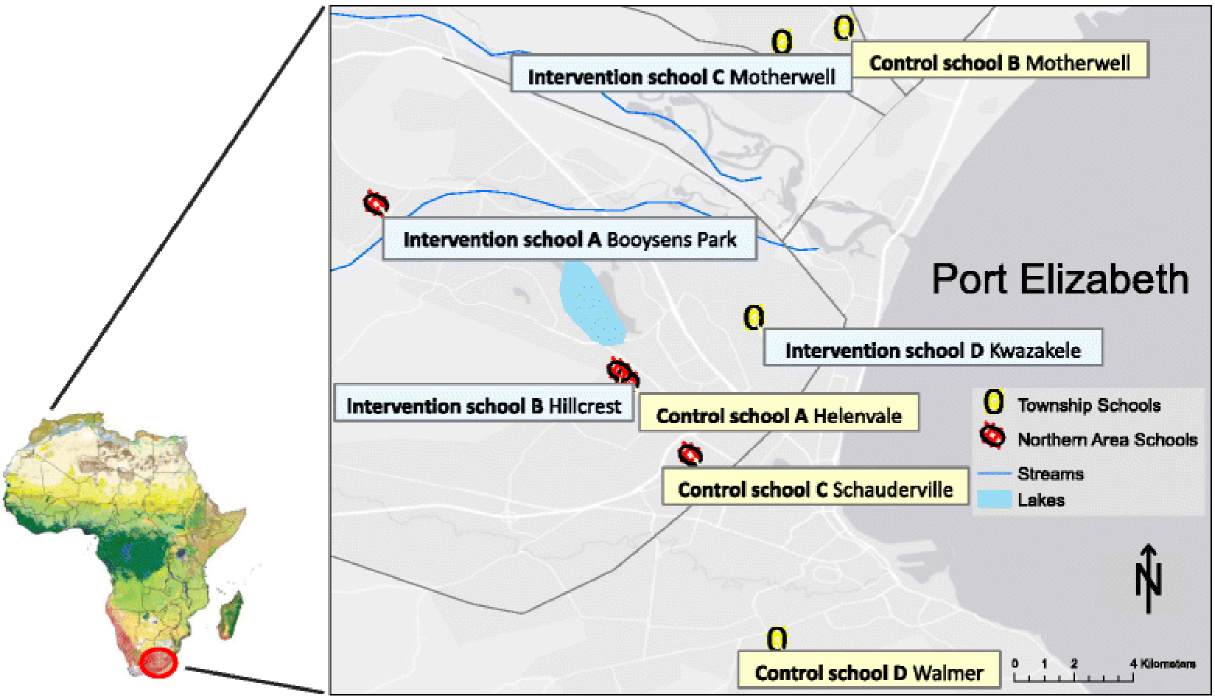


Figure 2.2 Study area and location of schools participating in the DASH study.

The areas populated by black Africans are commonly referred to as townships and include the areas of Kwazakhele, New Brighton, Zwide, and Motherwell. The "Northern areas" in Port Elizabeth are largely made up of coloured people who were forcefully relocated from the central areas of the city to the outlying northern areas, and include the areas of Schauderville, Gelvandale, Helenvale, Hillcrest and Booysens Park (Southern Africa Development, 2013, Agherdien et al., 1997). Government schools in South Africa are classified into 5 groups, called quintiles, mainly for the purpose of allocating financial resources, with quintile 1 being the poorest and quintile 5 being the "least poor". Schools in quintiles 1, 2 and 3 are proclaimed as no-fee schools, while schools in quintiles 4 and 5 are fee-paying schools (Release et al., 2013). The eight schools who will be participating in the DASH study belong to quintiles 3. Furthermore, the study area has been detrimentally affected by extreme poverty and high rates of unemployment, due to past government policies, as well as current public health and economic challenges faced by the country (Walter et al., 2011).

Study design

The study duration spans from February, 2015 to June, 2017 (Figure 2.3). The longitudinal cohort study consists of three cross-sectional surveys (baseline, mid- and final follow-up). At each survey time point, disease status, anthropometry and levels of physical fitness, cognitive performance and psychosocial health are measured.

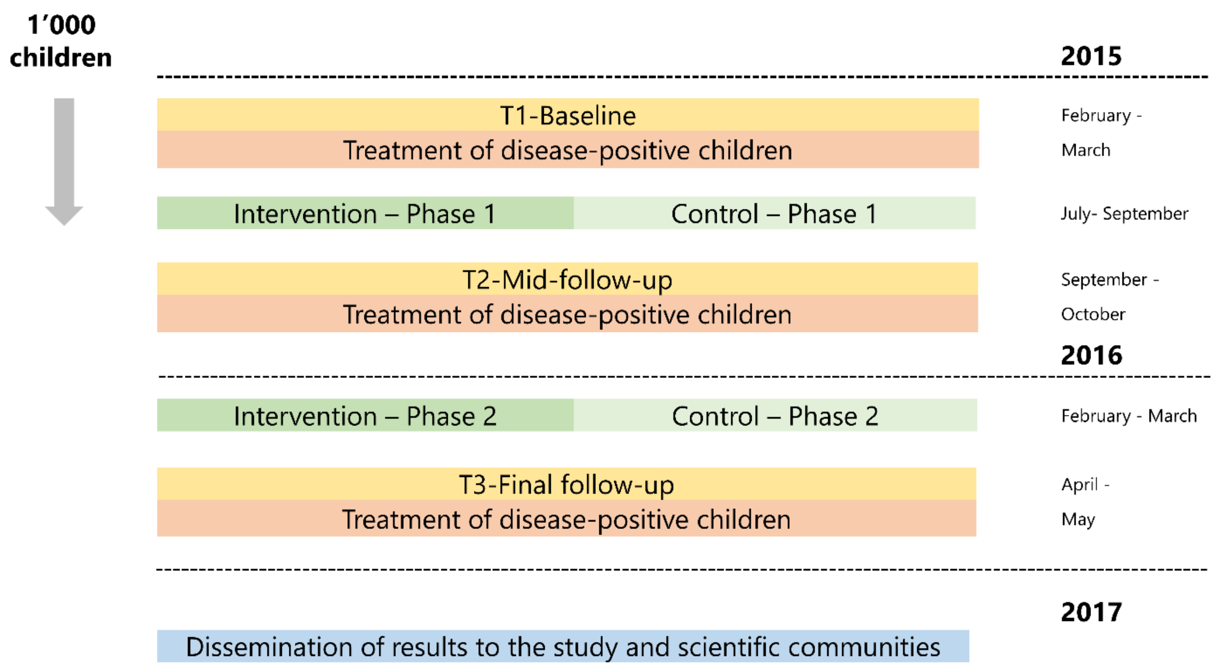


Figure 2.3 A pictorial display of the design and timeline of the DASH study

After each survey, infected individuals are either treated with anthelminthics (400 mg albendazole, single dose) for soil-transmitted helminths (Keiser and Utzinger, 2008) and/or referred to local clinics for the management of other intestinal parasite infections.

Based on results from the baseline survey, a package of setting-specific interventions is designed together with local students, teachers, school volunteers and parents. The intervention package consists of three main components:

(i) Physical activity (Draper et al., 2010, Kriemler et al., 2010): Regular physical activity opportunities, including two physical education (PE) lessons a week, weekly dancing-to-music classes, and in-class activity breaks will be incorporated into the main school curriculum and a physical activity friendly school environment will be created. These approaches could help improve children's physical fitness, and positively affect their psychosocial health (Muraven et al., 1999, Oaten, 2004, Baumeister et al., 2006, Oaten and Cheng, 2006, Gailliot et al., 2007).

(ii) Health education (Bieri et al., 2012): A series of classroom-based lessons will be developed to help increase the awareness for intestinal parasite infections among the schoolchildren and educate them on treatment and prevention methods, such as proper hygiene, sanitation habits and the importance of consuming clean water and food. It is also planned that schoolchildren will produce a theatre play to convey key messages they have learnt through the health education.

(iii) Nutritional interventions: A series of classroom-based lessons will be developed to help increase the awareness of the importance of healthy nutrition. In addition, an analysis of the school feeding programme will be done to identify ways to improve their current diet to be healthier. The schoolchildren will also be given a ready to use supplementary food (RUSF) in the form of an enriched lipid-based paste. The cooks in the schools will also be trained in basic nutrition and hygiene during preparation of the school meals.

The interventions will be embedded within the longitudinal study and be implemented in half of the schools, while the remaining schools will serve as controls. The intervention schools were either selected due to the soil-transmitted helminth prevalence, number of Grade 4 learners, geographical location and affiliation to a particular ethnic group or commitment of teachers or school staff. Implementation of the interventions will take place twice; in July-September, 2015, after the baseline survey, and in February-March, 2016, after the first follow-up. The first follow-up will allow the implementation feasibility of the designed interventions to be determined through focus-group discussions with teachers and students, while the subsequent surveys will allow assessing their impact on the measured health parameters.

Sample size

The sample size calculation for the study was based on achieving sufficient precision in estimating the prevalence of soil-transmitted helminth infections. We conducted our calculation under the following assumptions for the cross-sectional baseline study:

(i) a prevalence of soil-transmitted helminth infections, p, of approximately 3%;

(ii) an average number of children per school, B, of 150; and

(iii) an intra-class correlation coefficient for the clustering of outcomes within schools, ICC, of 0.15.

Requiring the standard error of the respective prevalence, SE, not exceeding 2.5%, we obtained a necessary sample size n of 1,088 children, using the formula (Kish, 1965)

$$n \geq \frac{p \cdot (1-p)}{SE^2}(1 + (B-1) \cdot ICC) \qquad \textbf{(Equation 1)}$$

As a consequence, eight clusters (schools) will be needed considering the fact, that with a total of 1,200 children from eight schools, we can accommodate 10% loss to follow-up.

Study participants

Children will be invited to participate if they meet the following inclusion criteria: (i) are willing to participate in the study; (ii) have a written informed consent by a parent/guardian; (iii) are not participating in other clinical trials during the study period; and (iv) do not suffer from medical conditions, which will prevent participation in the study, as determined by qualified medical personnel. Approximately 1000 Grade 4 primary schoolchildren, aged around 8 to 12 years, from 8 schools will be recruited during the baseline survey.

School selection, participant recruitment and written informed consent

School authorities will be briefed about the project and their approval sought. Subsequently, a description of the project will be delivered by hand to 103 government primary schools and principals will be encouraged to allow their schools to participate in the study. Those schools with positive written responses will be invited to a comprehensive information meeting with the study investigators. Thereafter, interested schools will be visited and the study investigators will talk to the school management from these schools to find out whether the school environment is conducive for the performance of the study. Selection of schools will be based on size of the Grade 4 classes (n>100), geographical location and population demographics (Xhosa-, Afrikaans- and English-speaking schoolchildren). School principals and teachers of the selected schools will be notified about the study aims, procedures and potential risks and benefits. Schoolchildren, parents or legal guardians of learners will then be informed and schoolchildren encouraged to participate in the study. Before the launch of the study, a patient information sheet in English, including translation into the local language (Xhosa or Afrikaans), will be given to all potential participants and their parents/guardians, explaining the objectives, procedures and potential risks and benefits of the study. The name and contact address of the main investigator on site will be provided for any specific follow-up question. Oral assent from each participating schoolchild will be sought, while individual written informed consent will be required from parents/guardians. For illiterate parents, the information sheet will be read aloud and, if need be, an oral translation of the information sheet into all the local languages (Xhosa, Afrikaans or English) will be given. Participation is voluntary, and hence, children can withdraw from the study at any time without consequences and further obligation. Finally, demographic data and socioeconomic status of each participant will be obtained via the use of a questionnaire.

Assessment methods

Figure 2.4 summarises the assessment methods to be used in this study. For each cross-sectional survey, a specific combination of the following procedures will be selected and conducted by well-trained staff, adhering to standardised and quality-controlled protocol.

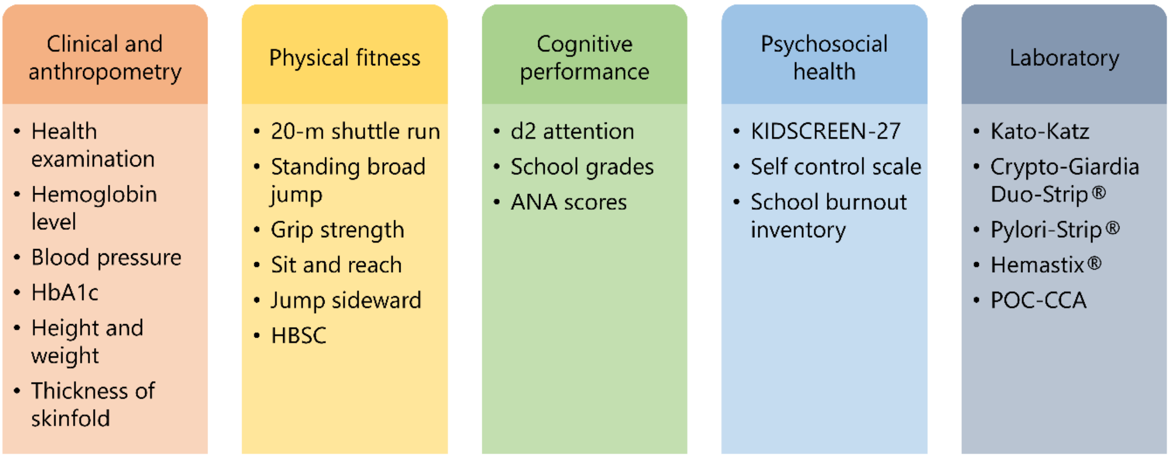


Figure 2.4 A summary of the measurements and tests performed under the DASH study

Health examinations

(i) Clinical examination of children will include detailed medical history taking and physical examination. Features of patient history will focus on fevers, constitutional symptoms, abdominal pain and change in bowel movements. Physical examination is directed towards evidence of anaemia (e.g. conjunctival pallor), detailed abdominal examination (e.g. tenderness, hepatomegaly and splenomegaly) and evidence of pulmonary hypertension (e.g. jugulovenous pressure and cardiac auscultation).

(ii) Four questions about food security in the past two days, based on a simplified version of the Household Food Insecurity Access Scale (HFIAS) will be asked (Coates et al., 2007).

(iii) For the detection of anaemia, the hemoglobin concentration will be measured once (to the nearest 0.1 g/l) using a HemoCue® Hb 301 system (HemoCue® AB; Ängelholm, Sweden). A fresh set of alcohol swab, safety lancet and microcuvette will be used for each child. After swabbing the fingertip with alcohol, the field investigator will prick it with a safety lancet and squeeze gently for two drops of blood. The first drop will be wiped away with the alcohol swab, while the second drop will be taken up by the microcuvette and read by the device. The Eurotrol Hb 301 Control will be used to verify the precision and accuracy of the measuring system (Since there will be other tests, which involve the use of whole blood from a finger prick, we will ensure an organised procedure so that each child is only pricked once.)

(iv) For the measurement of blood pressure, each child's blood pressure will be measured once with the Omron® digital blood pressure monitor, while the child is seated. The cuffs will be wrapped around the left arm such that one finger could fit between the cuff and the arm. The bottom of the cuff is about 4.0 cm above the elbow and the palm should be facing up while blood pressure is being measured.

(v) For the measurement of glycated haemoglobin (HbA1c) level, a point-of-care instrument employing the Afinion test (Alere Technologies) will be used. This test is based on boronate affinity separation and the use of fluorescence quenching, with results available in about 3 minutes. This method meets the generally accepted performance criteria for HbA1c as defined by the National Glycohemoglobin Standardization Program (NGSP) and has no interference from HbC, HbS, HbE and HbD traits results. Of note, the HbA1c level reflects the average plasma glucose concentration levels over the previous 8-12 weeks before measurement with no prior fasting required. A fresh set of alcohol swab, safety lancet and HbA1c test cartridge will be used for each child. After swabbing the fingertip with alcohol, the field investigator will prick it with a safety lancet and squeeze gently for two drops of blood. The first drop will be wiped away with the alcohol swab, while the second drop will be taken up by the test cartridge and read by the Alere Afinion AS 100 Analyzer. Identical Afinion HbA1 control blood will be used as an internal control and tested at regular intervals to control for potential laboratory drift.

Anthropometric measurements

(i) Each schoolchild will be asked to take off their shoes and sweater before standing on the digital weighing scale. Body weight will be measured once and recorded to the nearest 0.1 kg.

(ii) With the shoes off, each child will stand against a stadiometer with their back erect and shoulders relaxed. Body height will be measured once and recorded to the nearest 0.5 cm.

(iii) Body mass index (BMI) and two specific Z-scores will be calculated, as follows: (i) BMI = weight (kg) / (standing height [meters (m)]2); (ii) BMI-for-age (BMIZ); an indicator for weight-for-height proportion (WHO growth reference for children older than 60 months) (WHO, 2007); (iii) Height-for-age (HAZ); an indicator for stunting (WHO growth reference for children older than 60 months).

(iv) The thickness of the skinfold will be measured at two sites, namely triceps and subscapular (Niederer et al., 2009, Puder et al., 2011). Before measurement, the field investigator will show the Harpenden skinfold caliper to the child and clamp it normally on the child's finger to show that the process will not hurt. During the measurement, the child will stand with arms and shoulders relaxed. With the thumb and forefinger, the field investigator will gently pinch the skin (a vertical skinfold) slightly above the middle of the back of the arm (triceps) and clip the caliper (mouth of caliper is perpendicular to skinfold). After counting for 2 sec, the reading should stabilize, and hence, it will be recorded. The field investigator will release the pinch but let the fingers stay in the same position on the arm and repeat the measurements two additional times. The three values obtained should be no more than ±5% different from each other. If this is not the case, the measurements will be repeated. The final reading is an average of the three values. The same procedure applies for the subscapular site directly underneath the shoulder blade.

Physical fitness tests and self-reported physical activity

Previous studies in South Africa have used the Eurofit fitness testing battery (Europe, 1983). For the purpose of this project, specific tests from the Eurofit fitness testing battery will be conducted in outdoor settings.

(i) The children's cardiorespiratory fitness will be measured with the 20-m shuttle run test (Léger et al., 1988). In brief, a 20-m flat running course will be measured with a measuring tape and marked with cones. Ten running lanes will be designated. Before the start of the test, children will be told to indicate any body discomfort and anyone who feels sick or not comfortable will not take part in the test. The pre-recorded sound signals will be played to the children and they will be initiated to do trial run of two intervals (2 x 20 m). Once children are familiar with the test procedures, they will be asked to run, in groups of five or ten, back and forth on the 20 m flat course by following the pre-set pace of sound signals. Starting with a running speed of 8.5 km/h, the frequency of the signal will be gradually increased so that every minute, the pace increases by 0.5 km/h. When children fail to follow the pace in two consecutive intervals, they will be asked to stop and the stage and the distance completed (full laps) will be recorded. The age of the participating child and the speed at which the child stopped running will be converted into VO^2 max estimates, which is the maximum volume of oxygen that can be utilized within 1 min during exhaustive exercise, with an equation put forth by Léger et al. (Léger et al., 1988).

(ii) Lower body strength will be estimated with the standing broad jump test. Before the start of the test, the field investigator will demonstrate how exactly the standing broad jump is performed. Each child will stand behind a straight line and then jump as far forward as possible with both legs. Children will have 2 tries (with a 30 sec rest in between) and the longest jump will be recorded (to the nearest 1 cm). The distance of the jump is measured from the starting line to the heel of the most back foot.

(iii) Upper body strength will be determined with the grip strength test. The TKK® dynamometer will be used for this test. Before the start of the test, the hand span (distance from the tip of the thumb to the tip of the little finger) of the child's dominant hand will be measured (to the nearest 0.5 cm) and the grip span on the dynamometer adjusted accordingly (Ruiz et al., 2006, Espana-Romero et al., 2008). The field investigator also demonstrates how to grip the dynamometer to the child. Each child will have two tries (with a 30 sec rest in between) to grip the dynamometer as hard as possible with both hands and the maximum readings (measured to the nearest 0.5 kg) will be recorded. Additionally, the dominant hand will be noted.

(iv) The Sit-and-Reach Test (SRT) will be conducted as an indication of flexibility. This test measures flexibility of the hamstring muscles (back of the thigh) and, to a minor extent, the lower back muscles. The study participant will be asked to sit on the floor with stretched legs and feet against the sit-and-reach box. The hands are placed over each other and with the hips bent forward as far as possible, the fingers should move as far as possible to the front. The distance between the fingertips and the back edge of the box will be measured.

(v) For the measurement of coordination skills and speed strength of the leg muscles, we will use the jump-sideward test. The task for the participant is to jump laterally with both legs at the same time as many times as possible within 15 seconds across a wooden bar. A field investigator demonstrates the test in advance and five jumps can be practiced.

(vi) The children will be asked questions about experiencing physical activity, such as doing sports, specific activities during school, playing with friends in their free time and walking to school. A recall period of 7 days will be used. The questions will be adapted from the Health Behaviours in School Age Children Survey (HBSC), an instrument used to gain insight into young people's well-being, health behaviours and their social context (WHO, 2014).

Cognitive performance

Three measures will be considered as indicators of cognitive and academic performance, namely a standardized attention test (d2), children's school grades, and the results of standardized national tests (ANA).

(i) The d2 test will be employed to measure attention performance. This test is among the most widely used measures of attention, particularly visual attention, in Europe and the USA (Brickenkamp and Zillmer, 1998). The d2 paper-and-pencil version, which can be performed in a group setting, assesses several dimensions of cognitive performance: (i) total number of items processed (TN), a highly reliable measure of processing speed; (ii) percentage of errors (E%), measuring the qualitative aspects of performance; and (iii) the total number of items processed minus errors (TN-E), as an indication of the implications of the combined speed and accuracy scores for attentional and inhibitory control. Criterion, construct and predictive validity of the d2 test among children aged 9 years and above are well documented (Bates and Lemay, 2004, Wassenberg et al., 2008, Gallotta et al., 2012). Moreover, the test offers an extensive list of norms, according to age, sex and education.

(ii) In cooperation with the schools, we will obtain school test grades from the following subjects: English, mathematics, home language and life orientation. The sum-score of the four subjects will be used to estimate academic achievement.

(iii) The Annual National Assessments (ANA) are standardised tests for literacy and numeracy in the foundation phase (Grades 1-3) and Mathematics and languages in the intermediate phase (Grades 4-6). For the purpose of our study, Mathematics and home language ANA scores will also be used as a measure for academic achievement.

Questionnaires for assessment of psychosocial health

(i) To assess children's psychosocial health, the following paper-and-pencil questionnaires will be applied:

(ii) The KIDSCREEN-27 will be used to assess children's physical and psychological well-being, moods and emotions, self-perception, autonomy, parent relation and home life, financial resources, peers and social support, school environment and bullying. The questionnaire includes 27 items and has been proven to be a valid instrument to assess psychosocial health of children aged 8-18 years across various countries (Ravens-Sieberer et al., 2005, Hong et al., 2007, Ravens-Sieberer et al., 2008).

(iii) Six items of the short version of the Self-Control Scale (SCS) will be used to assess individual differences in the capacity for self-control (Tangney et al., 2006). The human capacity of self-control has been described as one of the most powerful and beneficial adaptations of the human psyche (Baumeister et al., 2006, Tangney et al., 2006, Hagger et al., 2009, Duckworth, 2011, Moffitt et al., 2011). The exertion of self-control strengthens the relationship between the self and the environment, which is an important prerequisite for individuals' satisfaction with life, well-being and positive development (Duckworth et al., 2010, Miller et al., 2011). Evidence for the reliability and validity of the SCS has been demonstrated previously (Tangney et al., 2006).

(iv) The 9-item School-Burnout Inventory (SBI) (Salmela-Aro et al., 2009a) will be applied to measure symptoms of school burnout. It has been shown that school burnout predicts subsequent depressive symptoms (Salmela-Aro et al., 2009b) and that low levels of physical activity are associated with increased school burnout among adolescents (Elliot et al., 2015). The SBI consists of 10 items and is a multifaceted instrument with three subscales: (i) exhaustion at school; (ii) cynicism towards the meaning of school; and (iii) sense of inadequacy at school. Answers are given on a 5-point Likert-scale ranging from 1 (never) to 5 (always). Evidence in support of the factorial and construct validity of the

SBI can be found in the literature (Salmela-Aro et al., 2009a, Salmela-Aro et al., 2009b, Salmela-Aro et al., 2008, Salmela-Aro and Tynkkynen, 2012).

Parasitological examinations

In order to determine the prevalence of various intestinal parasites, both stool and urine samples will be collected from each participant. The samples will be subjected to a suite of standardised, quality-controlled diagnostic work-up (Knopp et al., 2008, Sherkhonov et al., 2013).

(i) A single stool sample will be collected from each child and analysed on the same day. The procedures are as follows. Each student will be given a container, labelled with a unique identification number, in which they will be asked to deposit a stool sample of not more than half the container's size with their own stool at home and bring it to the school for collection the following morning. In a first step, stool sample (at least 15 g) will be visually examined for the presence of *Taenia* spp. proglottids as well as signs of blood, mucus and diarrhoea. Second, duplicate 41.7 mg Kato-Katz thick smears will be prepared from each stool sample (Yap et al., 2012). Slides will be allowed to clear for 30-45 minutes before being examined under a microscope by experienced laboratory technicians. The number of helminth eggs will be counted and recorded for each species separately. Helminth egg counts will be multiplied by a factor 24 to obtain a proxy for infection intensity, as expressed by the number of eggs per 1 g of stool (EPG) (Knopp et al., 2008, Utzinger et al., 2011). Possible helminth species to be detected include the three main species of soil-transmitted helminths (i.e. *Ascaris lumbricoides*, hookworm and *Trichuris trichiura*), *Fasciola hepatica* and *Schistosoma mansoni*. The presence of other helminth eggs will be noted, but not quantified.

(ii) For the detection of *Cryptosporidium* spp. and *Giardia intestinalis*, a Crypto-Giardia Duo-Strip® rapid diagnostic test (RDT) (CORIS, BioConcept; Gembloux, Belgium) will be performed on a stool sample, which has been diluted with a commercial buffer (Polman et al., 2015).

(iii) For the detection of *Helicobacter pylori*, a Pylori-Strip® RDT (CORIS, BioConcept; Gembloux, Belgium) will be performed on a stool sample, which has been diluted with a commercial buffer.

(iv) A single urine sample will be collected from each child. All children will be given a container, labelled with a unique identification number, which they will be asked to fill up full with their urine. Distribution and collection of filled containers will occur on the same day. Each sample will be analysed visually for macrohaematuria and tested with Hemastix® strips to detect blood in urine as a proxy for *Schistosoma haematobium*. A point-of-care circulating cathodic antigen (POC-CCA) urine casette test (Rapid Medical Diagnostics; Cape Town, South Africa) will be used to detect the presence of *S. mansoni* infections (Coulibaly et al., 2011).

(v) For quality control, a random sample of 10% of all Kato-Katz and urine filtration slides will be re-examined by a senior technician (Speich et al., 2015). In case of discordant results, the slides will be read a third time and results discussed among the technicians until agreement has been reached.

Following Table 2.1 depicts the various variables to be collected and applied cut-offs for the relevant research question and corresponding specific objectives set for the study.

Table 2.1 Summary of variables to be collected and applied cut-offs based on literature review (continues on next page)

Variables to be collected				Observation period		
		Units	Cut-offs	T1 2015	T2 2015	T3 2016
Schisto-somiasis	*Schistosoma mansoni*	eggs/g of stool	Light int. 1-99 epg; Moderate int. 100-399 epg; Heavy int. >399 epg	X	X	X
	Schistosoma haematobium	eggs/ml of urine	Light int. <50 eggs/10ml of urine; Heavy int. >49/10ml of urine or visible hematuria	X		
Soil-transmitted-helminthiasis	*Ascaris lumbricoides*	eggs/g of stool	Light int. 1-4999 epg; Moderate int. 5000-49999 epg; Heavy int. >49999 epg	X	X	X
	Trichuris trichiura	eggs/g of stool	Light int. 1-999 epg; Moderate int. 1000-9999 epg; Heavy int. >9999 epg	X	X	X
	Fasciola hepatica	eggs/g of stool	+/-	X	X	X
	Hookworm egg count	eggs/g of stool	Light int. 1-1999 epg; Moderate int. 2000-3999 epg; Heavy int. >3999 epg	X	X	X
	Taenia spp. proglottids	eggs/g of stool	+/-	X	X	X
Gastro-intestinal infections	Presence of intestinal protozoa (*Cryptosporidium* spp. and *Giardia intestinalis*)	+/-	+/-	X	X	X
	Presence of the bacterium *Helicobacter pylori*	+/-	+/-	X	X	X
Personal characteristics	Age	Years/ months		X	X	X
	Sex	male/ female		X	X	X
Functional signs	Diarrhoea events	#	#	X	X	X
	Presence of mucus	+/-	+/-	X		X
	Presence of fever	+/-	Oral temp. >37.8°C	X	X	X

Variables to be collected				Observation period		
		Units	Cut-offs	T1 2015	T2 2015	T3 2016
	Presence of abdominal pain, change in bowel movements	+/-	+/-	X	X	X
Physical examination	Detailed physical examination (e.g. tenderness, hepatomegaly, splenomegaly)	+/- on a scale	+/- on a scale	X		X
Blood measurements	Anaemia (e.g. conjunctival pallor; haemoglobin concentration in the blood)	g/L	Non-anaemia >114g/L; Mild 110-114g/L; Moderate 80-109g/L; Severe <80g/L	X	X	X
	Evidence of elevated blood pressure (jugulovenous pressure, cardiac auscultation, blood pressure)	+/- on a scale mm Hg	High blood pressure: >95th percentile of children who are the same sex, age and height	X	X	X
Diabetes	Presence of diabetes (HbA1c level)	mmol/ mol HbA1c	Non-diabetes <6%; Prediabetes 6-6.4%; Diabetes >6.5%	X	X	X
Malnutrition	2 Z-scores: BMI-for-age (BMIZ), Height-for-age (HAZ)	for years; cm for years	Wasting is defined as ≤-2 in BAZ score; Stunting is defined as ≤-2 HAZ score	X	X	X
Anthro-pometry	Height	cm		X	X	X
	Weight	kg		X	X	X
	Body mass index (BMI)	kg/m^2; for years; cm for years	WHO guide-lines 2 Z-scores: BMI-for-age (BMIZ), Height-for-age (HAZ)	X	X	X
	Upper arm circumference	cm		X	X	X
	Body composition (thickness of the skinfolds at two sites; triceps and subscapular)	mm		X	X	X
	Muscle mass at targeted sites (e.g.	mm		X	X	X

Variables to be collected				Observation period		
		Units	Cut-offs	T1 2015	T2 2015	T3 2016
	deltoid, vastus medialis)					
Cardio-respiratory fitness	VO^2 max (Maximum volume of oxygen uptake)	ml * O_2/min	Wilmore JH and Costill DL (2005)	X	X	X
Muscle strength	Upper body grip strength	kg	Eurofit	X	X	X
Flexibility	Sit & reach test	cm	Eurofit	X	X	X
Lower body strength	Standing broad jump test	cm	Eurofit	X	X	X
Coordination & Speed	Jump sideward test	#	Eurofit	X	X	X
Questionnaires	Hunger scale	-	WHO	X	X	X
	Socio-economic and demographic profile	-		X		X
	Physical activity and behavioral patterns (HBSC*)	-		X	X	X
	The test of attention d2; selective attention	-		X	X	X
	Children's physical and psychological well-being (Kidscreen-27)	-		X	X	X
	Individual differences in the capacity for self-control (SCS)	-		X	X	X
ANA* and EoYR*	Measuring symptoms of school burnout	Standardized school grades		X		X

*ANA: Annual National Assessment; *EoYR: End of the Year Results and *HBSC: Health Behaviours in School Age Children

Data collection and management

The type of data to be collected include: (i) quantitative data on the prevalence of intestinal parasites, measurements of blood pressure and glycated haemoglobin level, anthropometry and the level of physical fitness, cognitive performance and psychosocial health; (ii) socioeconomic status and demographic data, including the geographical location (latitude and longitude expressed in decimal degrees) of the students' households; and (iii) qualitative data on the feasibility and acceptability of the intervention measures implemented via focus-group discussions.

Data will be double-entered, cross-checked with EpiData 3.1 (EpiData Association; Odense, Denmark) and merged into a single database using STATA version 13.0 (STATA Corp.; College Station, TX, USA).

Data analysis

The primary objectives of the statistical analysis will be to assess (i) the prevalence of infections and conditions, and their associations with physical fitness, nutritional status, cognitive performance and psychosocial health at baseline and over time; and (ii) the effects of interventions on disease status and other health parameters. The secondary objective will be to assess the feasibility and acceptability of the health interventions implemented.

Parasitological status will be assessed in terms of prevalence and intensity of infection with specific parasite species and the extent of multiparasitism. Clinical and anthropometric indicators, physical fitness, cognitive performance and psychosocial health scores will be characterised by their mean and standard deviation if they are normally distributed and by their median and interquartile range otherwise. Questionnaire data pertaining to the psychosocial health will be expressed as percentages. All indicators will be compared between physically fit/non-infected and physically unfit/infected children and between intervention and control schools.

To assess the effects of the different interventions on the parasitological status, clinical and anthropometric indicators, physical fitness, cognitive performance and psychosocial health, the following statistical procedures will be employed:

(i) Mixed logistic regression models with random intercepts for schools will be used to compare binary data, such as parasitological status and clinical indicators, between the intervention and control groups.

(ii) Linear mixed models with random intercepts for schools will be used for numeric data, such as anthropometric measurements, physical fitness, cognitive performance, and psychosocial health scores and haemoglobin concentration measurements.

These models will include sex and age of the child, socioeconomic status of the parents or health status or fitness at the baseline survey as well as variables which were not perfectly randomised and might therefore act as confounders. Moreover, as intervention effects might depend on baseline characteristics of the child, stratified analyses and analyses involving interaction terms will be performed. The potential effect modifiers tested include sex, age, socioeconomic status of the parents or health status or fitness at the baseline survey.

Ethical approval and considerations

Ethical approval for the study has been obtained from the Ethics Committee Northwest and Central Switzerland (EKNZ) in Basel, Switzerland (reference no. 2014-179; obtained on 1 August 2014), and the following ethics committees in Port Elizabeth, South Africa:

(i) NMMU Human Ethics Committee (Human) (reference no. H14-HEA-HMS-002; obtained on 4 July 2014);

(ii) Eastern Cape Department of Education (obtained on 13 August 2014); and

(iii) Eastern Cape Department of Health (obtained on 7 November 2014).

Besides obtaining written informed consent, confidentiality of the study participants will be ensured by giving each participant a unique project-ID number so that all collected data of the schoolchildren will remain anonymous. Data will be used exclusively for scientific research and samples will be discarded after laboratory analyses have been completed. Paper records of the study are kept in locked cupboards in South Africa, accessible only by the main investigators. After 5 years, these records will be destroyed. Data entered into computerised files will be accessible only to authorised investigators or medical personnel directly involved with the study. At the end of the project, successful and appropriate interventions will be provided to the control schools so that the whole community can benefit from this project.

2.6 Discussion

The baseline survey of this study has been conducted in February-March 2015. Subsequently, eight schools, with approximately 1000 schoolchildren, were selected for the study. During this first survey time point, several challenges were met and needed to be addressed. First, the study is conducted in impoverished and harsh environments, where illiteracy and violence are common (Deaton and Tortora, 2015, Deaton, 2007). In these challenging socioeconomic conditions, the recruited schoolchildren may often be subjected to the lack of sufficient care or neglect by their parents (Case and Deaton, 2005, Case and Deaton, 1999, Steptoe et al., 2015). As such, it was difficult to obtain support and written informed consent from the parents/guardians even if the schoolchildren have provided their oral assent. To address this issue, we prepared and conducted several pre-study workshops in the selected schools. The study purposes were explained in detail to the school principals, teachers and parents/guardians, in order to garner their strong support. We also adapted our study as much as possible in response to ideas voiced by teachers and parents to tailor the study further to the needs of the people concerned. Second, three languages, namely Afrikaans, Xhosa and English, are being spoken by the communities in the study area. For example, certain schoolchildren might prefer to speak and write in English, while others from the same school prefer Afrikaans. In addition, Xhosa-speaking children often preferred the tests to be administered in English, with explanations in Xhosa. This proved to be challenging when questionnaires were administered. Furthermore, although the questionnaires were pre-tested with some schoolchildren, the content of the questionnaires employed, particularly the ones focusing on psychosocial health indicators, did not fully match the educational level of the schoolchildren, making it hard for them to understand and answer the questions. To address these issues, we employed native speakers to perform the translation and to pre-test the translated questionnaires among teachers and students before the start of the study. During the actual administration of the questionnaires, we had the help of teachers and school volunteers to explain the questions to the children in their preferred language.

During our sample size calculation, we accounted for a 10% loss to follow-up. Moving forward with the follow-ups and second phase of intervention, we might expect a more substantial loss (30-40%) to follow-up as people show considerable mobility in this setting. We will address the potential bias resulting from differential loss to follow-up using inverse probability weighting, i.e. by assigning each follow-up participant the inverse of their prior probability of participation in the follow-up as weight in the follow-up analyses. In addition, multiple imputation will be used to deal with missing data where appropriate. However, it is difficult to predict the extent of the movement of people and hence, our presumed loss to follow-up might not be accurate.

Based on the obtained results, we have designed the health interventions together with local principals and teachers. Such collaboration is aimed at bolstering a sense of community ownership and empowerment, where the community feels that they are taking steps to improve the health of their children. We hope that this approach will further encourage the continued participation of the children and their parents/guardians during the study and sustained use of the interventions after the study has ceased.

In conclusion, the DASH study described here will provide a snapshot on the status of intestinal parasite infections and risk factors for diabetes and hypertension in selected disadvantaged primary schools in Port Elizabeth, South Africa. To our knowledge, such data are currently not available, and hence, our study fills an important void and generates new local evidence. By linking children's parasitic infection status with the physical fitness, nutritional status, cognitive performance and psychosocial health, this wealth of information will help shed new light on the health consequences incurred by the children and provide guidance for further health interventions in this area. Implementation of setting-specific interventions within the longitudinal study will further highlight the feasibility and scalability of these health interventions in the study area.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

PY, IM, PS and JU designed the study, established the methods and questionnaires and wrote the original study protocol. All other authors contributed to the development of the study protocol. UP is the principal investigator. CW, IM, PY and DS were the main coordinators of the study. IM, PY, DS, NSNH, LS, AG, BPD, MG, SG, TH, DB, RDR, UP and CW conducted the study. CW is responsible for community sensitization; IM is liable for drug administration. IM managed data entry, cleaning and preparation of the database for statistical analysis, supported by HS. PY, IM and JU wrote the first draft of the manuscript. All authors read and provided comments on the drafts and approved the final version of the paper prior to submission.

Acknowledgements

The study is embedded within the scope of the Swiss-South African Joint Research Programme (SSAJRP), where the Swiss National Science Foundation (SNSF) and the National Research Foundation (NRF) in South Africa have issued a call for joint research projects (JRPs). The DASH study is funded by the SNSF (project no. IZLSZ3 149015) and the NRF of South Africa (project no. 87397). The funders played no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

2.7 References

Affairs, U. N. D. o. E. a. S. 2014. Open working group proposal for sustainable development goals. United Nations Department of Economic and Social Affairs.

Agherdien, Y., George, A. C. & Hendricks, S. 1997. *South End as we knew it,* Port Elizabeth, Western Research Group.

Bates, M. E. & Lemay, E. P., Jr. 2004. The d2 test of attention: construct validity and extensions in scoring techniques. *J Int Neuropsychol Soc,* 10**,** 392-400.

Baumeister, R. F., Gailliot, M., DeWall, C. N. & Oaten, M. 2006. Self-regulation and personality: how interventions increase regulatory success, and how depletion moderates the effects of traits on behavior. *J Pers,* 74**,** 1773-801.

Bieri, F. A., Gray, D. J., Raso, G., Li, Y. S. & McManus, D. P. 2012. A systematic review of preventive health educational videos targeting infectious diseases in schoolchildren. *Am J Trop Med Hyg,* 87**,** 972-8.

Boutayeb, A. 2006. The double burden of communicable and non-communicable diseases in developing countries. *Trans R Soc Trop Med Hyg,* 100**,** 191-199.

Brickenkamp, R. & Zillmer, E. 1998. *The d2 test of attention,* Seattle, Hogrefe & Huber Publishers.

Case, A. & Deaton, A. 1999. School inputs and educational outcomes in South Africa. *Q J Econ,* 114**,** 1047-1084.

Case, A. & Deaton, A. 2005. Health and wealth among the poor: India and South Africa compared. *Am Econ Rev,* 95**,** 229-233.

Coates, J., Swindale, A. & Bilinsky, P. 2007. *Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator Guide,* Washington, D.C., Academy for Educational Development.

Coulibaly, J. T., Knopp, S., N'Guessan, N. A., Silué, K. D., Fürst, T., Lohourignon, L. K., Brou, J. K., N'Gbesso, Y. K., Vounatsou, P., N'Goran, E. K. & Utzinger, J. 2011. Accuracy of urine circulating cathodic antigen (CCA) test for *Schistosoma mansoni* diagnosis in different settings of Côte d'Ivoire. *PLoS Negl Trop Dis,* 5**,** e1384.

Deaton, A. 2007. Height, health, and development. *Proc Natl Acad Sci USA,* 104**,** 13232-7.

Deaton, A. & Tortora, R. 2015. People in Sub-Saharan Africa rate their health and health care among the lowest in the world. *Health Affairs,* 34**,** 519-527.

Draper, C. E., de Villiers, A., Lambert, E. V., Fourie, J., Hill, J., Dalais, L., Abrahams, Z. & Steyn, N. P. 2010. HealthKick: a nutrition and physical activity intervention for primary schools in low-income settings. *BMC Public Health,* 10**,** 398.

Duckworth, A. L. 2011. The significance of self-control. *Proc Natl Acad Sci USA,* 108**,** 2639-40.

Duckworth, A. L., Grant, H., Loew, B., Oettingen, G. & Gollwitzer, P. M. 2010. Self-regulation strategies improve self-discipline in adolescents: benefits of mental contrasting and implementation intentions. *J Educ Psychol,* 31**,** 17-26.

Elliot, C., Lang, C., Brand, S., Holsboer-Trachsler, E., Pühse, U. & Gerber, M. 2015. Burnout symptoms among adolescents above versus below current recommendations for vigorous physical activity: An exploratory study with vocational students. *J Sport Exercise Psychol*.

Espana-Romero, V., Artero, E. G., Santaliestra-Pasias, A. M., Gutierrez, A., Castillo, M. J. & Ruiz, J. R. 2008. Hand span influences optimal grip span in boys and girls aged 6 to 12 years. *J Hand Surg Am,* 33**,** 378-84.

Europe, C. o. 1983. Testing physical fitness: Eurofit experimental battery. *Strasbourg: Council of Europe.*

Gailliot, M. T., Plant, E. A., Butz, D. A. & Baumeister, R. F. 2007. Increasing self-regulatory strength can reduce the depleting effect of suppressing stereotypes. *Pers Soc Psychol Bull,* 33**,** 281-94.

Gallotta, M. C., Guidetti, L., Franciosi, E., Emerenziani, G. P., Bonavolonta, V. & Baldari, C. 2012. Effects of varying type of exertion on children's attention capacity. *Med Sci Sports Exerc,* 44**,** 550-5.

Hagger, M. S., Wood, C., Stiff, C. & Chatzisarantis, N. L. D. 2009. The strength model of self-regulation failure and health-related behavior. *Health Psychol Rev,* 3**,** 208-238.

Hong, S. D., Yang, J. W., Jang, W. S., Byun, H., Lee, M. S., Kim, H. S., Oh, M. Y. & Kim, J. H. 2007. The KIDSCREEN-52 quality of life measure for children and adolescents (KIDSCREEN-52-HRQOL): reliability and validity of the Korean version. *J Korean Med Sci,* 22**,** 446-52.

Hürlimann, E., Houngbedji, C. A., N'Dri, P. B., Bänninger, D., Coulibaly, J. T., Yap, P., Silué, K. D., N'Goran, E. K., Raso, G. & Utzinger, J. 2014. Effect of deworming on school-aged children's physical fitness, cognition and clinical parameters in a malaria-helminth co-endemic area of Côte d'Ivoire. *BMC Infect Dis,* 14**,** 411.

Keiser, J. & Utzinger, J. 2008. Efficacy of current drugs against soil-transmitted helminth infections: systematic review and meta-analysis. *JAMA,* 299**,** 1937-1948.

Kimani-Murage, E. W., Kahn, K., Pettifor, J. M., Tollman, S. M., Dunger, D. B., Gomez-Olive, X. F. & Norris, S. A. 2010. The prevalence of stunting, overweight and obesity, and metabolic disease risk in rural South African children. *BMC Public Health,* 10**,** 158.

Kish, L. 1965. Sampling organizations and groups of unequal sizes. *Am Sociol Rev,* 30**,** 564-72.

Knopp, S., Mgeni, A. F., Khamis, I. S., Steinmann, P., Stothard, J. R., Rollinson, D., Marti, H. & Utzinger, J. 2008. Diagnosis of soil-transmitted helminths in the era of preventive chemotherapy: effect of multiple stool sampling and use of different diagnostic techniques. *PLoS Negl Trop Dis,* 2**,** e331.

Kriemler, S., Zahner, L., Schindler, C., Meyer, U., Hartmann, T., Hebestreit, H., Brunner-La Rocca, H. P., van Mechelen, W. & Puder, J. J. 2010. Effect of school based physical activity programme (KISS) on fitness and adiposity in primary schoolchildren: cluster randomised controlled trial. *BMJ,* 340**,** c785.

Léger, L. A., Mercier, D., Gadoury, C. & Lambert, J. 1988. The multistage 20 meter shuttle run test for aerobic fitness. *J Sports Sci,* 6**,** 93-101.

Marshall, S. J. 2004. Developing countries face double burden of disease. *Bull World Health Organ,* 82**,** 556.

Miller, H. V., Barnes, J. C. & Beaver, K. M. 2011. Self-control and health outcomes in a nationally representative sample. *Am J Health Behav,* 35**,** 15-27.

Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H., Houts, R., Poulton, R., Roberts, B. W., Ross, S., Sears, M. R., Thomson, W. M. & Caspi, A. 2011. A gradient of childhood self-control predicts health, wealth, and public safety. *Proc Natl Acad Sci USA,* 108**,** 2693-8.

Muraven, M., Baumeister, R. F. & Tice, D. M. 1999. Longitudinal improvement of self-regulation through practice: building self-control strength through repeated exercise. *J Soc Psychol,* 139**,** 446-57.

Niederer, I., Kriemler, S., Zahner, L., Bürgi, F., Ebenegger, V., Hartmann, T., Meyer, U., Schindler, C., Nydegger, A., Marques-Vidal, P. & Puder, J. J. 2009. Influence of a lifestyle intervention in preschool children on physiological and psychological parameters (Ballabeina): study design of a cluster randomized controlled trial. *BMC Public Health,* 9**,** 94.

Oaten, M. & Cheng, K. 2006. Longitudinal gains in self-regulation from regular physical exercise. *Br J Health Psychol,* 11**,** 717-33.

Oaten, M., Cheng, K. 2004. Improvements in self-control from financial monitoring. *J Econ Psychol,* 28**,** 487-501.

Polman, K., Becker, S. L., Alirol, E., Bhatta, N. K., Bhattarai, N. R., Bottieau, E., Bratschi, M. W., Burza, S., Coulibaly, J. T., Doumbia, M. N., Horie, N. S., Jacobs, J., Khanal, B., Landoure, A., Mahendradhata, Y., Meheus, F., Mertens, P., Meyanti, F., Murhandarwati, E. H., N'Goran, E. K., Peeling, R. W., Ravinetto, R., Rijal, S., Sacko, M., Saye, R., Schneeberger, P. H., Schurmans, C., Silué, K. D., Thobari, J. A., Traoré, M. S., van Lieshout, L., van Loen, H., Verdonck, K., von Muller, L., Yansouni, C. P., Yao, J. A., Yao, P. K., Yap, P., Boelaert, M., Chappuis, F. & Utzinger, J. 2015. Diagnosis of neglected tropical diseases among patients with persistent digestive disorders (diarrhoea and/or abdominal pain >/=14 days): Pierrea multi-country, prospective, non-experimental case-control study. *BMC Infect Dis,* 15**,** 338.

Puder, J. J., Marques-Vidal, P., Schindler, C., Zahner, L., Niederer, I., Bürgi, F., Ebenegger, V., Nydegger, A. & Kriemler, S. 2011. Effect of multidimensional lifestyle intervention on fitness and adiposity in predominantly migrant preschool children (Ballabeina): cluster randomised controlled trial. *BMJ,* 343**,** d6195.

Ravens-Sieberer, U., Gosch, A., Rajmil, L., Erhart, M., Bruil, J., Duer, W., Auquier, P., Power, M., Abel, T., Czemy, L., Mazur, J., Czimbalmos, A., Tountas, Y., Hagquist, C., Kilroe, J. & Kidscreen Group, E. 2005. KIDSCREEN-52 quality-of-life measure for children and adolescents. *Expert Rev Pharmacoecon Outcomes Res,* 5**,** 353-64.

Ravens-Sieberer, U., Gosch, A., Rajmil, L., Erhart, M., Bruil, J., Power, M., Duer, W., Auquier, P., Cloetta, B., Czemy, L., Mazur, J., Czimbalmos, A., Tountas, Y., Hagquist, C., Kilroe, J. & Group, K. 2008. The KIDSCREEN-52 quality of life measure for children and adolescents: psychometric results from a cross-cultural survey in 13 European countries. *Value Health,* 11**,** 645-58.

Release, M., Grant, M. o. E. D. & Cape, W. 2013. Background to the national quintile system. Western Cape Education Department.

Ruiz, J. R., Espana-Romero, V., Ortega, F. B., Sjostrom, M., Castillo, M. J. & Gutierrez, A. 2006. Hand span influences optimal grip span in male and female teenagers. *J Hand Surg Am,* 31**,** 1367-72.

Salmela-Aro, K., Kiuru, N., Leskinen, E. & Nurmi, J.-E. 2009a. School-Burnout Inventory (SBI). Reliability and validity. *EJPA,* 25**,** 48-57.

Salmela-Aro, K., Kiuru, N. & Nurmi, J. E. 2008. The role of educational track in adolescents' school burnout: a longitudinal study. *Br J Educ Psychol,* 78**,** 663-89.

Salmela-Aro, K., Savolainen, H. & Holopainen, L. 2009b. Depressive symptoms and school burnout during adolescence: evidence from two cross-lagged longitudinal studies. *J Youth Adolesc,* 38**,** 1316-27.

Salmela-Aro, K. & Tynkkynen, L. 2012. Gendered pathways in school burnout among adolescents. *J Adolesc,* 35**,** 929-39.

Santosa, A., Wall, S., Fottrell, E., Hogberg, U. & Byass, P. 2014. The development and experience of epidemiological transition theory over four decades: a systematic review. *Glob Health Action,* 7**,** 23574.

Sherkhonov, T., Yap, P., Mammadov, S., Sayfuddin, K., Martinez, P., Amoss, W. P., Wientzen, R. L. & Steinmann, P. 2013. National intestinal helminth survey among schoolchildren in Tajikistan: prevalences, risk factors and perceptions. *Acta Trop,* 126**,** 93-8.

Southern Africa Development, R. a. T. I. 2013. *One community many communities: a Nelson Mandela Bay Heritage and History Project (NMBHHP): forced removals in South End, North End, Salisbury Park, Fairview, Willowdene and Korsten.*

Speich, B., Ali, S. M., Ame, S. M., Albonico, M., Utzinger, J. & Keiser, J. 2015. Quality control in the diagnosis of *Trichuris trichiura* and *Ascaris lumbricoides* using the Kato-Katz technique: experience from three randomised controlled trials. *Parasit Vectors,* 8**,** 82.

Steptoe, A., Deaton, A. & Stone, A. A. 2015. Subjective wellbeing, health, and ageing. *Lancet,* 385**,** 640-8.

Tangney, J. P., Baumeister, R. F. & Boone, A. L. 2006. High self-control predicts good adjustment, less pathology, better grades, and interpersonal success. *J Pers,* 72**,** 271-324.

Tian, H., Du Toit, D. & Toriola, A. L. 2015. The effects of an enhanced quality physical education programme on the physical activity levels of grade 7 learners in Potchefstroom, South Africa. *Phys Educ Sport Pedagog,* 22**,** 35-50.

Utzinger, J., N'Goran, E. K., Caffrey, C. R. & Keiser, J. 2011. From innovation to application: social-ecological context, diagnostics, drugs and integrated control of schistosomiasis. *Acta Trop,* 120 Suppl 1**,** S121-37.

Walter, C. M. 2011. In-school physical activity patterns of primary school learners from disadvantaged schools in South Africa. *Afr J Phys Health Educ Recreat Dance* 17**,** 780-789.

Walter, C. M., Du Randt, R. & Venter, D. J. L. 2011. The physical activity and health status of two generations of black South African professional women. *Health SA Gesondheid,* 16**,** 538.

Wassenberg, R., Hendriksen, J. G., Hurks, P. P., Feron, F. J., Keulers, E. H., Vles, J. S. & Jolles, J. 2008. Development of inattention, impulsivity, and processing speed as measured by the d2 test: results of a large cross-sectional study in children aged 7-13. *Child Neuropsychol,* 14**,** 195-210.

WHO. 2007. *Growth reference 5-19 years* [Online]. Available: http://www.who.int/growthref/en/ [Accessed].

WHO 2014. Health Behaviour In School-Aged Children. St. Andrews: WHO.

Yap, P., Fürst, T., Müller, I., Kriemler, S., Utzinger, J. & Steinmann, P. 2012. Determining soil-transmitted helminth infection status and physical fitness of school-aged children. *J Vis Exp***,** e3966.

Yap, P., Wu, F. W., Du, Z. W., Hattendorf, J., Chen, R., Jiang, J. Y., Kriemler, S., Krauth, S. J., Zhou, X. N., Utzinger, J. & Steinmann, P. 2014. Effect of deworming on physical fitness of school-aged children in Yunnan, China: a double-blind, randomized, placebo-controlled trial. *PLoS Negl Trop Dis,* 8**,** e2983.

Chapter 3 Article I

3.1 Associations between selective attention and soil-transmitted helminth infections, socio-economic status, and physical fitness in disadvantaged children in Port Elizabeth, South Africa: an observational study

Short title: Possible determinants of selective attention in South African school children

Stefanie Gall[1*], Ivan Müller[1,2,3], Cheryl Walter[4], Harald Seelig[1], Liana Steenkamp[4, 5], Uwe Pühse[1], Rosa du Randt[4], Danielle Smith[4], Larissa Adams[4], Siphesihle Nqweniso[4], Peiling Yap[6], Sebastian Ludyga[1], Peter Steinmann[2,3], Jürg Utzinger[2,3], Markus Gerber[1]

Affiliations

[1] Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland

[2] Swiss Tropical and Public Health Institute, Basel, Switzerland

[3] University of Basel, Basel, Switzerland,

[4] Department of Human Movement Science, Nelson Mandela Metropolitan University, Port Elizabeth, South Africa,

[5] Department of HIV&AIDS Research, Nelson Mandela Metropolitan University, Port Elizabeth, South Africa,

[6] Institute of Infectious Disease and Epidemiology, Tan Tock Seng Hospital, Singapore

[*]Corresponding author

E-mail: stefanie.gall@unibas.ch

This study has been published in **PLoS Neglected Tropical Diseases** 2017

3.2 Abstract

Background: Socioeconomically deprived children are at increased risk of ill-health associated with sedentary behavior, malnutrition, and helminth infection. The resulting reduced physical fitness, growth retardation, and impaired cognitive abilities may impede children's capacity to pay attention. The present study examines how socioeconomic status (SES), parasitic worm infections, stunting, food insecurity, and physical fitness are associated with selective attention and academic achievement in school-aged children.

Methodology: The study cohort included 835 children, aged 8-12 years, from eight primary schools in socioeconomically disadvantaged neighborhoods of Port Elizabeth, South Africa. The d2-test was utilized to assess selective attention. This is a paper and pencil letter-cancellation test consisting of randomly mixed letters *d* and *p* with one to four single and/or double quotation marks either over and/or under each letter. Children were invited to mark only the letters *d* that have double quotation marks. Cardiorespiratory fitness was assessed via the 20 m shuttle run test and muscle strength using the grip strength test. The Kato-Katz thick smear technique was employed to detect helminth eggs in stool samples. SES and food insecurity were determined with a pre-tested questionnaire, while end of year school results were used as an indicator of academic achievement.

Principal findings: Children infected with soil-transmitted helminths had lower selective attention, lower school grades (academic achievement scores), and lower grip strength (all $p<0.05$). In a multiple regression model, low selective attention was associated with soil-transmitted helminth infection ($p<0.05$) and low shuttle run performance ($p<0.001$), whereas higher academic achievement was observed in children without soil-transmitted helminth infection ($p<0.001$) and with higher shuttle run performance ($p<0.05$).

Conclusions/significance: Soil-transmitted helminth infections and low physical fitness appear to hamper children's capacity to pay attention and thereby impede their academic performance. Poor academic achievement will make it difficult for children to realize their full potential, perpetuating a vicious cycle of poverty and poor health.

Author summary: Children growing up in challenging environments, such as townships in South Africa, are at an increased risk of ill-health associated with sedentary behavior, poor nutrition, growth retardation, and infections with parasitic worms. Negative factors such as limited educational resources, insufficient health care, and safety are exacerbating the effects of poverty and, taken together, might cause developmental delays and school failure. A total of 835 school children aged 8-12 years were examined for soil-transmitted helminth infection, physical fitness, selective attention, stunting, household socioeconomic conditions, and food security. Furthermore, children's academic achievement scores were utilized as a proxy for academic achievement. The multivariate analyses showed that low selective attention was associated with soil-transmitted helminth infection and low shuttle run performance, whereas higher academic achievement was observed in children without soil-transmitted helminth infection and with higher shuttle run performance. Our study suggests that soil-transmitted helminths and low physical fitness hinder children from realizing their full potential.

Trial registration: ClinicalTrials.gov ISRCTN68411960

3.3 Introduction

Attention skills are relevant for academic foundations and are important for learning (Duncan et al., 2007). Selective attention is the ability to select and focus on a particular task, while simultaneously suppressing irrelevant or distracting information. Competing information can occur both externally and internally due to visual or auditory distractions or distracting thoughts (Stevens and Bavelier, 2012). Selective attention has been associated with important domains in education, such as language processing (Sussman and Steinschneider, 2009), literacy (Stevens et al., 2009), and numeracy (Checa and Rueda, 2011), and hence, plays an important role in academic achievement. A growing body of literature documents that children from low-income households exhibit more attention deficits compared to their higher-income peers (Mezzacappa, 2004, Farah et al., 2004). Of note, academic achievement depends on multiple factors such as educational opportunity, socioeconomic status (SES), health and nutritional status, family environment (Basch, 2011, Chung, 2015), social competence (Wentzel, 1991), cognitive skills, and the ability to pay attention (Stevens and Bavelier, 2012).

Children growing up in socioeconomically deprived environments face multiple challenges. Essential services, such as health care, sanitation, physical security, electricity, and high quality academic and physical education are often lacking, with serious consequences for children's psychological and physiological development and wellbeing (Lu et al., 2016). Poverty also limits the parents' ability to provide a responsive, supportive, and safe learning environment (Ferguson et al., 2001), and lessens the probability that children will have access to cognitively stimulating materials (e.g., books and toys) (Riley et al., 2014). Families with low income often invest most of their resources into covering their basic needs, such as food and housing, and have therefore limited means to invest in the future of their children (Bradley and Corwyn, 2002). Poverty also puts children at risk of chronic malnutrition (Bradley and Corwyn, 2002). Chronic malnutrition causes stunting and has been found to be associated with poor cognitive development resulting in low IQ, and problems with motor development (Anthony et al., 2011). This, in turn, can impede children's ability to concentrate, process information, and focus on academic work (Bloom et al., 2006).

Poor living conditions with a lack of clean water, inadequate sanitation, and insufficient hygiene also favor parasitic worm and intestinal protozoa infections (Strunz et al., 2014, Speich et al., 2016), which may lead to symptoms such as abdominal pain, diarrhea, anemia, growth retardation, reduced physical fitness, cognitive impairment, and poor academic achievement (Utzinger et al., 2012, Yap et al., 2014). Recent systematic reviews suggest associations between parasitic worm infection and children's cognitive function and academic performance, but positive effects of mass deworming on cognition or school performance remain elusive (Nokes et al., 1992, Taylor-Robinson et al., 2015, Welch et al., 2017, Liu et al., 2015). A study by Ezeamama et al. (2005) found that roundworm (*Ascaris lumbricoides*) infection was associated with poor performance on tests of memory, whereas whipworm (*Trichuris trichiura*) infection was associated with poor performance on tests of verbal fluency among Filipino children. To our knowledge, there is a paucity of studies investigating whether soil-transmitted helminth infections are associated with selective attention.

Children from families with low SES are also less likely to have access to health care or health insurance, resulting in a greater risk of illness and school absenteeism and consequently a lack of academic input compared to better-off peers (Bloom et al., 2006). Recent reviews and meta-analyses have shown that physical activity elicits short- and long-term benefits for children's executive function (Ludyga et al., 2016), attention (Tomporowski et al., 2015), and other academic outcomes (Tomporowski et al., 2008). Yet, physical activity levels are often low among poor children and youth, also in South Africa (Draper et al., 2014). For instance, a study by Walter (2011), which focused on primary school children in disadvantaged schools, observed that most children do not achieve the recommended 60 min of daily moderate-to-vigorous physical activity (MVPA). These results are not surprising given that sport and recreation facilities are often inadequate, inaccessible, or in poor condition, while qualified teachers are scarce and physical education and extramural sport programs are rare (McHunu and Le Roux, 2010).

The purpose of the present study was to find out how children's selective attention and academic achievement relate to age, sex, SES, helminth infection status, stunting, food security, and physical fitness. In a first step, we looked at bivariate associations and compared children with or without helminth infection, and stunted or non-stunted children. In a second step, we examined multivariate associations to find out whether and how age, sex, SES, helminth infection status, stunting, food security, and physical fitness relate to selective attention and academic achievement if all these variables are considered simultaneously.

3.4 Methods

Ethics statement

The "Disease, Activity and Schoolchildren's Health" (DASH) cohort study was approved by the ethical review board of Northwestern and Central Switzerland (EKNZ; reference no. 2014-179, approval date: 17 June 2014), the Nelson Mandela Metropolitan University (NMMU) Human Ethics Committee (study number H14-HEA-HMS002, approval date: 4 July 2014), the Eastern Cape Department of Education (approval date: 3 August 2014), and the Eastern Cape Department of Health (approval date: 7 November 2014) in Port Elizabeth, South Africa. The study is registered at ISRCTN registry under controlled-trials.com (unique identifier: ISRCTN68411960, registration date: 1 October 2014).

Details regarding the information of potential study participants, exclusions due to medical reasons, management of helminth infections, and referrals, are provided in a previously published study protocol (Yap et al., 2015). In brief, oral assent from each participating child was sought and individual written informed consent was obtained from parents/guardians. Participation was voluntary and children could withdraw from the study at any time without further obligations. Children were eligible for this study if they met the following inclusion criteria: (i) are willing to participate in the study; (ii) have a written informed consent by a parent/guardian; (iii) are not participating in other clinical trials during the study period; and (iv) do not suffer from medical conditions, which will prevent participation in the study, as determined by qualified medical personnel. To ensure confidentiality, each study participant was given a unique identification number. All tests were available in English, Xhosa, and Afrikaans. To ensure optimal translation of the tests, we collaborated with independent professional translators and followed the procedure set out by Brislin (1986). Thus, test instructions and items were translated from English into Xhosa and Afrikaans, and pilot-tested with a small sample of Xhosa and Afrikaans speaking students and school children the same age as the study cohort. Schools were recruited from 2014 to 2015. Data assessment took place between February 2015 and March 2015.

Study population and procedures

The study involved 8- to 12-year-old children attending grade 4 from eight schools located in socioeconomically disadvantaged neighborhoods in Port Elizabeth, South Africa. South African public schools are classified into five groups, with quintile one standing for the poorest and quintile five for the least poor (Hall and Giese, 2009). Study schools belonged to quintile three. The sample size calculation for the study was based on achieving sufficient precision in estimating the prevalence of soil-transmitted helminth infections, with a targeted sample size of approximately 1000 grade 4 school children (for more details regarding power calculation see Yap et al. (2015)).

Body weight and height

All children were asked to remove their shoes and jerseys/jackets before standing on a digital weighing scale (Micro T7E electronic platform scale, Optima Electronics; George, South Africa). Body weight was measured once and recorded to the nearest 0.1 kg. With the shoes removed, each child then stood against a Seca stadiometer (Surgical SA; Johannesburg, South Africa) with their back erect and shoulders relaxed. Body height was measured once and recorded to the nearest 0.1 cm.

Physical fitness

Upper body strength was determined by the grip strength test (Europe, 1983). The Saehan hydraulic hand dynamometer (MSD Europe BVBA; Tisselt, Belgium) was employed. The field investigator demonstrated how to hold the hand dynamometer and instructed the child to sit relaxed, spine erect, and arm position at a 90° angle. Each child had six trials, alternating between the right and left hand with a 30 sec resting period between trials, griping the hand dynamometer as hard as possible. All six trials were recorded to the nearest 1 kg and averaged.

To measure children's aerobic fitness, the 20 m shuttle run test was utilized, following the test protocol described by Léger et al. (1988). A premeasured running course was laid out on a flat terrain and marked with color-coded cones. Children who felt sick or voiced discomfort were excluded. The test procedures were explained and a researcher demonstrated two trial runs. Once children were familiar with the test procedures, they started with a running speed of 8.5 km/h, following a researcher who set the pace according to the acoustic signal. The frequency of the sound signal gradually increased every min by 0.5 km/h. If a child was unable to cross the marked 2 m line before each end of the course at the moment of the sound signal for two successive intervals, the individual maximum was reached. Children were then asked to stop running and the fully completed laps were noted.

Socioeconomic status

To estimate children's SES, they were asked to answer nine items, covering household-level living standards, such as infrastructure and housing characteristics (house type, number of bedrooms, type of toilet and access to indoor water, indoor toilet/bathroom, and electricity) and questions related to ownership of three durable assets (presence of a working refrigerator, washing machine, and car). The dichotomized items (0=poor quality, not available; 1=higher quality, available) were summed up to build an overall SES index, with higher scores reflecting higher SES. The validity of similar measures has been established in previous research (Filmer and Pritchett, 2001).

Food insecurity

Food insecurity was measured with four questions about hunger, portion size, and meal frequency (e.g., "did you go to bed hungry last night?"). The items were adapted from the Household Hunger Scale (Ballard et al., 2011). Response options were summed up to obtain a score for each participant ranging from 0 (food insecure/hungry) to 4 (food secure/not hungry). This score was used to obtain an overall index of food security, with higher scores reflecting higher food security.

Helminth infections

To diagnose helminth infections, stool containers with unique identifiers were handed out to school children with the instruction to return them with a small portion of their own morning stool. The diagnostic work-up was done on the same day. Duplicate 41.7 mg Kato-Katz thick smears were prepared from each stool sample (Katz et al., 1972). Slides were independently read under a microscope by experienced laboratory technicians who counted the number of helminth eggs and recorded them for each species separately. For quality control, a random sample of 10% of all Kato-Katz thick smears were re-examined by a senior technician. In case of discordant results, the slides were re-read a third time and results discussed among the technicians until agreement was reached. Soil-transmitted helminth egg counts were multiplied by a factor of 24 to obtain a proxy for helminth infection intensity, as expressed by the number of eggs per 1 g of stool (EPG) (Knopp et al., 2008). Subsequently, a single 400 mg oral dose of albendazole (INRESA; Bartenheim, France) was administered to all children participating in the study, according to WHO and national treatment guidelines. Otherwise, to our knowledge, no further helminthiasis control interventions took place in recent years in the study community where the cohort group stems from.

Selective attention and academic achievement

Children's selective attention capacity was measured with the d2 attention test, developed by Brickenkamp et al. (Brickenkamp and Zillmer, 1998). The d2 test determines the capacity to focus on one stimulus/fact, while suppressing awareness to competing distractors. The d2 attention test is a paper and pencil letter-cancellation test that consists of 14 lines of 47 randomly mixed letters *d* and *p*. Participants were instructed to identify and mark all *d* letters with two dashes arranged either as single dashes (i.e., one above and one below the *d*s), or in pairs above or below the *d*s. After 20 sec, the researcher signaled to continue on the next line. Altogether, the test lasted 4 min and 40 sec. The test was performed in groups of 20-25 students and conducted during the first school lesson in a quiet room, with an average room temperature of 24 °C. Pencils were distributed and the test procedure was explained to the children in their native language. Additionally, a practice line was provided on the blackboard to ensure that all participants understood the test procedures. Furthermore, children were encouraged to practice on the test line prior to launching the test.

As shown in Table 3.1, several different parameters can be calculated after completion of the d2 test. For instance, the total number of items processed is a measure of processing speed (TN), while the number of all errors relative to the total number of items processed is a measure of precision and thoroughness, referred to as accuracy in the present text (E%). By contrast, the number of correctly marked characters minus the number of incorrectly marked characters is a measure of concentration ability and performance (CP). E% and CP are not inflated by excessive skipping as they are based on the number of target and non-target characters cancelled as opposed to processing speed which can be influenced by test strategies (Bates and Lemay, 2004). In our study, we therefore used E% and CP as dependent variables due to their resistance to falsification. Processes of selective attention are required for successful completion since not only the letter *d* is orthographically similar to the letter *p*, but there are many distracting letters with more or less than two dashes (Brickenkamp and Zillmer, 1998).

As an indicator of academic achievement, we collected from each school the children's end-of-year results which are based on the mean of four subjects: (i) Home Language (Xhosa or Afrikaans, in this case); (ii) first Additional Language (English, in this case); (iii) Mathematics; and (iv) Life Skills. Learner achievement in each subject is graded on a scale of 1 to 7, whereby a rating of 1 (0–29%) indicates "not achieved" and one of 7 (80–100%) indicates "outstanding achievement". A rating of 4 (50–59%) indicates "adequate achievement".

Table 3.1 Abbreviations, descriptions, and calculation of the d2 test of attention

d2 test measures	Acronym	Description of measure	Computation
Processing speed	TN*	Total number of characters processed	Sum of number of characters processed before the final cancellation on each trial
Processing speed	TN-E*	Total correctly processed	Total characters processed minus total errors made
Inattention	O*	Errors of omission	Sum of number of target symbols not cancelled
Impulsivity	C*	Errors of commission	Sum of number of non-targets symbols cancelled
Accuracy	E%*	Percentage of errors	Total number of errors divided by the total number of characters processed
Concentration performance	CP*	Concentration performance	Total number of correctly cancelled minus total number incorrectly cancelled

Notes. Abbreviations* designated in the d2 manual (Brickenkamp and Zillmer, 1998)

3.5 Statistical analysis

Data were double-entered, validated using EpiData version 3.1 (EpiData Association; Odense, Denmark), and merged into a single database. Statistical analyses were performed with SPSS version 23 (IBM Corporation; Armonk, United States of America) for Windows and STATA version 13.0 (STATA; College Station, United States of America). Anthropometric indicators and fitness performance scores were expressed as means (*M*) and standard deviations (*SD*). To describe the anthropometry of the children, body weight and height values were utilized to calculate the body mass index (BMI), defined as weight (in kg)/height^2 (in m^2). BMI-for-age and height-for-age (HAZ) were thus available for every participant (WHO, 2007). The BMI and height-for-age z-scores (HAZ) were calculated using the World Health Organization (WHO) growth reference (WHO, 2007). The sex-adjusted HAZ z-scores were used as an indicator for stunting (de Onis et al., 2007). The level at which the child stopped running during the 20 m shuttle run test was used to calculate an estimate of maximal oxygen uptake (VO_2 max), readily adjusted for age (Leger et al., 1988). The parasitological status was expressed in terms of prevalence of helminth infection. Selective attention was expressed as raw values. Statistical significance was set at $p<0.05$.

In a first step, separate mixed linear and mixed logistic regression models with random intercepts for school classes were calculated to compare selective attention and physical fitness among (i) stunted and normally grown children; and (ii) soil-transmitted helminth infected and non-infected children. In a second step, SES, age, sex, soil-transmitted helminth infection status, stunting, food insecurity, grip strength, and VO_2 max were analyzed simultaneously in multiple linear regression models, with random intercepts for school classes, in order to determine the simultaneous impact of these variables on selective attention and academic achievement. To interpret the findings, the following statistical coefficients were displayed: for mixed linear and mixed logistic regression models the means and 95% confidence interval (CI), and for multiple linear regression models the unstandardized B coefficients in combination with the 95% CI.

3.6 Results

Study population

As shown in the participant flow chart diagram (Figure 3.1), after receiving written informed consent from a parent or legal guardian, a total of 1,009 students agreed to take part in the study. Data of 970 children were available for further analyses. Complete data records were available for 835 children; 61.8% (n=516) were black African (mostly Xhosa speaking), while the remaining 38.2% (n=319) were colored African (mostly Afrikaans speaking). All analyses presented in this article refer to this final cohort, including 417 girls (49.9%) and 418 boys (50.1%).

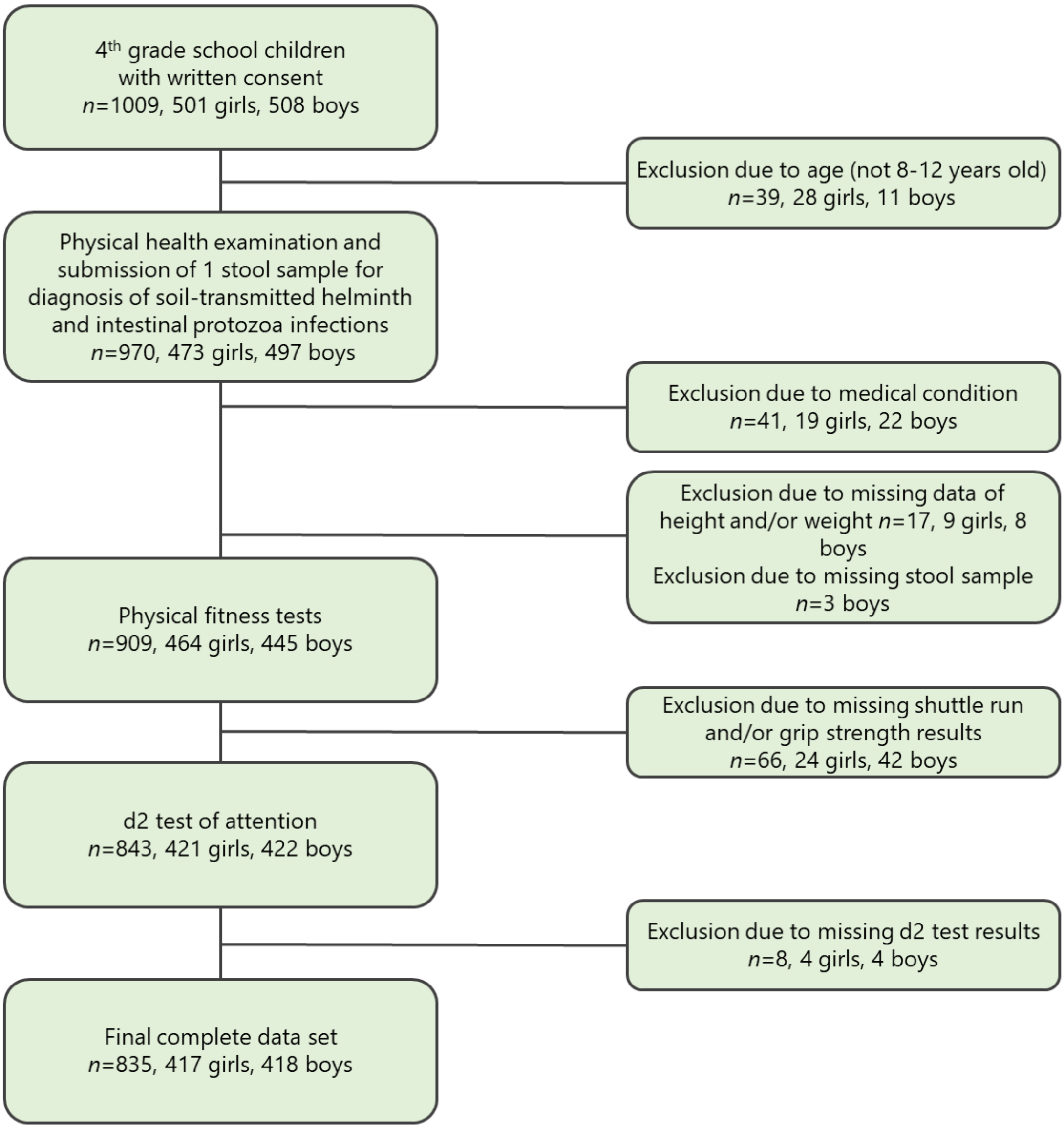


Figure 3.1 Participant flow chart diagram

Anthropometric indicators, helminth infection, stunting, food insecurity, and SES

An overview of the descriptive statistics and sex differences for all study variables is provided in Table 3.2. Boys were, on average, slightly older than girls and had a lower BMI. Overall, 31.0% of the children were infected with *T. trichiura* and/or *A. lumbricoides,* yet no hookworm infections were found. Stunting was observed in 12.3% of the children and the mean food insecurity score was 3.1. No significant sex differences were identified for height, weight, helminth infection status, stunting, food insecurity, and SES. Stratification by age (Table 3.3) revealed that older children were significantly taller, heavier, and more stunted, and had a higher prevalence of helminth infection.

Table 3.2 Characteristics of the study population, stratified by sex, based on mixed linear and mixed logistic regression analyses

	Total (*n*=835)	Males (*n*=418)	Females (*n*=417)	*p*-value[a]
Parameter	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	
Age and anthropometry				
Age (years)	9.5 (0.9)	9.7 (0.9)	9.4 (0.9)	<0.001
Height (cm)	133.2 (7.1)	133.3 (6.7)	133.1 (7.5)	0.584
Weight (kg)	30.5 (7.5)	30.0 (6.5)	31.0 (8.2)	0.087
BMI (kg/m^2)	17.0 (3.1)	16.8 (2.6)	17.3 (3.3)	0.015
Physical fitness				
VO_2 max[b] (in $ml\ kg^{-1}\ min^{-1}$)	49.1 (4.3)	50.8 (4.3)	47.3 (3.5)	<0.001
Grip strength[c] (in kg)	12.0 (3.1)	12.7 (3.1)	11.4 (2.9)	<0.001
Selective attention				
E%[d]	16.8 (12.9)	16.4 (13.3)	17.1 (12.4)	0.397
CP[e]	54.5 (30.5)	53.9 (29.9)	55.0 (31.2)	0.486
Academic achievement				
Academic achievement scores[f]	4.3 (1.5)	4.0 (1.6)	4.5 (1.4)	<0.001
Sociocultural characteristics				
Socioeconomic status (SES)[g]	7.2 (2.0)	7.2 (2.0)	7.3 (2.0)	0.778
Food security[h]	3.1 (0.9)	3.1 (0.9)	3.1 (0.9)	0.482
Prevalence of helminth infection and stunting	n (%)	n (%)	n (%)	
Infected[i]	333 (31.1)	182 (32.5)	151 (29.6)	0.462
Double infection[j]	135 (16.2)	75 (17.9)	60 (14.4)	0.089
Stunted[k]	103 (12.3)	50 (12.0)	53 (12.7)	0.535

All statistically significant differences are marked in bold. aAll p-values are calculated using either mixed linear or mixed logistic regression, as appropriate, adjusted for clustering of school classes. bAll mean VO2 estimates are expressed in ml kg-1 min-1 and adjusted for age. cAll mean grip strength values are expressed in kg and are not adjusted for age. dE%=Percent of errors. eCP=Concentration performance. fAcademic achievement scores: Average of the four subjects Home Language, Additional Language, Mathematics and Life Skills (n=777). gSES: Socioeconomic status measured by ownership and housing-related questions on a scale from 0 to 9 points (0=low score). hFood security measured with the hunger scale ranging from 0 to 4 (0=hungry/food insecure, 4=not hungry/food secure). iInfected with one or two soil-transmitted helminth species (A. lumbricoides and/or T. trichiura). jDouble infection: Infected with two soil-transmitted helminth species (A. lumbricoides and T. trichiura). kStunting is defined as <-2HAZ.

Table 3.3 Characteristics of the study population, stratified by age and expressed as means (M) and 95% confidence interval (CI) or %, and differences between age groups based on mixed linear and mixed logistic regression analyses

Age (years)	8 (*n*=76) *M* (95% CI) or %	9 (*n*=387) *M* (95% CI) or %	10 (*n*=245) *M* (95% CI) or %	11 (*n*=108) *M* (95% CI) or %	12 (*n*=19) *M* (95% CI) or %	*p*-value[h]
Anthropometry						
Height (cm)	130.5 (129.1-131.9)	131.3 (130.7-131.9)	134.4 (133.5-135.3)	137.7 (136.1-139.2)	139.9 (137.5-142.2)	<0.001
Stunted (%)[a]	2.6	6.7	16.3	25.0	42.1	<0.001
Weight (kg)	29.7 (28.2-31.1)	29.8 (29.0-30.5)	31.0 (30.0-31.9)	32.2 (30.8-33.6)	32.8 (30.5-35.1)	<0.001
BMI (kg/m^2)	17.3 (16.7-18.0)	17.1 (16.8-17.4)	17.0 (16.6-17.3)	16.8 (16.3-17.3)	16.7 (15.8-17.6)	0.675
Sociocultural characteristics						
Socioeconomic status (SES)[b]	7.9 (7.6-8.3)	7.5 (7.4-7.7)	6.8 (6.6-7.1)	6.6 (6.2-7.1)	6.8 (5.6-8.1)	<0.001
Food security[c]	3.1 (2.9-3.4)	3.1 (3.0-3.2)	3.1 (3.0-3.4)	3.2 (3.0-3.4)	3.0 (2.6-3.3)	0.959
Infected (%)[d]	5.3	23.3	41.2	51.9	42.1	0.007
Physical fitness						
VO_2 max (in ml kg^{-1} min^{-1})[e]	50.3 (49.5-51.1)	49.1 (48.7-49.5)	48.8 (48.2-49.3)	48.6 (47.5-49.6)	48.6 (46.0-51.3)	0.014
Grip strength (in kg)[f]	11.1 (10.4-11.8)	11.4 (11.1-11.7)	12.5 (12.1-12.8)	13.7 (13.1-14.4)	14.3 (12.9-15.6)	<0.001
Selective attention						
E% (percentage of errors)	14.4 (11.9-16.9)	15.8 (14.5-17.0)	16.8 (15.2-18.5)	21.1 (18.5-23.7)	20.3 (13.9-26.8)	<0.001
CP (concentration performance)	57.6 (52.0-63.1)	57.1 (54.2-60.0)	52.4 (48.5-56.3)	48.9 (42.1-55.8)	47.1 (29.8-64.3)	0.071
Academic achievement						
Academic achievement scores[g]	5.2 (4.9-5.8)	4.8 (4.7-5.0)	3.8 (3.6-3.9)	3.0 (2.8-3.3)	2.7 (2.0-3.3)	<0.001

Notes. All statistically significant coefficients are marked in bold. [a]Stunted: is defined as <-2HAZ. [b]SES: socioeconomic status measured by ownership and housing-related questions on a scale from 0-9 points (0=low score). [c]Food security measured with the hunger scale ranging from 0-4 (0=hungry/food insecure, 4=not hungry/food secure). [d]Infected with one or two soil-transmitted helminth species (*A. lumbricoides* and/or *T. trichiura*). [e]All mean VO_2 estimates are expressed in ml kg^{-1} min^{-1} and are adjusted for age. [f]All mean grip strength values are expressed in kg and are not adjusted for age. [g]Academic achievement scores: Average of the four subjects Home Language, Additional Language, Mathematics and Life Skills, n=777. [h]All *p*-values are calculated using either mixed linear or mixed logistic regression, adjusted for clustering within school classes.

Physical fitness, stratified by sex and age

As shown in Table 3.2, boys achieved significantly higher mean grip strength and had a higher mean VO_2 max estimate than girls. As shown in Table 3.3, older children (aged 10-12 years) achieved higher mean grip strength scores than their younger peers (8- to 9-years old). The stratification by age also revealed that the younger group (8-9 years) reached a higher estimated VO_2 max than the older group (10-12 years).

Selective attention, stratified by sex and age

As displayed in Table 3.2, stratification by sex revealed that girls and boys did not differ with regard to their selective attention capacity. Younger children had a significantly lower percentage of errors (see Table 3.3for mean scores).

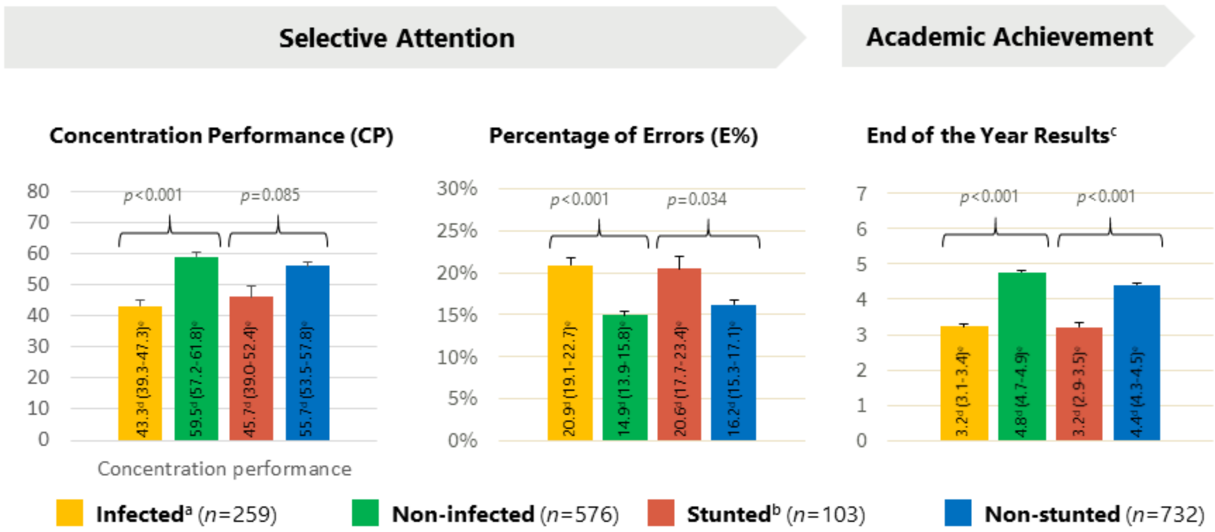
Academic achievement, stratified by sex and age

Girls reached statistically significantly higher academic scores than boys (Table 3.2). Stratification by age revealed that older children's academic achievement was lower than younger children's academic achievement (see Table 3.3 for mean scores). A higher percentage of errors in the attention test was associated with poorer academic achievement (r=-0.33, p<0.05), whereas a positive association was observed between concentration performance (CP) and academic achievement (r=0.33, p<0.05), as assessed by students' academic achievement scores.

Association of soil-transmitted helminth infection status and stunting with physical fitness, selective attention, and academic achievement

As shown in Table 3.4, children with no soil-transmitted helminth infection had higher mean grip strength test results compared to their infected counterparts. The comparison between stunted and non-stunted children revealed that children not classified as being stunted achieved significantly higher mean grip strength test results. The mean VO_2 max results did not differ between the two groups.

Figure 3.2 shows the univariate comparisons between infected versus non-infected and stunted versus non-stunted children in selective attention and academic performance.



Notes. [a]Infected with one or two soil-transmitted helminth species (*Ascaris lumbricoides* and/or *Trichuris trichiura*). [b]Stunted: defined as < -2 HAZ. [c]End of the year results: average of the four subjects Home Language, Additional Language, Mathematics and Life Skills, *n*=777, [d]Mean, [e]95% Confidence interval.

Figure 3.2 Group differences between infected and non-infected children and stunted and non-stunted children in their concentration performance, percentage of errors, and academic achievement scores

As illustrated, in these uncontrolled analyses, children infected with soil-transmitted helminths performed weaker on the d2 test of attention, compared to their non-infected counterparts. Stunted children had a lower mean concentration performance and a higher mean percentage of errors, but only the latter was statistically significant. Children without a soil-transmitted helminth infection and non-stunted children achieved statistically significantly higher academic achievement scores compared to their infected and stunted peers. Additional analyses showed that infected children had a significantly higher risk of being stunted, and *vice versa* (infected children: 25% stunted; non-infected children: 7% stunted; stunted children: 62% infected; non-stunted children: 27% infected $\chi^2[1,835]=53.2$, $p<.001$). Accordingly, multivariate analyses were performed in the next step to avoid problems associated with multi-collinearity.

Table 3.4 Physical fitness, stratified by soil-transmitted helminth infection and stunting (means and 95% CI); between-group differences based on mixed linear and mixed logistic regression analyses

	Non-infected (*n*=576) *M* (95% CI)	Infected[c] (*n*=259) *M* (95% CI)	*p*-value[d]	Non-stunted (n=732) *M* (95% CI)	Stunted[e] (n=103) *M* (95% CI)	*p*-value[c]
Fitness						
VO_2 max (in ml kg^{-1} min^{-1})[a]	49.3 (48.9-49.6)	48.6 (48.1-49.1)	0.149	49.0 (48.7-49.4)	49.1 (48.2-49.9)	0.664
Grip strength (in kg)[b]	12.4 (12.2-12.7)	11.2 (10.9-11.54)	0.013	12.3 (12.1-12.5)	10.2 (9.7-10.7)	<0.001

Notes. All statistically significant coefficients are marked in bold. [a]All mean VO_2 max estimates are expressed in ml kg^{-1} min^{-1} and are adjusted for age. [b]All mean grip strength values are expressed in kg and are not adjusted for age. [c]Infected with one or two soil-transmitted helminth species (*A. lumbricoides* and/or *T. trichiura*). [d]All *p*-values are calculated using either mixed linear or mixed logistic regression, adjusted for clustering within school classes. [e]Stunted: is defined as <-2 HAZ.

Multivariate associations with selective attention

In the multiple linear regression model presented in Table 3.5, soil-transmitted helminth infection was statistically significantly and negatively associated with the mean CP score. The mean CP score of children with soil-transmitted helminth infection was 7.99 points lower compared to their non-infected peers. Grip strength and the estimated mean VO_2 max were statistically significantly and positively associated with the mean CP score. The mean CP score increased by 0.98 points per ml kg^{-1} min^{-1} VO_2 max, whereas the mean CP score increased by 0.92 points per kg grip strength. Age and soil-transmitted helminth infection were negatively associated with the error percentage in the d2 test of attention. The mean error percentage increased by 1.6% per year of age whereas a soil-transmitted helminth infection was associated with a 3.3% higher error percentage compared to non-infected children. The mean VO_2 max was statistically significantly and positively associated with the mean E% score. The mean E% score decreased by 0.24% per ml kg^{-1} min^{-1} VO_2 max.

Table 3.5 Demography, socioeconomic status, helminth infection, nutrition, and physical fitness as risk factors for selective attention and academic performance (continues on next page)

Mean concentration (CP)	Multiple linear regression		
Explanatory variables	B	95% CI	*p*-value[i]
Socioeconomic status (in points 0-9)[a]	0.19	-0.87 to 1.25	0.725
Age (in years)	-1.91	-4.62 to 0.80	0.166
Sex (reference: male)[b]	5.47	1.05 to 9.89	**0.015**
Helminth infection (reference: uninfected)[c]	-7.99	-14.15 to -1.84	**0.011**
Stunting (reference: non-stunted)[d]	-0.35	-2.70 to 2.01	0.711
Food insecurity[e]	1.40	-0.74 to 3.54	0.201
VO_2 max (in ml kg^{-1} min^{-1})[f]	0.98	0.47 to 1.50	**<0.001**
Grip strength (in kg)[g]	0.92	0.08 to 1.77	**0.032**

(Table continues on the next page)

Mean error percentage (E%)	Multiple linear regression		
Explanatory variables	B	95% CI	*p*-value[i]
Socioeconomic status (in points 0-9)[a]	-0.05	-0.51 to 0.40	0.813
Age (in years)	1.58	0.42 to 2.74	**0.008**
Sex (reference: male)[b]	0.14	-1.76 to 2.04	0.889
Helminth infection (reference: uninfected)[c]	3.27	0.75 to 5.79	**0.011**
Stunting (reference: non-stunted)[d]	0.07	-0.94 to 1.08	0.893
Food insecurity[e]	-0.57	-1.49 to 0.35	0.226
VO_2 max (in ml kg^{-1} min^{-1})[f]	-0.24	-0.46 to -0.02	**0.035**
Grip strength (in kg)[g]	-0.19	-0.55 to 0.18	0.069
Academic achievement scores[h]	Multiple linear regression		
Explanatory variables	B	95% CI	*p*-value[i]
Socioeconomic status (in points 0-9)[a]	0.06	0.14 to 0.10	**0.008**
Age (in years)	-0.43	-0.54 to -0.33	**<0.001**
Sex (reference: male)[b]	0.42	0.25 to 0.60	**<0.001**
Helminth infection (reference: uninfected)[c]	-0.45	-0.72 to -0.18	**0.001**
Stunting (reference: non-stunted)[d]	0.01	-0.09 to 0.10	0.914
Food security[e]	0.07	-0.02 to 0.15	0.123
VO_2 max (in ml kg^{-1} min^{-1})[f]	0.02	-0.00 to 0.04	**0.032**
Grip strength (in kg)[g]	0.02	-0.02 to 0.05	0.370

Notes. Statistically significant variables are marked in bold. [a]SES: socioeconomic status measured by ownership and housing-related questions on a scale from 0 to 9 points (0=low score). [b]Sex reference (male=1, female=2). [c]Helminth infection: infected with one or two soil-transmitted helminth species (*A. lumbricoides* and/or *T. trichiura*) (0=uninfected, 1=infected). [d]Stunted is defined as: <-2HAZ (0=non-stunted, 1=stunted). [e]Food security: measured with the hunger scale ranging from 0 to 4 (0=hungry/food insecure, 4=not hungry/food secure). [f]All mean VO_2 max estimates are expressed in ml kg^{-1} min^{-1} and are adjusted for age. [g]All mean grip strength values are expressed in kg and are not adjusted for age. [h]Academic achievement scores: average of the four subjects Home Language, Additional Language, Mathematics, and Life Skills (n=777). [i]All *p*-values are calculated using multiple linear regression, and are adjusted for clustering within school classes.

Multivariate associations with academic achievement

In the multiple linear regression model, lower SES, male sex, higher age, being infected with soil-transmitted helminths, and a lower cardiorespiratory fitness were statistically significantly and negatively associated with academic achievement. The mean academic achievement score increased by 0.06 per point in the SES score. By contrast, children's academic achievement score decreased by 0.43 per additional year of age and was 0.45 lower among children classified as being infected with soil-transmitted helminths compared to non-infected peers. Boys had 0.42 lower academic achievement scores than girls and a higher VO_2 max was associated with higher academic achievement, yet only with a marginal increase of 0.02 per ml kg^{-1} min^{-1} VO_2 max. No significant associations were observed for stunting, food insecurity, and grip strength.

3.7 Discussion

The most important findings of the present study are that, in the multivariate analyses, soil-transmitted helminth infections and lower physical fitness were negatively associated with selective attention, while lower SES, positive soil-transmitted helminth infection status, lower cardiorespiratory fitness, and higher age were associated with poorer academic achievement. Without implying causality, our data suggest that an infection with *T. trichiura*, *A. lumbricoides*, or both, is associated with lower selective attention capacity (in terms of attention capacity and accuracy) and reduced physical fitness among school-aged children in terms of muscular strength measured as grip strength. Moreover, children infected with soil-transmitted helminths had significantly lower academic achievement scores. It is conceivable that the general well-being of infected children, as expressed in abdominal pain, fatigue, and listlessness, negatively affects their cognitive performance (Nokes et al., 1992, Ezeamama et al., 2005). In a study by Liu et al. (2015) carried out in south-western China, children infected with either *T. trichiura* or *A. lumbricoides* were also lagging behind their non-infected peers. In the same study from China, infection with one or multiple species of soil-transmitted helminths was associated with reduced speed of processing and working memory performance and worse school performance (in terms of standardized Mathematics test scores).

Heavy *A. lumbricoides* and *T. trichiura* infections have been associated with cognitive impairment and were both linked with significantly increased disability weight (DW) in the Global Burden of Disease (GBD) study (WHO, 2004). Our finding that soil-transmitted helminths are associated with reduced attention capacity and accuracy is novel and warrants further investigation. Yet, to our knowledge, there is no conclusive evidence whether reduced physical fitness and strength are a direct consequence of soil-transmitted helminth infection. Our analyses did not reveal any associations between VO_2 max and single or double species helminth infections. Müller et al. (2016) found that 9-year-old boys infected with *T. trichiura* had a lower mean VO_2 max estimate in a slightly different sample of children from the same cohort. Of note, another cross-sectional study by Müller et al. (2011) did not find any correlation between VO_2 max results and soil-transmitted helminth infections among school-aged children from Côte d'Ivoire, which is at odds with findings from China by Yap et al. (2012) who reported reduced VO_2 max estimates of school-aged children infected with *T. trichiura*. In our study, irrespective of age, children infected with *A. lumbricoides*, *T. trichiura*, or both species concurrently had a lower mean grip strength compared to non-infected children. Yap et al. (2014) reported increased grip strength one month after albendazole treatment. Given these findings, further research is needed to deepen the understanding of whether and how soil-transmitted helminth infections are related to VO_2 max and grip strength among school-aged children.

The univariate analyses also suggested that stunted children have deficits in selective attention and achieve lower academic performance compared to non-stunted children. However, these associations disappeared in the multiple regression analyses. Thus, while previous research suggested that the main causes of stunting include intrauterine growth retardation, inadequate nutrition, and poor dietary diversity to support the rapid growth and development of infants and young children (Dewey and Begum, 2011), and that stunting can result in cognitive impairments (Dewey and Begum, 2011, Kar et al., 2008), the association between stunting and the outcomes was no longer significant after all possible influences were taken into account. In the present study, multivariate analyses are warranted as some of the independent variables were associated. For instance, our findings confirmed that stunted children had a significantly higher risk of being infected with soil-transmitted helminth, which is in line with prior research showing that chronic soil-transmitted helminthiasis is a cause of stunting (Dewey and Begum, 2011).

The univariate analyses further showed that stunted and non-stunted children differed significantly in grip strength, whereas they had similar mean VO_2 max values. Our findings align with a study of Malina et al. (2011) reporting that stunted children had lower grip strength than their non-stunted peers. Grip strength was shown to be a valid indicator for total muscle strength in children (Wind et al., 2010), and was associated with physical health outcomes in previous studies with children and adolescents. While we did not observe a statistically significant difference, a recent study by Armstrong et al. (2016) found that stunted South African primary school children also performed poorer in a 20 m shuttle run test as well as in other physical fitness tests, a finding corroborated by Yap et al. (2012) who reported a lower mean VO_2 max estimate of stunted school children in China.

With regard to selective attention and academic achievement and how they might be associated with soil-transmitted helminth infection status, stunting, food insecurity, and physical fitness, we found that attention capacity is associated with infection status and physical fitness. This confirms the notion of a negative relationship between *T. trichiura* and *A. lumbricoides* on the one hand and cognition on the other, as reported in prior research (Nokes et al., 1992, Liu et al., 2015, Ezeamama et al., 2005, Jardim-Botelho et al., 2008). Furthermore, our findings suggest that after controlling for confounding factors, academic achievement is negatively associated with age and soil-transmitted helminth infection, and positively associated with SES.

Only few studies have looked at the relationship between children's physical fitness and their selective attention in low socioeconomic settings. A study by Tine and Butler (2012) reported improvements in selective attention after a 12 min session of aerobic exercise in both lower- and higher-income children. Lower-income children exhibited greater improvements in selective attention compared to their higher income peers. The fact that aerobic fitness was associated with selective attention in our sample of disadvantaged school children, combined with the finding of Tine et al. (2012) is highly encouraging since (i) primary school children's aerobic fitness can be improved through regular training (Kriemler et al., 2010), and (ii) selective attention is associated with academic and cognitive outcomes (Stevens and Bavelier, 2012). As highlighted by Armstrong et al. (2011), there is a particularly pronounced need for encouraging fitness in South African primary schools. However, the multifactorial nature of physical fitness and attention capacity of children growing up in socioeconomically deprived environments requires that health conditions such as asthma, fetal alcohol syndrome, and human immunodeficiency virus (HIV) infection status, which were not assessed in the present study, must also be considered (Fleisch, 2008).

Stratification by age revealed that 8- and 9-year-old children achieved better academic achievement scores than their 10- to 12-year-old peers. This may be explained by the fact that disadvantaged communities do not have the financial means to promote children with special needs or learning disabilities (Fleisch, 2008). Children suffering from reading difficulties, attention deficit hyperactivity disorder (ADHD), fetal alcohol syndrome or neglect do not get the required academic support and as a consequence are not able to keep up with their peers. Students failing to achieve adequate grades are retained up to 3 years until they get too old and automatically progress to the next grade (Fleisch, 2008, Spaull, 2013), which explains the wide age range of the participants in the current study. Girls seemed to achieve better academic results compared to boys, while there was no statistically significant difference between sex in the test of attention. A meta-analysis by Voyer and Voyer (2014) found a consistent female advantage in school marks for all course content areas.

The present study expands previous research in several important ways; to our knowledge, associations between selective attention and soil-transmitted helminth infection status as well as stunting has not previously been investigated. It also contributes to the finding that chronic soil-transmitted helminth infections and cognitive impairment are associated (Jukes, 2003). Furthermore, this study provides new evidence that physical fitness might be associated with increased selective attention in children from a low socioeconomic environment, even after controlling for major covariates.

Our study has several limitations. First, our results are derived from a cross-sectional study and causal inferences cannot be drawn. Second, academic achievement was measured with the average end-of-year mark (achieved at the end of grade 3), which corresponds to the summary of four subjects (Mathematics, Home Language, Additional Language, and Life Skills). While the objectivity of school grades can be questioned as a reliable outcome in empirical research (e.g., due to attributions or stereotypes of the teachers, different standards between classes/schools), this measure has a high ecological validity because sufficiently high grades are needed for academic promotion. Moreover, the influence of class was controlled for, and our study showed that selective attention and the academic achievement scores were moderately correlated ($r > 0.30$). Third, we used an indirect measurement of VO_2 max to assess aerobic fitness and it is still debated whether the maximal oxygen uptake is receptive enough for change (Rowland, 1985) due to varying personal living conditions. However, this test was chosen because it seemed well suited for a resource-constrained setting due to its ease of application (Leger et al., 1988). Furthermore, the 20 m shuttle run test proved to be a valid measure of children's physical fitness in previous studies (Mayorga-Vega et al., 2015), and could be related to various health outcomes in school-aged children (Ruiz et al., 2009). Fourth, anthropometric measurements were taken only once, which could be a source of increased measurement error. Fifth, only a single stool sample was obtained from each child. Hence, some of the helminth infections, particularly those of light intensity, were missed. Finally, we acknowledge that our study took place in disadvantaged communities (quintile three schools). As a consequence, variation in SES was limited, which might have resulted in an underestimation of SES as a predictor of selective attention and academic achievement.

In conclusion, our study provides new insights into the relative importance of different determinants of school children's selective attention in a disadvantaged setting of South Africa. We found that soil-transmitted helminth infection and lower physical fitness may hamper children's capacity to pay attention during cognitive tasks, and directly or indirectly impede their academic performance. It is conceivable that poor academic achievement will hinder children from realizing their full potential and disrupt the vicious cycle of poverty and ill health.

Acknowledgments

We are grateful to Mrs. Leyli Zondie, Head of the Department of Medical Laboratory Sciences at the Nelson Mandela Metropolitan University, and her team. We thank Dominique Bänninger, Thomas Hager, and Nandi Joubert for their contribution to data collection. Furthermore, we would like to express our gratitude to Bruce Damons, former principal of the Sapphire Road Primary School, who acted as a key person in the coordination between the schools and our study. In the name of all the study children, we would like to thank Mr. Joel Huber on behalf of CURAPROX for the donation of toothbrushes and toothpaste.

The study is embedded within the scope of the Swiss-South African Joint Research Programme (SSAJRP), where the Swiss National Science Foundation (SNSF) and the National Research Foundation (NRF) in South Africa have issued a call for joint research projects (JRPs).

3.8 References

Anthony, E. K., King, B. & Austin, M. J. 2011. Reducing child poverty by promoting child well-being: Identifying best practices in a time of great need. *Child Youth Serv Rev,* 33**,** 1999-2009.

Armstrong, M. E., Lambert, E. V. & Lambert, M. I. 2011. Physical fitness of South African primary school children, 6 to 13 years of age: discovery vitality health of the nation study. *Percept Mot Skills,* 113**,** 999-1016.

Armstrong, M. E., Lambert, M. I. & Lambert, E. V. 2016. Relationships between different nutritional anthropometric statuses and health-related fitness of South African primary school children. *Ann Hum Biol***,** 1-6.

Ballard, T., Coates, J., Swindale, A. & Deitchler, M. 2011. Household hunger scale : indicator definition and measurement guide. Washington, DC.

Basch, C. E. 2011. Healthier students are better learners: a missing link in school reforms to close the achievement gap. *J Sch Health,* 81**,** 593-8.

Bates, M. E. & Lemay, E. P., Jr. 2004. The d2 test of attention: construct validity and extensions in scoring techniques. *J Int Neuropsychol Soc,* 10**,** 392-400.

Bloom, B., Dey, A. N. & Freeman, G. 2006. Summary health statistics for U.S. children: National Health Interview Survey, 2005. *Vital Health Stat 10***,** 1-84.

Bradley, R. H. & Corwyn, R. F. 2002. Socioeconomic status and child development. *Annu Rev Psychol,* 53**,** 371-99.

Brickenkamp, R. & Zillmer, E. 1998. *The d2 test of attention,* Seattle, Hogrefe & Huber Publishers.

Brislin, R. W. 1986. The wording and translation of research instruments. *In:* Lonner, W. L. & Berry, J. W. (eds.) *Field methods in cross-cultural research.* Newbury Park, CA: Sage.

Checa, P. & Rueda, M. R. 2011. Behavioral and brain measures of executive attention and school competence in late childhood. *Dev Neuropsychol,* 36**,** 1018-32.

Chung, K. K. H. 2015. Socioeconomic status and academic achievement. *In:* Wright, J. D. (ed.) *International encyclopedia of the social & behavioral sciences.* Second ed. Amsterdam: Elsevier.

de Onis, M., Onyango, A. W., Borghi, E., Siyam, A., Nishida, C. & Siekmann, J. 2007. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ,* 85**,** 660-7.

Dewey, K. G. & Begum, K. 2011. Long-term consequences of stunting in early life. *Matern Child Nutr,* 7 Suppl 3**,** 5-18.

Draper, C., Basset, S., de Villiers, A., Lambert, E. V. & Group, H. W. 2014. Results from South Africa's 2014 report card on physical activity for children and youth. *J Phys Act Health,* 11 Suppl 1**,** S98-104.

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., Pagani, L. S., Feinstein, L., Engel, M., Brooks-Gunn, J., Sexton, H., Duckworth, K. & Japel, C. 2007. School readiness and later achievement. *Dev Psychol,* 43**,** 1428-46.

Europe, C. o. 1983. *Testing physical fitness: Eurofit experimental battery,* Strasbourg, Council of Europe.

Ezeamama, A. E., Friedman, J. F., Acosta, L. P., Bellinger, D. C., Langdon, G. C., Manalo, D. L., Olveda, R. M., Kurtis, J. D. & McGarvey, S. T. 2005. Helminth infection and cognitive impairment among Filipino children. *Am J Trop Med Hyg,* 72**,** 540-548.

Farah, M. J., Noble, K. G. & Hurt, H. 2004. Poverty, privilege, and brain development: empirical findings and ethical implications. *Neuroethics: defining the issues in theory, practice, and policy.* Oxford: Oxford University Press.
Ferguson, P., Jimerson, S. R. & Dalton, M. J. 2001. Sorting out successful failures: exploratory analyses of factors associated with academic and behavioral outcomes of retained students. *Psychol Schools,* 38**,** 327-341.
Filmer, D. & Pritchett, L. H. 2001. Estimating wealth effects without expenditure data - or tears: an application to educational enrollments in states of India. *Demography,* 38**,** 115-132.
Fleisch, B. 2008. *Primary education in crisis: why South African schoolchildren underachieve in reading and mathematics,* Cape Town, Juta & Co.
Hall, K. & Giese, S. 2009. Addressing quality through school fees and school funding. *S Afr Child Gauge***,** 35-40.
Jardim-Botelho, A., Raff, S., Rodrigues Rde, A., Hoffman, H. J., Diemert, D. J., Correa-Oliveira, R., Bethony, J. M. & Gazzinelli, M. F. 2008. Hookworm, Ascaris lumbricoides infection and polyparasitism associated with poor cognitive performance in Brazilian schoolchildren. *Trop Med Int Health,* 13**,** 994-1004.
Jukes, M. 2003. Do parasitic worm infections impair cognitive development? *Alternation,* 10**,** 202-228.
Kar, B. R., Rao, S. L. & Chandramouli, B. A. 2008. Cognitive development in children with chronic protein energy malnutrition. *Behav Brain Funct,* 4**,** 31.
Katz, N., Chaves, A. & Pellegrino, J. 1972. A simple device for quantitative stool thick-smear technique in Schistosomiasis mansoni. *Rev Inst Med Trop Sao Paulo,* 14**,** 397-400.
Knopp, S., Mgeni, A. F., Khamis, I. S., Steinmann, P., Stothard, J. R., Rollinson, D., Marti, H. & Utzinger, J. 2008. Diagnosis of soil-transmitted helminths in the era of preventive chemotherapy: effect of multiple stool sampling and use of different diagnostic techniques. *PLoS Negl Trop Dis,* 2**,** e331.
Kriemler, S., Zahner, L., Schindler, C., Meyer, U., Hartmann, T., Hebestreit, H., Brunner-La Rocca, H. P., van Mechelen, W. & Puder, J. J. 2010. Effect of school based physical activity programme (KISS) on fitness and adiposity in primary schoolchildren: cluster randomised controlled trial. *BMJ,* 340**,** c785.
Leger, L. A., Mercier, D., Gadoury, C. & Lambert, J. 1988. The multistage 20 metre shuttle run test for aerobic fitness. *J Sports Sci,* 6**,** 93-101.
Liu, C., Luo, R., Yi, H., Zhang, L., Li, S., Bai, Y., Medina, A., Rozelle, S., Smith, S., Wang, G. & Wang, J. 2015. Soil-transmitted helminths in southwestern China: a cross-sectional study of links to cognitive ability, nutrition, and school performance among children. *PLoS Negl Trop Dis,* 9**,** e0003877.
Lu, C., Black, M. M. & Richter, L. M. 2016. Risk of poor development in young children in low-income and middle-income countries: an estimation and analysis at the global, regional, and country level. *Lancet Glob Health,* 4**,** e916-e922.
Ludyga, S., Gerber, M., Brand, S., Holsboer-Trachsler, E. & Pühse, U. 2016. Acute effects of moderate aerobic exercise on specific aspects of executive function in different age and fitness groups: A meta-analysis. *Psychophysiology,* 53**,** 1611-1626.
Malina, R. M., Pena Reyes, M. E., Tan, S. K. & Little, B. B. 2011. Physical fitness of normal, stunted and overweight children 6-13 years in Oaxaca, Mexico. *Eur J Clin Nutr,* 65**,** 826-34.

Mayorga-Vega, D., Aguilar-Soto, P. & Viciana, J. 2015. Criterion-related validity of the 20-m shuttle run test for estimating cardiorespiratory fitness: a meta-analysis. *J Sports Sci Med,* 14**,** 536-47.
McHunu, S. & Le Roux, K. 2010. Non-participation in sport by black learners with special reference to gender, grades, family income and home environment. *S Afr J Res Sport Phys Educ Rec,* 32**,** 85-98.
Mezzacappa, E. 2004. Alerting, orienting, and executive attention: developmental properties and sociodemographic correlates in an epidemiological sample of young, urban children. *Child Dev,* 75**,** 1373-86.
Müller, I., Coulibaly, J. T., Furst, T., Knopp, S., Hattendorf, J., Krauth, S. J., Stete, K., Righetti, A. A., Glinz, D., Yao, A. K., Pühse, U., N'Goran E, K. & Utzinger, J. 2011. Effect of schistosomiasis and soil-transmitted helminth infections on physical fitness of school children in Cote d'Ivoire. *PLoS Negl Trop Dis,* 5**,** e1239.
Müller, I., Yap, P., Steinmann, P., Damons, B. P., Schindler, C., Seelig, H., Htun, N. S., Probst-Hensch, N., Gerber, M., du Randt, R., Pühse, U., Walter, C. & Utzinger, J. 2016. Intestinal parasites, growth and physical fitness of schoolchildren in poor neighbourhoods of Port Elizabeth, South Africa: a cross-sectional survey. *Parasit Vectors,* 9**,** 488.
Nokes, C., Grantham-McGregor, S. M., Sawyer, A. W., Cooper, E. S. & Bundy, D. A. 1992. Parasitic helminth infection and cognitive function in school children. *Proc Biol Sci,* 247**,** 77-81.
Riley, M. R., Scaramella, L. V. & McGoron, L. 2014. Disentangling the associations between contextual stress, sensitive parenting, and children's social development. *Fam Relat,* 63**,** 287-299.
Rowland, T. W. 1985. Aerobic response to endurance training in prepubescent children: a critical analysis. *Med Sci Sports Exerc,* 17**,** 493-7.
Ruiz, J. R., Castro-Pinero, J., Artero, E. G., Ortega, F. B., Sjostrom, M., Suni, J. & Castillo, M. J. 2009. Predictive validity of health-related fitness in youth: a systematic review. *Br J Sports Med,* 43**,** 909-23.
Spaull, N. 2013. Poverty & privilege: primary school inequality in South Africa. *Int J Educ Dev,* 33**,** 436-447.
Speich, B., Croll, D., Furst, T., Utzinger, J. & Keiser, J. 2016. Effect of sanitation and water treatment on intestinal protozoa infection: a systematic review and meta-analysis. *Lancet Infect Dis,* 16**,** 87-99.
Stevens, C. & Bavelier, D. 2012. The role of selective attention on academic foundations: a cognitive neuroscience perspective. *Dev Cogn Neurosci,* 2**,** 30-48.
Stevens, C., Lauinger, B. & Neville, H. 2009. Differences in the neural mechanisms of selective attention in children from different socioeconomic backgrounds: an event-related brain potential study. *Dev Sci,* 12**,** 634-46.
Strunz, E. C., Addiss, D. G., Stocks, M. E., Ogden, S., Utzinger, J. & Freeman, M. C. 2014. Water, sanitation, hygiene, and soil-transmitted helminth infection: a systematic review and meta-analysis. *PLoS Med,* 11**,** e1001620.
Sussman, E. & Steinschneider, M. 2009. Attention effects on auditory scene analysis in children. *Neuropsychologia,* 47**,** 771-85.
Taylor-Robinson, D. C., Maayan, N., Soares-Weiser, K., Donegan, S. & Garner, P. 2015. Deworming drugs for soil-transmitted intestinal worms in children: effects on nutritional indicators, haemoglobin, and school performance. *Cochrane Database Syst Rev,* 7**,** CD000371.

Tine, M. T. & Butler, A. G. 2012. Acute aerobic exercise impacts selective attention: an exceptional boost in lower-income children. *J Educ Psychol,* 32**,** 821-834.
Tomporowski, P. D., Davis, C. L., Miller, P. H. & Naglieri, J. A. 2008. Exercise and Children's Intelligence, Cognition, and Academic Achievement. *Educ Psychol Rev,* 20**,** 111-131.
Tomporowski, P. D., McCullick, B., Pendleton, D. M. & Pesce, C. 2015. Exercise and children's cognition: The role of exercise characteristics and a place for metacognition. *J Sport Health Sci,* 4**,** 47-55.
Utzinger, J., Becker, S. L., Knopp, S., Blum, J., Neumayr, A. L., Keiser, J. & Hatz, C. F. 2012. Neglected tropical diseases: diagnosis, clinical management, treatment and control. *Swiss Med Wkly,* 142**,** w13727.
Voyer, D. & Voyer, S. D. 2014. Gender differences in scholastic achievement: a meta-analysis. *Psychol Bull,* 140**,** 1174-204.
Walter, C. M. 2011. In-school physical activity patterns of primary school learners from disadvantaged schools in South Africa. *Afr J Phys Health Educ Recreat Dance* 17**,** 780-789.
Welch, V. A., Ghogomu, E., Hossain, A., Awasthi, S., Bhutta, Z. A., Cumberbatch, C., Fletcher, R., McGowan, J., Krishnaratne, S., Kristjansson, E., Sohani, S., Suresh, S., Tugwell, P., White, H. & Wells, G. A. 2017. Mass deworming to improve developmental health and wellbeing of children in low-income and middle-income countries: a systematic review and network meta-analysis. *Lancet Glob Health,* 5**,** e40-e50.
Wentzel, K. R. 1991. Relations between social competence and academic achievement in early adolescence. *Child Dev,* 62**,** 1066-78.
WHO 2004. Global Burden of Disease 2004 update: disability weights for diseases and conditions. Geneva: World Health Organization.
WHO. 2007. *Growth reference 5-19 years* [Online]. Available: http://www.who.int/growthref/en/ [Accessed].
Wind, A. E., Takken, T., Helders, P. J. & Engelbert, R. H. 2010. Is grip strength a predictor for total muscle strength in healthy children, adolescents, and young adults? *Eur J Pediatr,* 169**,** 281-7.
Yap, P., Du, Z. W., Chen, R., Zhang, L. P., Wu, F. W., Wang, J., Wang, X. Z., Zhou, H., Zhou, X. N., Utzinger, J. & Steinmann, P. 2012. Soil-transmitted helminth infections and physical fitness in school-aged Bulang children in southwest China: results from a cross-sectional survey. *Parasit Vectors,* 5**,** 50.
Yap, P., Müller, I., Walter, C., Seelig, H., Gerber, M., Steinmann, P., Damons, B. P., Smith, D., Gall, S., Bänninger, D., Hager, T., Htun, N. S., Steenkamp, L., Gresse, A., Probst-Hensch, N., Utzinger, J., Du Randt, R. & Pühse, U. 2015. Disease, activity and schoolchildren's health (DASH) in Port Elizabeth, South Africa: a study protocol. *BMC Public Health,* 15**,** 1285.
Yap, P., Wu, F. W., Du, Z. W., Hattendorf, J., Chen, R., Jiang, J. Y., Kriemler, S., Krauth, S. J., Zhou, X. N., Utzinger, J. & Steinmann, P. 2014. Effect of deworming on physical fitness of school-aged children in Yunnan, China: a double-blind, randomized, placebo-controlled trial. *PLoS Negl Trop Dis,* 8**,** e2983.

Chapter 4 Article II

4.1 Physical activity and health-related quality of life among schoolchildren from disadvantaged neighbourhoods in Port Elizabeth, South Africa

Marina Salvini[1]*, Stefanie Gall[1]*, Ivan Müller[1,2,3], Cheryl Walter[4], Rosa du Randt[4], Peter Steinmann[2,3], Jürg Utzinger[2,3], Uwe Pühse[1], Markus Gerber[1†]

[1] Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland

[2] Swiss Tropical and Public Health Institute, Basel, Switzerland

[3] University of Basel, Basel, Switzerland

[4] Department of Human Movement Science, Nelson Mandela Metropolitan University, Port Elizabeth, South Africa

*These two authors contributed equally to this article.

[†]Corresponding author:

E-mail: markus.gerber@unibas.ch

This article has been published in **Quality of Life Research** 2017

4.2 Abstract

Purpose: The relationship between health-related quality of life (HRQoL), physical activity (PA), and cardiorespiratory fitness (CRF) among disadvantaged communities in low- and middle-income countries is poorly understood. In South Africa, children from socioeconomically deprived households are at an elevated risk of sedentary lifestyles and poor HRQoL. We examined whether higher self-reported PA and higher CRF levels are associated with better HRQoL in South African schoolchildren from disadvantaged neighbourhoods.

Methods: Overall, 832 children aged 8–12 years participated in this cross-sectional study. HRQoL was assessed through five dimensions of the KIDSCREEN-27 tool. Self-reported PA was measured using a single item of the Health-Behaviour of School-Aged Children test, and CRF with the 20-m shuttle run test.

Results: Higher self-reported PA was significantly and positively related to HRQoL. Significant, but small group differences existed across all dimensions of HRQoL between low and high self-reported PA. No significant associations were observed between CRF levels and HRQoL.

Conclusions: Schoolchildren reporting PA of at least 60 min on at least 6 days a week (the recommended minimum) report higher HRQoL than their peers with lower PA levels.

Keywords: Health-related quality of life Physical activity Cardiorespiratory fitness Schoolchildren South Africa

4.3 Introduction

Physical activity (PA) and cardiorespiratory fitness (CRF) are important indicators of health (Ortega et al., 2008). A central aspect of health is health-related quality of life (HRQoL), which can be seen as a subjective representation of wellbeing and overall functioning of the body (Ravens-Sieberer et al., 2006). Moreover, HRQoL has become an important factor in the medical and caring sciences (Haraldstad et al., 2011). The assessment of HRQoL can serve as a benchmark for monitoring population health over time, identifying subgroups with poor HRQoL that require specific attention, and measuring the impact of public health interventions within a given population (Ravens-Sieberer et al., 2001). HRQoL of children is an important predictor of health and wellbeing, and thus for estimating health care costs in later life (Seid et al., 2004), as it is characterised by remarkable stability over time (Meade and Dowswell, 2016).

Research has shown that HRQoL is influenced by many factors. For instance, lower HRQoL is reported by children with lower socioeconomic status (SES) (von Rueden et al., 2006) or children who are overweight or obese (Chen et al., 2014). Some studies also showed that HRQoL declines from childhood to adolescents (Michel et al., 2009, Bisegger et al., 2005). Meaningful gender differences occurred from the age of 13 years onwards, with females generally reporting lower HRQoL after that age (Michel et al., 2009, Bisegger et al., 2005, Helseth et al., 2015). Bisegger et al. (2005) have argued that HRQoL in adolescence governs HRQoL in adulthood. In South African children living in disadvantaged neighbourhoods, a strong and persistent relationship has been recorded between low SES and impaired HRQoL (Ataguba et al., 2011).

PA, on the other hand, has been associated with multiple health benefits across different age groups (Boreham and Riddoch, 2001). Participating in regular PA and being in good physical constitution reduces the risk of cardiovascular diseases and type II diabetes, helps to control body weight, has a positive impact on muscles and bones, and contributes to improved psychological wellbeing. Furthermore, regular PA is associated with an improved capacity to deal with stress, better quality of sleep, and decreased risk of developing symptoms of depression and anxiety (Kohl and Murray, 2012). Among children, regular PA is associated with improved HRQoL (Penedo and Dahn, 2005). For instance, Wafa et al. (2016) reported that among 156 Malaysian children aged 9-11 years, those with higher levels of moderate-to-vigorous PA reported better HRQoL. Additionally, Shoup et al. (2008) found in a study of 177 overweight and obese children aged 8-12 years that those who met PA recommendations reported higher HRQoL, irrespective of their body weight. Gopinath et al. (2012) showed in a longitudinal study with 2,553 children with a median age of 12.7 years that those with high PA levels reported significantly higher HRQoL 5 years later. Gu et al. (2016) observed in a sample of 201 children from the United States with a mean age of 9.8 years that PA was positively related to several dimensions of HRQoL, a relationship which was mediated by children's CRF. Kantor et al. (2015) revealed in a study of 448 Hispanic children attending grades 3-5 that greater participation in sport teams was associated with better physical and social functioning and a higher total HRQoL. The authors concluded that their findings have important implications for the development of interventions to promote health and wellbeing among children and adolescents.

Taken together, previous research suggests that regular PA is associated with increased HRQoL among children, but most of the evidence stems from high-income countries (Petersen et al., 2012). A few studies suggest that increased PA might be especially beneficial for disadvantaged children. For instance, Crews et al. (2004) found that aerobic exercise training had a positive impact on psychological wellbeing among Hispanic children from low-income districts in the United States. To our knowledge, in South Africa, only one study has been conducted that examined the relationship between children's PA and quality of life (Van Hout et al., 2013). It was found that schoolchildren from a disadvantaged community who participated in sports at least twice per week had higher scores across all quality of life domains compared to less physically active counterparts. Yet, physical education is often absent from the school curriculum in many low- and middle-income countries (Pühse and Gerber, 2005). As a result, children do not engage in the recommended daily 60 min of moderate-to-vigorous PA (Strong et al., 2005). Walter (2011) speculates that this is an important reason for the increasing sedentariness observed among South African schoolchildren.

The purpose of the present study was to investigate whether higher self-reported PA and higher CRF levels are associated with higher HRQoL among 8- to 12-year-old schoolchildren from disadvantaged neighbourhoods in South Africa.

4.4 Methods

Participants and procedures

South African public schools are classified into five groups depending on their financial resources, ranging from quintile one (poorest) to quintile five (least poor) (Hall and Giese, 2009). The present study was conducted in eight quintile three schools, located in disadvantaged neighbourhoods of Port Elizabeth. Details regarding the information provided to eligible participants as well as inclusion and exclusion criteria have been published elsewhere (Yap et al., 2015). In brief, oral assent from each participating child was sought and written informed consent was obtained from parents/guardians. Participation was voluntary, and hence, children could withdraw at any time without further obligations.

As shown in the participant flow chart, after receiving written informed consent from a parent/guardian, a total of 1,009 grade four schoolchildren, aged 8-12 years, agreed to participate in the baseline cross-sectional survey in February and March 2015 (Figure 4.1).

Complete data records were available for 832 (82.5%) children. All analyses refer to this final cohort, including 417 girls (50.1%) and 415 boys (49.9%).

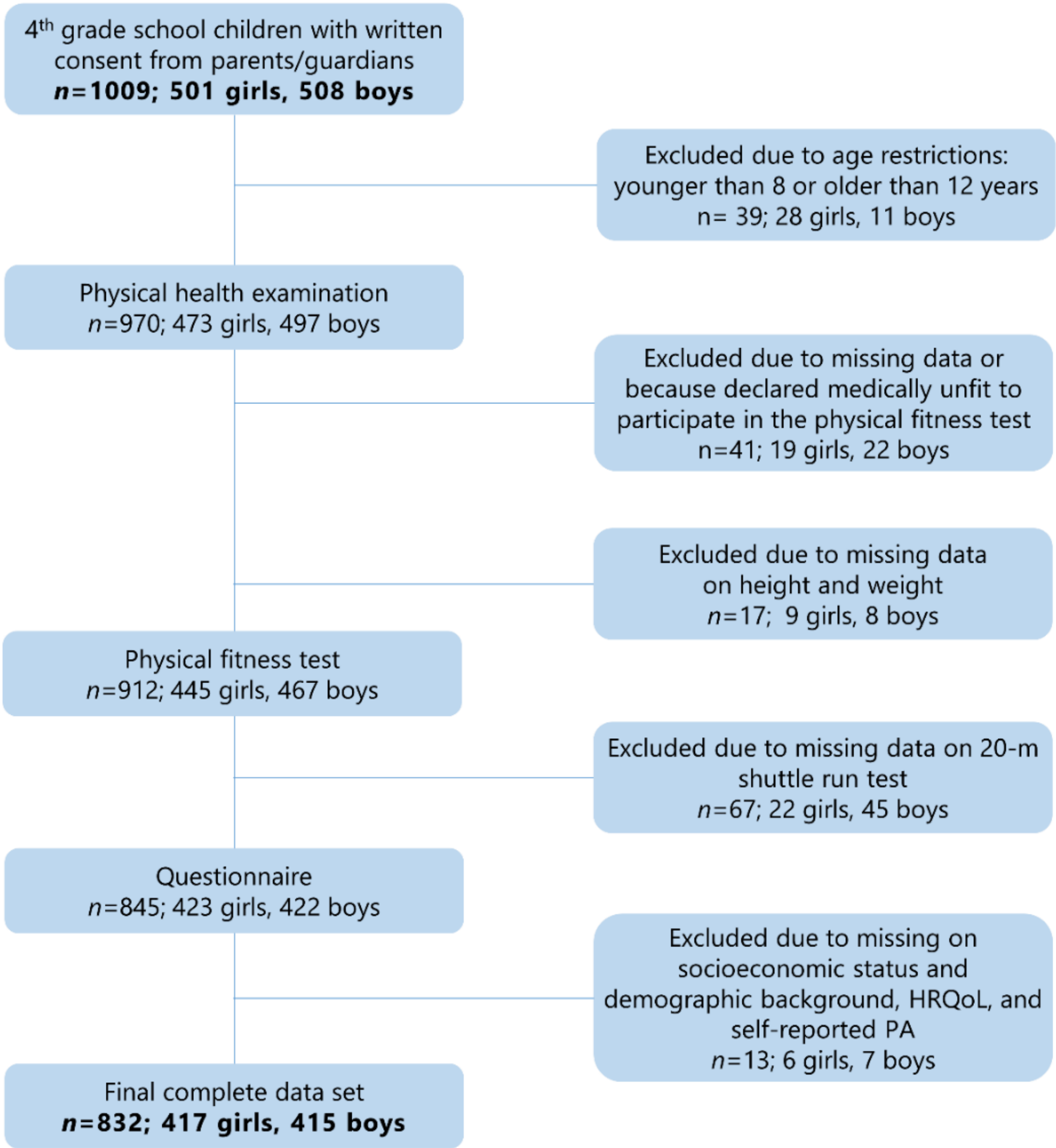


Figure 4.1 Participant flow chart

Data were collected during an official school lesson under the supervision of the class teacher and a trained research assistant. To ensure confidentiality, each participant was assigned a unique identification number. All tests were available in English, Xhosa, and Afrikaans. All items were pilot-tested with a small sample of Xhosa and Afrikaans speaking schoolchildren of the same age as the study cohort.

The "Disease, Activity and Schoolchildren's Health" (DASH) study was approved by the ethical review board of North-western and Central Switzerland (reference no. EKNZ 2014-179), the Nelson Mandela University Human Ethics Committee (reference no. H14-HEA-HMS-002), the Eastern Cape Department of Education, and the Eastern Cape Department of Health in Port Elizabeth, South Africa.

Assessment of PA

PA behaviour was assessed with a single-item question from the Health-Behaviour of School-Aged Children (HBSC) study (Inchley et al., 2016): "Over the past 7 days (1 week), on how many days were you physically active for a total of at least 60 min (1 hour) a day?" The options to answer the question ranged from zero days to seven days. This question is based on the recommendation for PA among young people stating that children and youth aged 6-17 years should perform at least 60 min of moderate-to-vigorous-intensity PA per day (United States Department of Health and Human Services, 2008, Biddle et al., 1998). Children were classified into groups with low PA (0 or 1 active day per week), moderate PA (2-5 active days per week), and high PA (6 or 7 active days per week). This classification was chosen to ensure that children in the highest category were active on almost every day for at least 60 min, and thus met PA recommendations. By contrast, children with moderate PA levels were active on some days a week, and therefore did not meet PA recommendations. Finally, children with low PA levels failed to accumulate 60 min of PA on almost all days of the week, and were therefore far from meeting recommended PA levels (United States Department of Health and Human Services, 2008, Biddle et al., 1998).

Assessment of CRF

In order to measure children's CRF, the 20-m shuttle run test was employed (Léger et al., 1988). In brief, a premeasured running course was laid out on a flat terrain and marked with colour-coded cones. Children who felt sick or were not comfortable enough to run did not participate in the test. The procedures were explained, and a researcher demonstrated two trial runs. Once children were familiar with the test procedures, they started with a running speed of 8.5 km/h, following a researcher who set the pace according to a sound signal. The frequency of the sound-signal steadily increased every min by 0.5 km/h. If a child was unable to cross the marked 2-m line at each end of the course at the moment of the sound signal for two successive intervals, the individual maximum was reached, and the child was asked to stop. Only the fully completed laps were noted. The level at which the child stopped running during the 20-m shuttle run test was used to calculate the age-adjusted estimate of maximal oxygen uptake (VO_2 max) (Léger et al., 1988). Based on their VO_2 max scores (ml kg^{-1} min^{-1}), children were categorised into three groups: (i) low CRF (children in the lowest quartile); (ii) moderate CRF (second and third quartiles); and (iii) high CRF (fourth quartile).

Assessment of HRQoL

HRQoL was assessed with the 27-item version of the KIDSCREEN questionnaire (The Kidscreen Group, 2006), which was developed to assess HRQoL among children and adolescents aged 8-18 years. The KIDSCREEN-27 consists of five subscales, namely (i) physical wellbeing (5 items: e.g., "Have you physically felt fit and well?"); (ii) psychological wellbeing (7 items: e.g., "Has your life been enjoyable?"); (iii) autonomy and parent relation (7 items: e.g., "Have you been able to talk to your parent(s)/guardian(s) when you wanted to?"); (iv) social support and peers (4 items: e.g., "Have you spent time with your friends?"); and (v) school environment (4 items: e.g., "Have you been happy at school?"). All items were anchored on a 5-point Likert-type scale ranging from 1 (never or not at all) to 5 (always or extremely). Negatively poled items were reverted before calculating the subscale scores, to ensure that higher values reflect higher HRQoL across all subscales.

Following recommended procedures (The Kidscreen Group, 2006), we first summed up the item scores of the respective scales to obtain raw scores, and then transformed these raw scores into Rasch person parameter estimates using the available SPSS software (IBM Corporation, Armonk NY, USA) syntax for each dimension (The Kidscreen Group, 2006). Finally, these steps resulted in T-values with a scale mean of 50 and a standard deviation (SD) of 10. Higher mean scores generally reflect higher HRQoL across all KIDSCREEN subscales. The subscale scores can be compared with the norm scores of an international survey sample of 5,754 European children, which are shown in Table 4.1, stratified by gender. To be classified as "normal", the threshold chosen by the KIDSCREEN developers was the mean, plus or minus half a SD.

Assessment of potential confounders

Nine questions covering household-level living standards, such as infrastructure and housing characteristics (e.g., wall and roof type, number of bedrooms) and the ownership of three durable assets (e.g., refrigerator) were used to estimate children's SES. The dichotomized items (0=poor quality, not available; 1=higher quality, available) were summed up to build an overall SES index, with higher scores reflecting higher SES (the full instrument and scoring instructions are shown in the Appendix).

To assess children's body weight, they were asked to take off their shoes and sweater before stepping on a digital weighing scale (Micro T7E electronic platform scale, Optima Electronics; George, South Africa). Body weight was measured once and recorded to the nearest 0.1 kg. With the shoes removed, each child then stood against a Seca stadiometer (Surgical SA; Johannesburg, South Africa) with their back erect and shoulders relaxed. Body height was measured once and recorded to the nearest 0.1 cm. Body weight and height values were used to calculate body mass index (BMI), defined as weight (in kg)/height^2 (in m^2). The BMI was calculated using growth reference put forth by the World Health Organization (WHO, 2007).

4.5 Statistical analysis

Data were double-entered, validated using EpiData version 3.1 (EpiData Association; Odense, Denmark), and merged into a single master file. Statistical analyses were performed with SPSS® version 23 (IBM Corporation; Armonk, United States) for Windows® and STATA version 13.0 (Stata Corp.; College Station, United States). Statistical significance was set at $p<.05$ across all analyses. Descriptive statistics are displayed as means (*M*) and SD. Before calculating the main analyses, tests of normality were performed by examining data for kurtosis and skewness. Both kurtosis and skewness were in the acceptable range (between -1 and +1) across all KIDSCREEN subscales (Hair et al., 2010). Univariate analyses of variance (ANOVAs) were calculated to examine gender differences in the main study variables. χ^2-tests were calculated to examine whether boys and girls were equally represented in the groups with low, moderate, or high PA and CRF levels. Finally, multi- and univariate analyses of variance ([M]ANOVA) and covariance ([M]ANCOVA) were calculated to test whether children classified in the groups with low, moderate, or high PA or CRF differed with regard to HRQoL, before and after controlling for gender, age, SES, BMI, school class, and CRF (if PA was used as dependent variable) or PA (if

CRF was used as dependent variable). Following Cohen (1988), η^2 values from .010 to <.059 were interpreted as small group differences, from .059 to <.138 as medium-sized group differences and from .138 as large group differences.

4.6 Results

Anthropometric indicators, HRQoL, PA, and CRF

Table 4.1 provides an overview of the descriptive statistics and gender differences for all study variables. The internal consistency of all HRQoL subscales was acceptable in this sample, with Cronbach's alpha values varying between .67 and .72 (Nunnally and Bernstein, 1994). Girls were significantly younger than boys and had a higher BMI. No gender differences were identified for height, weight, and SES. Boys achieved significantly higher mean VO_2 max estimates than girls. However, no significant gender difference was found for self-reported PA.

Table 4.1 Characteristics of the study population, descriptive statistics, and differences between boys and girls, as assessed in a cross-sectional survey among disadvantaged South African schoolchildren in February/March 2015

Parameter	Total *n*=832 *M* (*SD*)	Boys *n*=417 *M* (*SD*)	Girls *n*=415 *M* (*SD*)	*F*	*p*	η^2
Age and anthropometry						
Age (years)	9.5 (0.9)	9.7 (0.9)	9.4 (0.9)	26.10	<.001	.030
Height (cm)	133.1 (7.1)	133.2 (6.7)	133.0 (7.5)	0.19	.663	.000
Weight (kg)	30.5 (7.5)	30.0 (6.5)	31.0 (8.3)	3.27	.071	.004
BMI (kg/m^2)	17.0 (3.0)	16.8 (2.6)	17.3 (3.3)	6.25	.013	.007
Sociocultural characteristics						
Socioeconomic status[a]	7.3 (1.9)	7.3 (1.9)	7.4 (1.9)	0.38	.539	.000
Cardiorespiratory fitness						
Shuttle run (VO_2 max)[b]	49.0 (4.3)	50.8 (4.3)	47.2 (3.5)	174.46	<.001	.174
Self-reported physical activity						
60 min active per day/week[c]	3.5 (2.5)	3.7 (2.4)	3.3 (2.5)	3.63	.057	.004
Health-related quality of life						
Physical wellbeing[d]	50.5 (13.2)	50.3 (13.4)	50.7 (13.0)	0.28	.598	.000
Psychological wellbeing[d]	38.3 (8.6)	38.3 (9.8)	38.3 (7.2)	0.00	.996	.000
Autonomy and parent relations[d]	49.5 (12.4)	48.4 (12.6)	50.6 (12.2)	6.21	.013	.007
Social support and peers[d]	48.6 (11.8)	48.0 (12.0)	49.3 (11.4)	2.74	.099	.003
School environment[d]	55.4 (12.4)	53.6 (12.9)	57.1 (11.7)	16.84	<.001	.020
Norm data for health-related quality of life based on 5,754 European children (8-11 years)						
Physical wellbeing		54.47 (9.90)	53.01 (9.95)			
Psychological wellbeing		53.40 (9.79)	52.70 (10.07)			
Autonomy and parent relations		51.40 (10.16)	51.73 (10.46)			
Social support and peers		50.78 (9.92)	51.20 (10.13)			
School environment		52.89 (10.42)	55.13 (10.17)			

[a]Socioeconomic status measured by ownership and housing questions on a scale from 0-9 points (0 = low score)[b]All mean VO_2 max estimates are expressed in ml kg^{-1} min^{-1} and are adjusted for age
[c]Physical activity measured by question on how many days achieved activity of at least 60 min on a scale from 0-7 days (0=never, 7=each day of the week)
[d]KIDSCREEN questionnaire scores should be considered as "normal" if they are within the following threshold: mean of the age and gender specific norm scores of the international survey sample (5,754 European children), plus or minus half a standard deviation. Thus, with regard to physical wellbeing, values can be regarded as normal for girls if they vary between 48.03 and 57.99 (M = 53.01 ± SD/2 = 4.98). With regard to psychological wellbeing, among girls, values should range between 47.66 and 57.74 (M = 52.70 ± SD/2 = 5.04). To illustrate, in the present sample, girls' HRQoL for physical wellbeing is in the "normal" range, whereas they report psychological wellbeing below the "normal" range.

With regard to HRQoL, girls had significantly higher scores than boys in two HRQoL subscales (autonomy and parent relations, social support and peers). Table 4.2 shows the number and percentage of children classified into the three groups with low, moderate, or high PA/CRF. Boys and girls were equally distributed among the groups with low, moderate, and high PA levels, $\chi^2(2,832)=2.82$, $p=.244$, whereas girls were overrepresented in the group with low CRF scores, and underrepresented among children with high CRF levels, $\chi^2(2,832)=122.4$, $p<.001$.

Table 4.2 Levels of self-reported physical activity and cardiorespiratory fitness among disadvantaged South African schoolchildren in a cross-sectional survey conducted in February/March 2015, stratified by boys and girls

	Total *n*=832		Boys *n*=417		Girls *n*=415	
Self-reported physical activity	*n*	%	*n*	%	*n*	%
Low (0-1 days/week)	229	27.5	104	24.9	125	30.1
Moderate (2-5 days/week)	376	45.2	196	47.0	180	43.4
High (6-7 days/week)	227	27.3	117	28.1	110	26.5
Cardiorespiratory fitness	*n*	%	*n*	%	*n*	%
Low (1st quartile)[a]	236	28.4	61	14.6	175	42.2
Moderate (2nd and 3rd quartile)[b]	382	45.9	189	45.3	193	46.5
High (4th quartile)[c]	214	25.7	167	40.0	47	11.3

[a]Scores of students in the first quartile range from 37.78 to 45.68.
[b]Scores of students in the second and third quartiles range from 45.69 to 51.96.
[c]Scores of students in the fourth quartile range from 51.97 to 61.86.

HRQoL as a function of self-reported PA

The results of the MANOVA indicated an overall significant effect of self-reported PA on HRQoL, Wilk's lambda: $F(10,1650)=6.70$, $p<.001$, $\eta^2=.039$. Results of the follow-up ANOVAs (Model 1: uncontrolled) showed that there were significant group differences across all dimensions of HRQoL (Table 4.3). Bonferroni post-hoc tests revealed that children with low and moderate PA had lower scores on physical wellbeing, psychological wellbeing, autonomy, and parent relations, social support and peers, and school environment than their peers with high

PA levels. Children with low PA also scored significantly lower on physical and psychological wellbeing compared to their peers with moderate PA levels.

After controlling for age, gender, SES, school class, and CRF (Model 2), the MANCOVA still showed a significant main effect for PA, Wilk's lambda: $F(10,1638)=4.64$, $p<.001$, $\eta^2=.028$. In the univariate follow-up ANCOVAs, the group differences persisted after controlling for covariates, although the effect sizes were slightly lower (Table 4.3).

HRQoL as a function of CRF

With CRF as independent variable, the MANOVA did not show significant group differences in HRQoL, Wilk's lambda: $F(10,1650)=0.61$, $p=.809$, $\eta^2=.004$. Accordingly, all univariate ANOVAs were not significant (Table 4.4). The same pattern was observed after controlling for covariates, with both the MANCOVA, Wilk's lambda: $F(10,1638)=0.78$, $p=.648$, $\eta^2=.005$, and all follow-up ANCOVAs showing non-significant relationships (Table 4.4).

Table 4.3 Health-related quality of life as a function of self-reported physical activity among disadvantaged South African schoolchildren in a cross-sectional survey conducted in February/March 2015

	Low physical activity (0-1 days/week) (*n*=229)	Moderate physical activity (2-5 days/week) (*n*=376)	High physical activity (6-7 days/week) (*n*=227)	Model 1			Model 2		
	M (SD)	*M (SD)*	*M (SD)*	*F*	*p*	η^2	*F*	*p*	η^2
Physical wellbeing	46.4 (12.4)[a,b]	50.3 (13.1)[a,c]	54.1 (13.3)[b,c]	20.52	<.001	.047	15.89	<.001	.037
Psychological wellbeing	36.3 (8.3)[a,b]	38.2 (9.1)[a,c]	40.3 (7.4)[b,c]	12.70	<.001	.030	6.79	<.001	.016
Autonomy and parent relations	46.7 (10.7)[a]	49.0 (12.4)[b]	53.0 (13.3)[a,b]	15.90	<.001	.037	12.11	<.001	.029
Social support and peers	47.0 (11.3)[a]	47.7 (11.3)[b]	51.9 (12.2)[a,b]	12.74	<.001	.030	6.56	<.001	.016
School environment	52.6 (12.3)[a]	54.7 (12.1)[b]	59.4 (12.4)[a,b]	17.69	<.001	.041	9.12	<.001	.022

Degrees of freedom = 2,832 across all analyses. [a,b,c] Bonferroni post-hoc tests: Mean values with equal letters are significantly different ($p<.05$). Model 1 = uncontrolled. Model 2 = controlled for age, gender, body mass index, socioeconomic status, cardiorespiratory fitness, and school class.

Table 4.4 Health-related quality of life as a function of cardiorespiratory fitness among disadvantaged South African schoolchildren in February/March 2015

	Low fitness (1st quartile) (*n*=236)	Moderate fitness (2nd and 3rd quartiles) (*n*=382)	High fitness (4th quartile) (*n*=214)	Model 1			Model 2		
	M (SD)	*M (SD)*	*M (SD)*	*F*	*p*	η^2	*F*	*p*	η^2
Physical wellbeing	49.7 (13.3)	51.3 (13.2)	50.5 (13.3)	1.17	.311	.003	0.60	.551	.001
Psychological wellbeing	38.0 (8.1)	38.5 (8.8)	38.1 (8.7)	0.26	.768	.001	0.20	.822	.000
Autonomy and parent relations	48.7 (12.7)	50.5 (12.8)	48.5 (11.3)	2.41	.090	.006	1.97	.140	.005
Social support and peers	48.3 (12.6)	48.9 (11.8)	48.5 (10.7)	0.20	.818	.000	0.12	.888	.000
School environment	55.0 (12.6)	55.9 (12.5)	54.8 (12.3)	0.65	.521	.002	1.31	.270	.003

Degrees of freedom = 2,832 across all analyses. Model 1 = uncontrolled. Model 2 = controlled for age, gender, body mass index, socioeconomic status, physical fitness, and school class.

4.7 Discussion

We examined whether self-reported PA and CRF are associated with HRQoL in 8- to 12-year-old children from disadvantaged neighbourhoods in Port Elizabeth, South Africa. We found that schoolchildren who reported to be physically active for more than 60 min on at least six days per week report significantly higher HRQoL than their peers with lower PA levels, even after controlling for various confounders. However, no significant association was found between CRF levels and HRQoL.

Children with high self-reported PA reached higher scores across all five HRQoL dimensions compared to their peers with low PA levels. Our findings support the recommendation of the United Kingdom Expert Consensus Group (Biddle et al., 1998) and the Centers for Disease Control and Prevention (United States Department of Health and Human Services, 2008) suggesting daily activity of at least one hour among children aged 6-17 years. Furthermore, our data revealed that children reporting low PA levels had the lowest scores across all HRQoL dimensions, with children in this group differing significantly from peers with moderate PA levels in both physical and psychological wellbeing. Hence, even a medium amount of self-reported PA is positively associated with HRQoL among children living in disadvantaged areas in a low- and middle-income countries.

Our findings are in line with previous investigations showing that physically active children generally report better HRQoL (Gu et al., 2016, Kantor et al., 2015, Wafa et al., 2016, Gopinath et al., 2012). In the European HBSC study, which used the same item to assess PA as we did, 30% of boys and 21% of girls reported at least one hour of moderate-to-vigorous PA on all days of the week among 11-year-old children surveyed in 2013/2014 (Kalman et al., 2015, WHO, 2016). In our sample, the number of children who achieved recommended PA levels was similar among girls (20%), but slightly lower among boys (24%). Nevertheless, our findings also show that almost every third child (27.5%) failed to accumulate 60 min of PA on almost all days of the week, which is far below recommended PA levels (United States Department of Health and Human Services, 2008, Biddle et al., 1998).

With regard to the magnitude of the group differences, as shown in Table 4.3, the effect sizes (η^2) ranged between .030 and .047 in the uncontrolled model, and between .016 and .037 after controlling for the covariates. Furthermore, if using international norms established with

European children as a reference (see Table 4.1), our findings revealed that, although in our population children with high PA levels reported higher scores for psychological wellbeing than peers with low PA levels, they still reported psychological wellbeing below the threshold considered “normal” in European children. Taken together, we can conclude that while significant differences exist between South African schoolchildren with low, moderate, and high PA levels in terms of HRQoL, these differences are rather small, and even children with the highest PA levels reported lower psychological wellbeing than European children.

The reasons why physically active children report higher QoL are multifactorial. First, Breslin (2012) argued that there might be a connection between PA and higher overall wellbeing because participation in sports, games, and playground activities may result from and contribute to being socially accepted, popular, and spending time actively with friends. Second, Anokye et al. (2012) suggested that higher HRQoL might be attributable to the fact that PA is associated with improved self-esteem, a relationship which is mediated through positive perceptions of competences and a positive physical self-concept (Lindwall and Lindgren, 2005). Third, researchers have claimed that PA is associated with increased mental toughness (Brand et al., 2016, Brand et al., 2017), a mindset which may help physically active children to better cope with stress (Gerber et al., 2017, Gerber et al., 2016). In line with this notion, a study with 8-year-old children showed that children who engaged in regular PA exhibited a lower adrenocortical reactivity when exposed to a psychosocial laboratory stressor (Martikainen et al., 2013). Fourth, increased PA might be associated with better quality of sleep (Lang et al., 2016), which, in turn, can have a positive impact on physical health indicators, as well as behavioural/emotional health outcomes (Hatzinger et al., 2010). Fifth, a significant relationship has been described between regular PA and reduced depressive symptoms (Korczak et al., 2017). For instance, Tomson et al. (2003) showed that among 8- to 12-year-old children, being classified as inactive, not playing sport outside, or not meeting health-related CRF goals, was associated with a 1.3- to 4.0-times higher risk of reporting high depressive symptoms. This relationship was corroborated in a study using objective PA assessments and semi-structured clinical interviews to diagnose depression (Zahl et al., 2017). Despite these insights, there is a paucity of studies directly testing the mediating role of the aforementioned factors. Studies with a longitudinal component are urgently needed to deepen our understanding of the underlying mechanisms that may explain the beneficial impact of PA on HRQoL (or *vice versa*). Moreover, although the present study suggests that already moderate PA levels can have a beneficial effect, little is known about the dose-response-relationships. Hence, additional research is warranted, in which PA is assessed with more precise methods (e.g., accelerometry), to determine how much PA is needed to increase children's HRQoL.

The fact that no significant differences in HRQoL were found between children with low, moderate, and high CRF levels was unexpected. Indeed, previous research with children showed that PA and CRF are independently associated with reduced risk of cardiometabolic diseases (Ekelund et al., 2007). In the present study, however, Bonferroni post-hoc tests indicated that even children in the highest and lowest CRF quartile did not differ with regard to their self-reported HRQoL. Levels of CRF observed in our sample were slightly higher compared to European reference data. For instance, while Silva et al. (2012) reported average VO_2 max scores of 43.9 (girls) and 46.3 (boys) for 10-year-old children from Portugal, the VO_2 max scores in our sample were 47.2 for girls and 50.8 for boys. Several explanations are offered for consideration. First, researchers found that only a small correlation exists between self-reported PA and children's performance in the 20-m shuttle run test (Gerber et al., 2017). This was supported in the present sample with a correlation of r=.15 (p=.66). Second, although CRF can generally be regarded as a proxy measure of PA, CRF also depends on genetic factors, whereas PA is a behavioural variable (Bouchard et al., 1997). Third, because PA and HRQoL are based on self-reports, these constructs may share common method variance (Byrne, 2010). For instance, previous research has shown that how people think about their PA is related to their mental wellbeing (Gerber et al., 2010). Fourth, in a study with Swedish adults, Lindwall et al. (2012) observed that self-reported PA is more closely associated with mental health outcomes than objectively assessed CRF. Lindwall et al. argued that PA does not primarily affect mental health via improved CRF and cardiovascular change, but that psychological processes (e.g., perceptions of mastery, perceived control over one's health and body) might play a more important role. Nevertheless, other researchers have found positive associations between CRF and HRQoL (Gu et al., 2016), which they attributed to enhanced body image or an effect on neurochemicals in the brain (e.g., serotonin), known to be involved in the regulation of mood (Ortega et al., 2008). Moreover, researchers reported positive relationships between higher CRF levels and other psychological variables, such as selective attention or academic performance (Gall et al., 2017). Therefore, increased CRF should still be considered as a key variable for public health promotion, despite the lack of a clear association with HRQoL in the present study. This applies particularly to South African schoolchildren living in deprived neighbourhoods, where good academic performances represent a major factor to escape the vicious circle of poverty and poor health.

A particular strength of the current study is that PA and CRF were assessed simultaneously in a relatively large sample of schoolchildren. The 20-m shuttle run test proved to be a valid measure of children's CRF in prior research (Léger et al., 1988) and could be associated with both physical and psychological health outcomes (Reed et al., 2008, Ruggero et al., 2015). Moreover, an internationally accepted and validated instrument was used to measure children's HRQoL (Ravens-Sieberer et al., 2007). Using this instrument allows a comparison of HRQoL between South African children living in disadvantaged neighbourhoods and European KIDSCREEN norm data for 8- to 11-year-old children (The Kidscreen Group, 2006). While only minor differences were observed for physical wellbeing, autonomy and parent relations, and social support and peers, the children in the present study reported markedly lower scores with regard to psychological wellbeing than European peers. On the other hand, compared to European peers, South African children reported higher scores with regard to school environment. Although speculative, we assume that low scores for psychological wellbeing and positive perceptions of the school environment in the present sample result from the fact that many of the children are faced with difficult family situations and poor living conditions. Therefore, children might consider the school as a relative "sanctuary", which provides relief from the troubles associated with everyday life. In line with this, the 2016 South African Early Childhood Review showed that 63% of all South African children lived in poverty and 28% lived in households where nobody is employed (Hall et al., 2016). Another factor responsible for the positive perceptions of the school environment might be that in quintile three schools, children receive a daily meal through the National School Nutrition Programme (DoBE, 2014), and for many of the children, this may be the only warm meal of the day.

While the present study provides novel insights with regard to the association between PA and HRQoL in South African schoolchildren, the results must be considered in light of certain limitations. First, the sample is limited to fourth grade students attending quintile three schools in urban areas. Hence, caution is to be exerted when attempting to generalize the findings to children from other school grades, educational levels, or schools located in rural settings. Second, the cross-sectional nature of the data precludes conclusions about possible causal relationship between PA and HRQoL. While it is plausible that PA leads to increased HRQoL, it is just as likely that children with low HRQoL are less motivated to engage in regular PA (Aaltonen et al., 2016). With regard to the reciprocity between PA and mental health outcomes, one of the few studies with children showed that PA predicted later depressive symptoms, but that prior depression also had an impact on later PA (Stavrakakis et al., 2012). Third, information about HRQoL is exclusively based on self-reports. As shown previously, children's self-reports may differ considerably from data obtained through informants such as teachers or parents (Achenbach et al., 2002). Fourth, PA was assessed with a relatively simple 1-item measure. However, this item proved to be similarly associated with accelerometer data as more detailed questionnaires (Scott et al., 2015). Because such short measures take less time to complete, are simpler, and therefore do not require higher level cognitions (Scott et al., 2015), researchers have concluded that single-item instruments are valid screening tools useful for population surveys (Milton et al., 2013). Moreover, when creating categories of low, moderate, or vigorous PA, we referred to internationally accepted PA standards (United States Department of Health and Human Services, 2008, Biddle et al., 1998). Fifth, although the children were living in disadvantaged neighbourhoods, their responses on the 9-point scale to assess SES indicate that these children only had mid-level socioeconomic disadvantage. Nevertheless, the SD shows that there was considerable variation within our study population.

With regard to implications of our findings for South African policy makers, implementation of physical education in disadvantaged schools is currently not satisfactory. Indeed, not a single school among the study sample offered physical education classes at the time of our cross-sectional survey. The reasons include the downgrading of the subject to the life skills learning area, where it has lost its standalone status due to time constraints, teacher workloads, perception of physical education as an insignificant subject, etc. A number of non-governmental organizations (NGOs) and other organizations have stepped into this gap, but they currently reach only a limited number of schools. Despite this critical situation, in the Healthy Active Kids South Africa 2016 report card, government strategy, policy and investment has been given a generous B (= succeeding with well over half of children and youth). Taken together, it can be concluded that the South African government is mindful of the need for the promotion of physical activity in disadvantaged areas and schools. Through the Department of Basic Education and Sport and Recreation of South Africa, the government has pledged support to maximize access to sport, recreation, and physical activity, but these are limited by budgetary constraints. In other words, political "will" is there but more support is needed, engaging both the public and private sectors. In essence, there is a great awareness in South Africa of the need for increased PA of children from the government, academic, public, and private sectors, and public-private partnerships are working together to find solutions in the midst of many constraints. Our findings corroborate that efforts to further PA in disadvantages schools are well worthwhile and should be intensified.

4.8 Conclusion

Among children from poor neighbourhoods in South Africa, we found a positive association between self-reported PA and HRQoL. This finding is important because good HRQoL not only positively influences children's health and wellbeing, but also has measurable positive effects in later life at individual and societal levels. New research is needed to determine how PA levels of South African children can be increased, for example, through school-based PA interventions readily tailored to local contexts. The establishment of population-based cohort studies to monitor the impact of PA interventions on people's perceived and objectively measured health, happiness, and wellbeing is warranted to estimate the potential societal impact.

Acknowledgements

We are grateful to Ms. Siphesihle Nqweniso, Ms. Larissa Adams, Ms. Danielle Smith, Ms. Dominique Bänninger, Mr. Thomas Hager, and Ms. Nandi Joubert for their contribution to data collection. We also thank Mr. Bruce Damons and Ms. Mariandah Gerwel for enabling contacts to schools and their contribution to data collection.

Funding

This study was financially supported by the Swiss-South African Joint Research Programme (SSAJRP), jointly funded by the Swiss National Science Foundation (SNSF; project no. IZLSZ3 149015) and the National Research Foundation (NRF) in South Africa (project no. 87397). The funders played no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Compliance with Ethical Standards

Conflict of interest: None of the authors has any conflict of interest.

Ethical approval

The study was approved by the ethical review board of North-western and Central Switzerland (reference no. EKNZ 2014-179), the Nelson Mandela University Human Ethics Committee (reference no. H14-HEA-HMS-002), the Eastern Cape Department of Education, and the Eastern Cape Department of Health in Port Elizabeth, South Africa. All procedures performed in the study were in accordance with the ethical standards described in the institutional research committees and with the 1964 Helsinki declaration and its later amendments.

Informed consent

Each child provided oral assent and written informed consent was obtained from parents/guardians.

4.9 References

Aaltonen, S., Latvala, A., Rose, R. J., Kujala, U. M., Kaprio, J. & Silventoinen, K. 2016. Leisure-Time Physical Activity and Academic Performance: Cross-Lagged Associations from Adolescence to Young Adulthood. *Sci Rep,* 6**,** 39215.

Achenbach, T. M., Dumenci, L. & Rescorla, L. A. 2002. Ten-year comparisons of problems and competencies for national samples of youth: Self, parent, and teacher reports. *J Emot Behav Disord,* 10**,** 194-203.

Anokye, N. K., Trueman, P., Green, C., Pavey, T. G. & Taylor, R. S. 2012. Physical activity and health related quality of life. *BMC Public Health,* 12**,** 624.

Ataguba, J. E., Akazili, J. & McIntyre, D. 2011. Socioeconomic-related health inequality in South Africa: evidence from General Household Surveys. *Int J Equity Health,* 10**,** 48.

Biddle, S. J., Cavill, N. & Sallis, J. F. 1998. Policy framework for young people and health-enhancing physical activity. *In:* Biddle, S. J., Sallis, J. F. & Cavill, N. (eds.) *Young and active? Young people and health-enhancing physical activity – Evidence and implications.* London: Health Education Authority.

Bisegger, C., Cloetta, B., von Rueden, U., Abel, T., Ravens-Sieberer, U. & European Kidscreen, G. 2005. Health-related quality of life: gender differences in childhood and adolescence. *Soz Praventivmed,* 50**,** 281-91.

Boreham, C. & Riddoch, C. 2001. The physical activity, fitness and health of children. *J Sports Sci,* 19**,** 915-29.

Bouchard, C., Malina, R. M. & Perusse, L. 1997. *Genetics of fitness and physical activity,* Champaign, Human Kinetics.

Brand, S., Kalak, N., Gerber, M., Clough, P. J., Lemola, S., Pühse, U. & Holsboer-Trachsler, E. 2016. During early and mid-adolescence, greater mental toughness is related to increased sleep quality and quality of life. *J Health Psychol,* 21**,** 905-15.

Brand, S., Kalak, N., Gerber, M., Clough, P. J., Lemola, S., Sadeghi Bahmani, D., Pühse, U. & Holsboer-Trachsler, E. 2017. During early to mid adolescence, moderate to vigorous physical activity is associated with restoring sleep, psychological functioning, mental toughness and male gender. *J Sports Sci,* 35**,** 426-434.

Breslin, G., Gossrau-Breen, D., McCay, N., Gilmore, G., McDonald, L. & Hanna, D. 2012. Physical activity, gender, weight status, and wellbeing in 9- to 11-year-old children: a cross sectional survey. *J Phys Act Health,* 9**,** 394-401.

Byrne, B. M. 2010. *Structural equation modeling with AMOS. Basic concepts, applications, and programming,* New York, Taylor & Francis.

Chen, G., Ratcliffe, J., Olds, T., Magarey, A., Jones, M. & Leslie, E. 2014. BMI, health behaviors, and quality of life in children and adolescents: a school-based study. *Pediatrics,* 133**,** e868-74.

Cohen, J. 1988. *Statistical power analysis for the behavioral sciences,* Mahwah, Erlbaum.

Crews, D. J., Lochbaum, M. R. & Landers, D. M. 2004. Aerobic physical activity effects on psychological well-being in low-income Hispanic children. *Percept Mot Skills,* 98**,** 319-24.

DoBE 2014. *National School Nutrition Programme. Report 2013/2014,* Pretoria South Africa, Department of Basic Education.

Ekelund, U., Anderssen, S. A., Froberg, K., Sardinha, L. B., Andersen, L. B., Brage, S. & European Youth Heart Study, G. 2007. Independent associations of physical activity and cardiorespiratory fitness with metabolic risk factors in children: the European youth heart study. *Diabetologia,* 50**,** 1832-1840.

Gall, S., Müller, I., Walter, C., Seelig, H., Steenkamp, L., Pühse, U., du Randt, R., Smith, D., Adams, L., Nqweniso, S., Yap, P., Ludyga, S., Steinmann, P., Utzinger, J. & Gerber, M. 2017. Associations between selective attention and soil-transmitted helminth infections, socioeconomic status, and physical fitness in disadvantaged children in Port Elizabeth, South Africa: An observational study. *PLoS Negl Trop Dis,* 11.

Gerber, M., Brand, S., Holsboer-Trachsler, E. & Pühse, U. 2010. Fitness and exercise as correlates of sleep complaints. Is it all in our minds? *Med Sci Sports Exerc,* 43**,** 893-901.

Gerber, M., Endes, K., Brand, S., Herrmann, C., Colledge, F., Donath, L., Faude, O., Hanssen, H., Pühse, U. & Zahner, L. 2016. In 6- to 8-year-old children, cardiorespiratory fitness moderates the relationship between severity of life events and health-related quality of life. *Qual Life Res*.

Gerber, M., Endes, K., Herrmann, C., Colledge, F., Brand, S., Donath, L., Faude, O., Puhse, U., Hanssen, H. & Zahner, L. 2017. Fitness, Stress, and Body Composition in Primary Schoolchildren. *Med Sci Sports Exerc,* 49**,** 581-587.

Gopinath, B., Hardy, L. L., Baur, L. A., Burlutsky, G. & Mitchell, P. 2012. Physical activity and sedentary behaviors and health-related quality of life in adolescents. *Pediatrics,* 130**,** e167-74.

Gu, X. L., Chang, M. & Solmon, M. A. 2016. Physical Activity, Physical Fitness, and Health-Related Quality of Life in School-Aged Children. *J Teach Phys Educ,* 35**,** 117-126.

Hair, J. F., Black, W. C., Babin, B. J. & Anderson, R. E. 2010. *Multivariate data analysis,* Upper Saddle River, Pearson Education.

Hall, K. & Giese, S. 2009. Addressing quality through school fees and school funding. *S Afr Child Gauge***,** 35-40.

Hall, K., Sambu, W., L., B., Giese, S., Almeleh, C. & Rosa, S. 2016. *South African Early Childhood Review 2016,* Cape Town, Children's Institute, University of Cape Town and Ilifa Labantwana.

Haraldstad, K., Christophersen, K. A., Eide, H., Nativg, G. K. & Helseth, S. 2011. Predictors of health-related quality of life in a sample of children and adolescents: a school survey. *J Clin Nurs,* 20**,** 3048-56.

Hatzinger, M., Brand, S., Perren, S., Stadelmann, S., von Wyl, A., von Klitzing, K. & Holsboer-Trachsler, E. 2010. Sleep actigraphy pattern and behavioral/emotional difficulties in kindergarten children: association with hypothalamic-pituitary-adrenocortical (HPA) activity. *J Psychiatr Res,* 44**,** 253-61.

Helseth, S., Haraldstad, K. & Christophersen, K. A. 2015. A cross-sectional study of Health Related Quality of Life and body mass index in a Norwegian school sample (8-18 years): a comparison of child and parent perspectives. *Health Qual Life Outcomes,* 13**,** 47.

Inchley, J., Currie, D., Young, T., Samdal, O., Torsheim, T., Auguston, L., Mathison, F., Aleman-Diaz, A., Molcho, M., Weber, M. W. & Barnekow, V. 2016. Growing up unequal: Gender and socioeconomic differences in young people's health and well-being. Health Behaviour in School-aged Children (HBSC) study: International report from the 2013/2014 survey. *Health Policy for Children and Adolescents,* 7**,** 276-276.

Kalman, M., Inchley, J., Sigmundova, D., Iannotti, R. J., Tynjala, J. A., Hamrik, Z., Haug, E. & Bucksch, J. 2015. Secular trends in moderate-to-vigorous physical activity in 32 countries from 2002 to 2010: a cross-national perspective. *Eur J Public Health,* 25 Suppl 2**,** 37-40.

Kantor, R. M., Grimes, G. R. & Limbers, C. A. 2015. Physical activity, sedentary behaviors, and health-related quality of life in rural Hispanic youth. *Transl Iss Psychol Sci,* 1**,** 239-249.

Kohl, H. W. r. & Murray, T. 2012. *Foundations of physical activity and public health,* Champaign, Human Kinetics.
Korczak, D. J., Madigan, S. & Colasanto, M. 2017. Children's Physical Activity and Depression: A Meta-analysis. *Pediatrics,* 139.
Lang, C., Kalak, N., Brand, S., Holsboer-Trachsler, E., Pühse, U. & Gerber, M. 2016. The relationship between physical activity and sleep from mid adolescence to early adulthood. A systematic review of methodological approaches and meta-analysis. *Sleep Med Rev,* 28**,** 32-45.
Léger, L. A., Mercier, D., Gadoury, C. & Lambert, J. 1988. The multistage 20 meter shuttle run test for aerobic fitness. *J Sports Sci,* 6**,** 93-101.
Lindwall, M. & Lindgren, E. C. 2005. The effects of a 6-month exercise intervention programme on physical self-perceptions and social physique anxiety in non-physically active adolescent Swedish girls. *Psychol Sport Exerc,* 6**,** 643-658.
Lindwall, M., Ljung, T., Hadzibajramovic, E. & Jonsdottir, I. 2012. Self-reported physical activity and aerobic fitness are differently related to mental health. *Ment Health Phys Act,* 5**,** 28-34.
Martikainen, S., Pesonen, A. K., Lahti, J., Heinonen, K., Feldt, K., Pyhala, R., Tammelin, T., Kajantie, E., Eriksson, J. G., Strandberg, T. E. & Raikkonen, K. 2013. Higher levels of physical activity are associated with lower hypothalamic-pituitary-adrenocortical axis reactivity to psychosocial stress in children. *J Clin Endocrinol Metab,* 98**,** E619-27.
Meade, T. & Dowswell, E. 2016. Adolescents' health-related quality of life (HRQoL) changes over time: a three year longitudinal study. *Health Qual Life Outcomes,* 14**,** 14.
Michel, G., Bisegger, C., Fuhr, D. C., Abel, T. & group, K. 2009. Age and gender differences in health-related quality of life of children and adolescents in Europe: a multilevel analysis. *Qual Life Res,* 18**,** 1147-57.
Milton, K., Clemes, S. & Bull, F. 2013. Can a single question provide an accurate measure of physical activity? *Br J Sports Med,* 47**,** 44-48.
Nunnally, J. & Bernstein, B. 1994. *Psychometric theory,* New York, McGraw-Hill.
Ortega, F. B., Ruiz, J. R., Castillo, M. J. & Sjostrom, M. 2008. Physical fitness in childhood and adolescence: a powerful marker of health. *Int J Obes (Lond),* 32**,** 1-11.
Penedo, F. J. & Dahn, J. R. 2005. Exercise and well-being: a review of mental and physical health benefits associated with physical activity. *Curr Opin Psychiatry,* 18**,** 189-93.
Petersen, S., Mavoa, H., Swinburn, B., Waqa, G., Goundar, R. & Moodie, M. 2012. Health-related quality of life is low in secondary school children in fiji. *Int J Pediatr,* 2012**,** 294530.
Pühse, U. & Gerber, M. 2005. *International comparison of physical education. Concepts, problems, prospects,* Aachen, Meyer & Meyer.
Ravens-Sieberer, U., Auquier, P., Erhart, M., Gosch, A., Rajmil, L., Bruil, J., Power, M., Duer, W., Cloetta, B., Czemy, L., Mazur, J., Czimbalmos, A., Tountas, Y., Hagquist, C., Kilroe, J. & European, K. G. 2007. The KIDSCREEN-27 quality of life measure for children and adolescents: psychometric results from a cross-cultural survey in 13 European countries. *Qual Life Res,* 16**,** 1347-56.
Ravens-Sieberer, U., Erhart, M., Wille, N., Wetzel, R., Nickel, J. & Bullinger, M. 2006. Generic health-related quality-of-life assessment in children and adolescents: methodological considerations. *Pharmacoeconomics,* 24**,** 1199-220.
Ravens-Sieberer, U., Gosch, A., Abel, T., Auquier, P., Bellach, B. M., Bruil, J., Dur, W., Power, M., Rajmil, L. & European, K. G. 2001. Quality of life in children and adolescents: a European public health perspective. *Soz Praventivmed,* 46**,** 294-302.

Reed, K. E., Warburton, D. E., Macdonald, H. M., Naylor, P. J. & McKay, H. A. 2008. Action Schools! BC: a school-based physical activity intervention designed to decrease cardiovascular disease risk factors in children. *Prev Med,* 46**,** 525-31.

Ruggero, C. J., Petrie, T., Sheinbein, S., Greenleaf, C. & Martin, S. 2015. Cardiorespiratory Fitness May Help in Protecting Against Depression Among Middle School Adolescents. *J Adolesc Health,* 57**,** 60-5.

Scott, J. J., Morgan, P. J., Plotnikoff, R. C. & Lubans, D. R. 2015. Reliability and validity of a single-item physical activity measure for adolescents. *J Paediatr Child Health,* 51**,** 787-93.

Seid, M., Varni, J. W., Segall, D. & Kurtin, P. S. 2004. Health-related quality of life as a predictor of pediatric healthcare costs: A two-year prospective cohort analysis. *Health Qual Life Outcomes,* 2**,** 48-48.

Shoup, J. A., Gattshall, M., Dandamudi, P. & Estabrooks, P. 2008. Physical activity, quality of life, and weight status in overweight children. *Qual Life Res,* 17**,** 407-12.

Silva, G., Aires, L., Mota, J., Oliveira, J. & Ribeiro, J. C. 2012. Normative and criterion-related standards for shuttle run performance in youth. *Pediatr Exerc Sci,* 24**,** 157-69.

Stavrakakis, N., de Jonge, P., Ormel, J. & Oldehinkel, A. J. 2012. Bidirectional prospective associations between physical activity and depressive symptoms. The TRAILS Study. *J Adolesc Health,* 50**,** 503-8.

Strong, W. B., Malina, R. M., Blimkie, C. J., Daniels, S. R., Dishman, R. K., Gutin, B., Hergenroeder, A. C., Must, A., Nixon, P. A., Pivarnik, J. M., Rowland, T., Trost, S. & Trudeau, F. 2005. Evidence based physical activity for school-age youth. *J Pediatr,* 146**,** 732-7.

The Kidscreen Group, E. 2006. *The KIDSCREEN questionnaires: Quality of life questionnaires for children and adolescents*.

Tomson, L. M., Pangrazi, R. P., Friedman, G. & Hutchison, N. 2003. Childhood depressive symptoms, physical activity and health related fitness. *J Sport Exercise Psychol,* 25**,** 419-439.

United States Department of Health and Human Services 2008. *2008 physical activity guidelines for americans,* Washington, U.S. Government Printing Office.

Van Hout, R., Young, M., Bassett, S. & Hooft, T. 2013. Participation in sport and the perceptions of quality of life of high school learners in the Theewaterskloof Municipality , South Africa. *AJPHES,* 19**,** 612-622.

von Rueden, U., Gosch, A., Rajmil, L., Bisegger, C. & Ravens-Sieberer, U. 2006. Socioeconomic determinants of health related quality of life in childhood and adolescence: results from a European study. *J Epidemiol Community Health,* 60**,** 130-5.

Wafa, S. W., Shahril, M. R., Ahmad, A. B., Zainuddin, L. R., Ismail, K. F., Aung, M. M. & Mohd Yusoff, N. A. 2016. Association between physical activity and health-related quality of life in children: a cross-sectional study. *Health Qual Life Outcomes,* 14**,** 71.

Walter, C. M. 2011. In-school physical activity patterns of primary school learners from disadvantaged schools in South Africa. *Afr J Phys Health Educ Recreat Dance* 17**,** 780-789.

WHO. 2007. *Growth reference 5-19 years* [Online]. Available: http://www.who.int/growthref/en/ [Accessed].

WHO 2016. *WHO fact sheet: Physical activity in adolescents (15 March 2016),* Geneva, WHO.

Yap, P., Müller, I., Walter, C., Seelig, H., Gerber, M., Steinmann, P., Damons, B. P., Smith, D., Gall, S., Bänninger, D., Hager, T., Htun, N. S., Steenkamp, L., Gresse, A., Probst-Hensch, N., Utzinger, J., Du Randt, R. & Pühse, U. 2015. Disease, activity and schoolchildren's health (DASH) in Port Elizabeth, South Africa: a study protocol. *BMC Public Health,* 15**,** 1285.

Zahl, T., Steinsbekk, S. & Wichstrom, L. 2017. Physical Activity, Sedentary Behavior, and Symptoms of Major Depression in Middle Childhood. *Pediatrics,* 139**,** doi:10.1542/peds.2016-1711.

4.10 Article II Appendix

Assessment of socioeconomic status

Asset ownership:

Do you have at home…

1. … a washing machine for clothes? ☐ Yes ☐ No

2. … a fridge ☐ Yes ☐ No

3. Does your family have a car? ☐ Yes, how many: ________ ☐ No

4. Do you live in a …

Shack in informal settlement ☐
Backyard shack/room ☐
Privately built house ☐
RDP house ☐
Council house ☐
Other, specify: ☐ | | | | | | | | | | | |

5. How many bedrooms does your house have? | | |

6. Do you have a bathroom/a toilet inside your house? ☐ Yes ☐ No

7. What type of toilet does your house have?

Flush toilet ☐
Pit toilet ☐
Bucket ☐
Communal toilet ☐

8. How does your family get water?

Taps inside house ☐
Tap in the yard ☐
Water tank ☐
Communal tap/tap shared with other families ☐

9. Does your house have electricity? ☐ Yes ☐ No

Scoring:

Question 1: Yes = 1, No = 0, Question 2: Yes = 1, No = 0, Question 3: Yes = 1, No = 0, Question 4: c-f = 1, a-b = 0, Question 5: ≥ 2 = 1, 0-1 = 0, Question 6: Yes = 1, No = 0, Question 7: a = 1, b-d = 0, Question 8: a = 1, b-d = 0, Question 9: Yes = 1, No = 0
Total Index: Sum of items 1-9

Chapter 5 Article III

5.1 Effect of a 20-week physical activity intervention on selective attention and academic performance in children living in disadvantaged neighbourhoods: a cluster randomized control trial

Stefanie Gall[1*], Larissa Adams[2], Nandi Joubert[2], Sebastian Ludyga[1], Ivan Müller[1,3,4], Siphesihle Nqweniso[2], Uwe Pühse[1], Rosa du Randt[2], Harald Seelig[1], Danielle Smith[2], Peter Steinmann[3,4], Jürg Utzinger[3,4], Cheryl Walter[2], Markus Gerber[1]

[1] Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland

[2] Department of Human Movement Science, Nelson Mandela University, Port Elizabeth, South Africa

[3] University of Basel, Basel, Switzerland

[4] Swiss Tropical and Public Health Institute, Basel, Switzerland

[*]Corresponding author

E-mail: stefanie.gall@unibas.ch

This article has been published in **PLoS One** 2018

5.2 Abstract

Objectives: To evaluate the effect of a 20-week school-based physical activity intervention program on academic performance and selective attention among disadvantaged South African primary school children.

Design: Cluster randomized control trial.

Methods: The study cohort included 663 children from eight primary schools, aged 8-13 years. Data assessment took place between February 2015 and May 2016 following the implementation of a 20-week school-based physical activity program. The d2 test was employed to assess selective attention, while the averaged end-of-year school results (math, life skills, home language, and additional language) were used as an indicator of academic performance. Physical fitness was assessed using the 20-m shuttle run test (VO_2 max) and grip strength tests. We controlled for cluster effects, baseline scores in selective attention or academic performance, and potential confounders, such as children's age, gender, socioeconomic status, self-reported physical activity (as determined by a pre-tested questionnaire), body mass index, hemoglobin (as a proxy for anemia, as measured by blood sampling), and soil-transmitted helminth infections (as assessed by the Kato-Katz technique).

Results: Our multivariate analysis suggested that the physical activity intervention had a positive effect on academic performance ($p=0.032$), while no effect was found on selective attention (concentration performance; $p=0.469$; error percentage; $p=0.237$). After controlling for potential confounders, the physical activity condition contributed to the maintenance of academic performance, whereas a decrease was observed in learners in the control condition. Furthermore, physically active and fit children tend to have better concentration performance (CP) than their less fit peers (self-reported activity; $p<0.016$, grip strength; $p<0.009$, VO_2 max $p>0.021$).

Conclusion: A 20-week physical activity intervention contributes to the maintenance of academic performance among socioeconomically deprived school children in South Africa. School administrators should ensure that their school staff implements physical activity lessons, which are a compulsory component of the school by the curriculum.

Keywords: Academic performance, children, physical activity, attention, fitness, South Africa

5.3 Introduction

Physical activity is widely accepted to be an important feature in the promotion of health and well-being (Janssen and Leblanc, 2010). In view of the mounting evidence of health-related benefits of regular physical activity among children (Biddle and Asare, 2011, Owen et al., 2010, Brown et al., 2013), concerns have been raised about decreasing physical activity and fitness levels in children and adolescents (Andersen, 2011, Dollman et al., 2005). New research reveals that regular physical activity not only contributes to improved physical health (Dobbins et al., 2013), but also has a beneficial effect on children's cognitive functioning, such as executive function (Ludyga et al., 2016), attention (Tomporowski et al., 2015), and academic performance (Tomporowski et al., 2008), all of which are important conditions for gains in academic performance. Yet, physical education has been neglected in many low- and middle-income countries (LMICs), while more time is being allocated to academic subjects (Pühse and Gerber, 2005). In South Africa, some teachers and parents believe that participation in physical activity might interfere with learners' academic success (Van Deventer, 2009). Educators often teach several subjects and do not feel confident enough to systematically instruct in sports and exercise as part of a school program. Indeed, they do not feel able to offer attractive and didactically well-conducted physical education classes. Furthermore, some of them lack the motivation to be physically active. Hence, physical education is not being taught in most public schools. As a result, a considerable number of children do not engage in the recommended daily 60 min of moderate-to-vigorous intensity physical activity (Strong et al., 2005). According to Walter (2011), this might be one of the key contributors to the increasing level of physical inactivity among South African school children.

While low physical activity levels constitute an important issue from a public health perspective (Kohl et al., 2012), children growing up and living in low socioeconomic environments are faced with a multitude of challenges that may jeopardize their health and well-being (Lu et al., 2016). These challenges include insufficient hygiene, lack of clean water, and inadequate sanitation, factors that all favor helminth and intestinal protozoa infection (Speich et al., 2016). This, in turn, can cause abdominal pain, diarrhea, growth retardation, anemia, cognitive impairment, poor academic performance and reduced physical fitness (Utzinger et al., 2012, Yap et al., 2014). Of note, the effects of mass deworming on children's cognition and school performance remain ambiguous (Taylor-Robinson et al., 2015). Another potentially harmful effect of living in deprived environments is the commonly limited access to health care in the absence of universal health coverage. Consequently, increased risk of illness causes more frequent school absenteeism, and hence, reduced academic exposure (Bloom et al., 2006). Poor nutrition and repeated infection causes stunting, which in turn has been found to be associated with motor development problems and poor cognitive development resulting in low intelligence quotient (Anthony et al., 2011). Taken together, these factors can obstruct children's ability to process information, concentrate, and focus on academic work (Bloom et al., 2006).

While researchers have pointed toward the potential of physical activity and physical education to increase cognitive performance and academic performance (Chomitz et al., 2009, Coe et al., 2006, Sibley and Etnier, 2003), there is a paucity of studies on the effects of school-based physical activity intervention programs on children's schooling outcomes in disadvantaged areas from LMICs. To fill this gap, the aim of the present study was to examine the impact of a 20-week school-based physical activity intervention on selective attention and academic performance on children attending schools in disadvantaged areas in Port Elizabeth, South Africa.

5.4 Materials and methods

Ethics statement

The study was approved by the ethics committee of Northwestern and Central Switzerland (EKNZ; reference no. 2014-179, approval date: 17 June 2014), the NMU Ethics Committee (study number H14-HEA-HMS002, approval date: 4 July 2014), the Eastern Cape Department of Health (approval date: 7 November 2014), and the Eastern Cape Department of Education (approval date: 3 August 2014). The study is registered at ISRCTN registry under controlled-trials.com (unique identifier: ISRCTN68411960, registration date: 1 October 2014). Written informed consent was obtained from the parents/legal guardians of children, while children assented orally. Details regarding the information provided to eligible participants and their parents/legal guardians, as well as the inclusion and exclusion criteria can be found in the study protocol (Yap et al., 2015). All procedures were in line with ethics principles described in the 1964 Declaration and its later amendments. Participation was voluntary, and children could withdraw at any time without further obligation.

Study area, school selection, and randomization

The DASH (Disease, Activity, and Schoolchildren's Health) study was carried out in quintile three schools, located in disadvantaged communities of Port Elizabeth, South Africa. All quintile three primary schools in the Port Elizabeth district (n=103) were invited to participate in the study. South African public schools are classified into five groups, with quintile five standing for the least poor and quintile one standing for the poorest. The quintiles are determined through the national poverty table, prepared by the Treasury. Areas are being ranked on the basis of income levels, dependency ratios, and literacy rates in the area. The quintile ranking of a school determines the no-fee status of the school and also the amount of money that a school receives, with the poorest schools receiving the greatest per-learner allocation (Hall and Giese, 2009).

From the 103 quintile three schools, 25 schools expressed an interest in the form of a written response. Those 25 schools were invited to an information sharing meeting, and 15 schools were represented, whereas 10 schools declined to attend the meeting. The final eight schools were selected based on (i) large grade four classes (n >100); (ii) geographical location; (iii) representation of the various target communities (black and colored inhabitants); and (iv) commitment to support the project activities. The seven schools that were excluded had all numbers <100 in grade four. Due to financial constraints, logistics, and limited manpower, we were able to implement the physical activity intervention program only in three schools. From the final eight schools, the DASH core team therefore randomly selected three intervention and five control schools, on the basis of a computer-generated random number list. A computer generated random number list was also used to allocate the intervention and control schools to one of five intervention/control conditions (seeTable 5.1).

Table 5.1 Intervention measures at the eight primary schools in Port Elizabeth, South Africa carried out between February 2015 and May 2016

Intervention	IG	CG
Physical activity	School 1	
Physical activity + health education	School 2	
Physical activity + health education + nutrition	School 3	
[No physical activity] + health education + nutrition		School 4
[No physical activity]		Schools 5, 6, 7, and 8

Notes: IG, intervention group; CG, control group.

Participants

As shown in Figure 5.1, 1009 grade four primary school children were assessed at baseline in February 2015. Data sets with complete records in the main outcome variables concentration performance (CP), error percentage (E%), and end of the year results (EoYR) were available for 663 learners at post-intervention in May 2016, after including only children aged 8-13 years. The mid-follow-up is not included in the present paper.

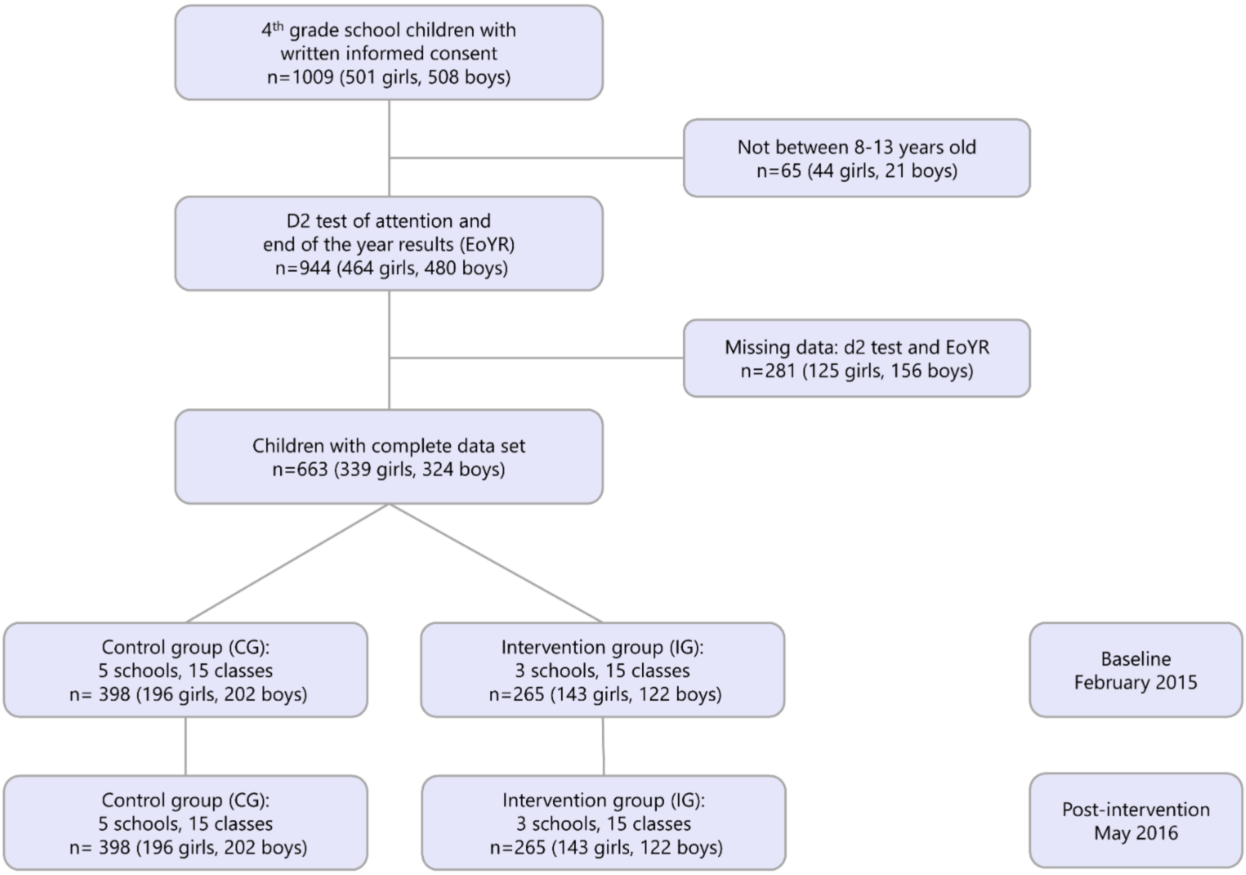


Figure 5.1 Participant flow chart

Notes: EoYR: end of the year results; average of the four subjects home language, additional language, mathematics, and life skills

Procedures

An overview of the study design is provided in Figure 5.2. Recruitment started in September 2014, and the practical intervention study took place between February 2015 and May 2016. The study length was restricted to 15 months due to financial reasons.

At the beginning of the study, project information sessions with principals, teachers, parents, and school governing bodies were held. Workshops with life orientation teachers and class teachers were organized to discuss the materials and information provided during the intervention.

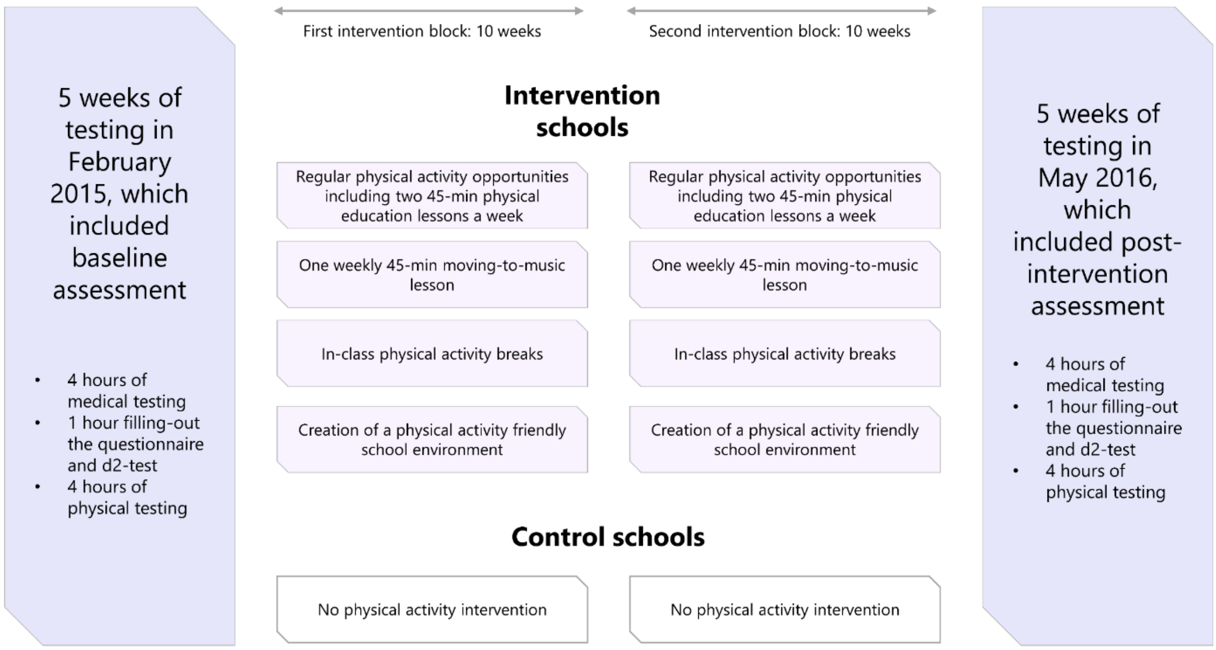


Figure 5.2 Overview of study design and the 20-week physical activity intervention, Port Elizabeth, South Africa carried out between February 2015 and May 2016

Multi-dimensional physical activity intervention

The multi-dimensional physical activity intervention started after the baseline assessment and was carried out during official school lessons. The lessons were taught in collaboration with the life orientation teachers, and moving-to-music lessons were led by students from the Nelson Mandela University (NMU). The control group followed their normal schedule, with physical education following the routine curriculum. The physical activity intervention module included four parts: (i) regular physical activity classes including two physical education lessons per week; (ii) one weekly moving-to-music class; (iii) regular in-class activity breaks incorporated into the main school curriculum; and (iv) school infrastructure adaptation to create a low cost "physical activity friendly" environment (Figure 5.2). The physical activity intervention was implemented at three schools, whereas five schools did not receive the physical activity intervention. Furthermore, in two schools, a nutrition intervention consisting of classroom-based lessons to help increase the awareness of the importance of healthy nutrition were held. At three schools, health education lessons were held to increase children's awareness for intestinal parasite infections (Table 5.1).

Selective attention

Main outcome variables were selective attention and academic performance. Children's selective attention capacity was measured with the d2 test, developed by Brickenkamp et al. (Brickenkamp and Zillmer, 1998). The d2 test determines the capacity to pay attention to one stimulus/fact, while suppressing distractor letters. The d2 attention test is a paper and pencil letter-cancellation test and was performed in groups of 20-25 children, during the first school lesson of the day in a quiet room. Detailed test procedures can be found in the test manual (Brickenkamp and Zillmer, 1998) and in a previous publication on selective attention (Gall et al., 2017). Selective attention capacity was operationalized via two indicators: (i) E% and (ii) CP. E% is calculated as percentage of errors relative to the total number of items processed and reflects a measure of accuracy (precision and thoroughness). CP represents a measure of overall concentration ability and performances and is calculated by subtracting the number of incorrectly marked characters from the number of correctly marked characters. Both E% and CP were chosen as outcome measures because they are tamper-resistant.

Academic performance

Children's academic performance was operationalized using routine EoYR. Note that EoYR are based on the average from four school subjects: (i) home language (Xhosa or Afrikaans); (ii) first additional language (English); (iii) mathematics; and (iv) life skills. Learners' achievement in each subject is graded on a 7-point scale ranging from 1 (0-29%, "not achieved") to 7 (80-100%; "outstanding achievement"), with a rating of 4 (50-59%) reflecting "adequate achievement". In order to control for potential confounders, a range of additional variables was assessed and considered in the present article.

Physical fitness tests

To control for children's cardiorespiratory fitness, the 20-m shuttle run test was applied using the test protocol by Léger et al. (1988). The fully completed laps were noted when a child was unable to follow the required pace in two consecutive intervals. The level at which the child failed to reach the cut-off line during the 20-m shuttle run test was used to calculate an estimate of maximal oxygen uptake (VO_2 max), which was then adjusted for age and gender (Léger et al., 1988).

Upper body strength was determined by the grip strength test (Europe, 1983). The Saehan hydraulic hand dynamometer (MSD Europe BVBA; Tisselt, Belgium) was used for this purpose. The trials were recorded to the nearest 1 kg and averaged. The detailed test description of the 20-m shuttle run and the grip strength test can be found in the study protocol (Yap et al., 2015).

Self-reported physical activity

To consider children's habitual physical activity levels, children were asked to self-report their physical activity levels using a single-item question from the Health-Behavior of School-Aged Children (HBSC) study (Inchley et al., 2016): "Over the past 7 days (1 week), on how many days were you physically active for a total of at least 60 min (1 hour) a day?" The answering options ranged from zero days to seven days. This question is based on the recommendation for physical activity among young people stating that children and youth aged 6-17 years should perform at least 60 min of moderate-to-vigorous intensity physical activity per day (United States Department of Health and Human Services, 2008).

Anthropometric indicators

To control for anthropometric factors, children's height and weight were assessed. Body weight was measured once to the nearest 0.1 kg (using a Micro T7E electronic platform scale, Optima Electronics; George, South Africa). The body height of each child was assessed to the nearest 0.1 cm with a Seca Stadiometer (Surgical SA; Johannesburg, South Africa). Body weight and height values were used to calculate body mass index (BMI), defined as weight (in kg)/height^2 (in m^2) and to reflect BMI-for-age (BAZ) and height-for-age (HAZ), respectively, both stratified by gender. The BAZ and HAZ were calculated using the World Health Organization (WHO) growth reference (2007). The gender-adjusted HAZ scores were used as an indicator for stunting (de Onis et al., 2007).

Hemoglobin

Hemoglobin (Hb) concentration was measured once to the nearest 0.1 g/l with the Hemocue HB 301 System (HemoCue AB; Ängelholm, Sweden) as a proxy for anemia. After swabbing the child's fingertip with alcohol, a field worker pricked the fingertip with a safety lancet and squeezed gently to obtain blood. The first drop was wiped away with the alcohol swab and the second drop was collected for testing with a micro cuvette.

Soil-transmitted helminth infections

To account for the potential influence of soil-transmitted helminths on selective attention and academic performance, stool samples were collected and analyzed. In brief, school children were instructed and informed in the course of a morning during a school day to return the distributed stool containers with a small portion of their own morning stool the following day. The diagnostic work-up of stool samples was done on the day of collection. From each stool sample duplicate 41.7 mg Kato-Katz thick smears were prepared (Katz et al., 1972). Experienced laboratory technicians independently read the slides under a microscope, counted the number of helminth eggs, and recorded them for each species separately. To obtain a proxy for infection intensity, the soil-transmitted helminth egg counts were multiplied by a factor of 24 to express the number of eggs per gram (EPG) of stool (Knopp et al., 2008).

Socioeconomic status

Children filled out a questionnaire pertaining to household-level living standards, such as infrastructure and housing characteristics (e.g., wall and roof type, number of bedrooms) and the ownership of three durable assets (e.g., refrigerator) to determine their socioeconomic status (SES) with nine questions. The binary items (1=high quality, available; 0=poor quality, not available) were summarized to build an overall index, with lower scores reflecting lower SES. Similar measures have been validated and established in previous research (Filmer and Pritchett, 2001).

Test sequence

Children were assessed class wise and the test procedure lasted for two full school days at each of the eight schools (baseline and post-intervention). In a first step, children completed the medical testing including the anthropometric indicators, followed by the grip strength test. On the second day, children completed the d2 test of attention and filled in a questionnaire for determining their SES. Then, children's cardiorespiratory fitness was assessed with the 20-m shuttle run test (Figure 5.2).

5.5 Statistical analysis

Data were double-entered and validated using EpiData version 3.1 (EpiData Association; Odense, Denmark), and merged into a single data file. Statistical analyses were performed with STATA version 13.0 (STATA; College Station, United States of America) and with SPSS version 23 (IBM Corporation; Armonk, United States of America) for Windows.

Sample size calculation is described in the study protocol (Yap et al., 2015). In brief, sample size was based on the prevalence of soil-transmitted helminth infections at baseline, taking into account clustering within schools and classes as well as loss to follow-up.

Descriptive statistics are provided as frequencies (n) and percentages (%) for categorical variables, and means (M) and 95% confidence interval (CI) for metric variables, separately for the total sample, and learners of the intervention group (IG) and control group (CG).

To determine whether a 20-week school-based physical activity intervention had an effect on selective attention (E% and CP) and academic performance (EoYR), three separate mixed linear regression models were employed with random intercepts for school classes, in order to adjust for cluster effects. This was facilitated using the *multilevel mixed effects linear regression* procedure (covariance structure=independent) in STATA version 13.0 (STATA; College Station, United States of America). In all three regression analyses, indicators of selective attention and academic performance at post-intervention were used as outcome/dependent variables. Before testing the effect of the intervention condition (IG *versus* CG), all regression analyses were controlled for baseline levels of selective attention and academic performance and potential confounders (gender, stunting, anemia, intestinal protozoa and soil-transmitted helminth infections, age, BMI, SES, self-reported physical activity, grip strength, and VO_2 max).

To interpret the findings, the unstandardized Beta coefficients and the 95% confidence intervals (CIs) are displayed. Statistical significance level was set at $p<0.05$ across all analyses. Some missing data occurred in the covariates in less than 5% of all possible data entries. Detailed missing data inspection revealed no systematic missing data pattern or significant correlations.

Hence, it was decided not to impute missing data and the mixed linear regression models were based on data of children with complete data records.

5.6 Results

Table 5.2 summarizes the descriptive statistics of selective attention and academic performance (at baseline and post-intervention) and of the potential confounders (at baseline), separately for the total sample, IG, and CG. A first inspection revealed that the descriptive measures indicate few noticeable differences between the IC and CG at baseline. The groups seemed to differ in levels of self-perceived physical activity (IG: M=4.03; 95% CI: 3.73 to 4.33] *versus* CG: M=2.97; 95% CI: 2.74 to 3.21), concentration (CP) (IG: M=51.33; 95% CI: 47.68 to 54.98 *versus* CG: M=58.34; 95% CI: 55.74 to 60.94) and academic performance (EoYR) (IG: M=3.90; 95% CI: 3.75 to 4.06 *versus* CG: M=4.93; 95% CI: 4.80 to 5.06).

Table 5.2 Descriptive statistics of all variables at baseline in February 2015 and outcome/dependent variables also at post-intervention in May 2016, Port Elizabeth, South Africa

	Baseline		
	Total	CG	IG[a]
Potential confounder	n (%)	n (%)	n (%)
Girls	339 (51)	196 (49)	143 (54)
Stunted[b]	57 (9)	26 (7)	31 (12)
Anemic[c]	106 (17)	65 (17)	41 (16)
Infected with Intestinal protozoa[d]	84 (14)	41 (11)	43 (18)
Infected with soil-transmitted helminths[e]	172 (28)	82 (22)	90 (38)
Potential confounder	M (95% CI)	M (95% CI)	M (95% CI)
Age in years	9.24 (9.19 to 9.30) n=663	9.22 (9.14 to 9.29) n=398	9.28 (9.20 to 9.36) n=265
Height in cm	132.37 (131.85 to 132.91) n=660	132.72 (132.06 to 133.38) n=398	131.85 (130.96 to 132.74) n=262
Weight in kg	30.21 (29.61 to 30.81) n=660	30.34 (29.57 to 31.10) n=398	30.01 (29.04 to 30.99) n=262
BMI in kg m^{-2}	17.06 (16.82 to 17.31) n=660	17.06 (16.75 to 17.38) n=398	17.07 (16.69 to 17.45) n=262
SES[f]	7.55 (7.40 to 7.71) n=660	7.53 (7.33 to 7.74) n=397	7.58 (7.34 to 7.82) n=263
Score of self-perceived physical activity[g]	3.41 (3.22 to 3.59) n=658	2.98 (2.75 to 3.21) n=393	4.03 (3.73 to 4.33) n=265
Grip strength in kg	11.81 (11.56 to 12.05) n=618	11.87 (11.55 to 12.20) n=371	11.70 (11.33 to 12.07) n=247
VO_2 max in ml kg^{-1} min^{-1}	49.19 (48.85 to 49.52) n=597	49.52 (49.09 to 49.95) n=356	48.69 (48.17 to 49.21) n=241

	Baseline		
	Total	CG	IG[a]
Potential confounder	n (%)	n (%)	n (%)
Selective attention and academic performance	Total (N=663)	CG (n=398)	IG[a] (n=265)
	M (95% CI)	M (95% CI)	M (95% CI)
CP in points[h]	55.54 (53.39 to 57.68)	58.34 (55.74 to 60.94)	51.33 (47.68 to 54.98)
E%[i]	15.74 (14.82 to 16.66)	14.74 (13.62 to 15.87)	17.24 (15.68 to 18.81)
EoYR[j]	4.52 (4.42 to 4.63)	4.93 (4.80 to 5.06)	3.90 (3.75 to 4.06)
	Post-intervention		
Selective attention and academic performance	Total (N=663)	CG (n=398)	IG (n=265)
	M (95% CI)	M (95% CI)	M (95% CI)
CP in points[h]	98.03 (95.30 to 100.76)	100.27 (96.85 to 103.70)	94.66 (90.18 to 99.15)
E%[i]	8.08 (7.31 to 8.84)	7.29 (6.36 to 8.22)	9.26 (7.95 to 10.57)
EoYR[j]	4.10 (4.02 to 4.18)	4.26 (4.16 to 4.36)	3.87 (3.75 to 4.00)

[a] School children from the intervention group took part in a 20-week physical activity intervention program, as described in Fig 2

[b] Stunting is defined as HAZ score ≤-2, (1=stunted, 0=normal)

[c] Anemic is defined as hemoglobin concentration in blood ≤114 g/l, (1=anemic, 0=normal)

[d] Infected with one or two intestinal parasite species (*Cryptosporidium* spp. and/or *Giardia intestinalis*) (1=infected, 0=not infected)

[e] Infected with one or two soil-transmitted helminth species (*Ascaris lumbricoides* and/or *Trichuris trichiura*) (1=infected, 0=not infected)

[f] Socioeconomic status (SES) measured by ownership and housing related questions on a scale from 0-9 points (0=lowest score, 9=highest score)

[g] Score of self-reported physical activity for the past 7 days on a scale from 0-7 (0=lowest score, 7=highest score)

[h] Concentration performance: total number of correctly cancelled minus total number incorrectly cancelled characters (d2 test of attention)

[i] Percentage of errors: total number of errors divided by the total number of characters processed (d2 test of attention)

[j] Average of the four subjects home language, additional language, mathematics, and life skills

Effect of the physical activity intervention on concentration performance

The results of the mixed linear regression models are provided in Table 5.3, after adjustment for clustering effects of school classes. In Model 1, concentration performance (CP) at post-intervention was used as outcome/dependent variable. After adjusting for confounding variables, this model shows that the physical activity intervention had no statistically significant effect on children's CP (B=2.93, 95% CI:-5.01 to 10.86, p=0.469). Model 1 shows that baseline CP was statistically significant and positively associated with children's post-intervention CP scores ($p<0.001$). Children scored 0.8 points higher at post-intervention per additional CP point at baseline. Moreover, Model 1 reveals a significant influence of some cofounding variables. At post-intervention, girls had a 7.05 point higher CP score than boys, and younger children scored 4.65 points higher per additional year of age. Furthermore, the CP increased by 1.27 per score of self-reported physical activity. Better grip strength and higher VO_2 max were independently and positively associated with higher CP at post-intervention. The mean CP score increased by 1.16 points per kg grip strength and by 0.77 points per $ml \cdot kg^{-1} \cdot min^{-1}$ VO_2 max.

Table 5.3 Effect of intervention condition on the three outcome variables at post-intervention (May 2016), after adjustment for clustering effects of school classes, controlling for baseline levels (February 2015) of selective attention and academic performance, and potential confounders, Port Elizabeth, South Africa

	Selective attention and academic performance (at post-intervention) as outcome/dependent variables								
	Model 1 Concentration performance (CP)*			Model 2 Error percentage (E%)*			Model 3 End of the year results (EoYR)*		
	B[a]	Estimate[b] (95% CI)	p-value[c]	B[a]	Estimate[a] (95% CI)	p-value[c]	B[a]	Estimate[b] (95% CI)	p-value[c]
Baseline levels of selective attention and academic performance									
Baseline CP (Model 1), Baseline E% (Model 2) and Baseline EoYR (Model 3)	0.80	0.71 to 0.88	<0.001	0.47	0.41 to 0.53	<0.001	0.47	0.41 to 0.54	<0.001
Confounders (as assessed at baseline)									
Gender[d]	7.05	1.98 to 12.11	0.006	-1.86	-3.46 to -0.26	0.023	0.35	0.19 to 0.52	<0.001
Stunted[e]	5.81	-2.23 to 13.85	0.157	0.73	-1.82 to 3.28	0.574	-0.17	-0.42 to 0.08	0.185
Anemic[f]	-1.38	-7.20 to 4.43	0.641	0.57	-1.28 to 2.42	0.544	-0.04	-0.22 to 0.14	0.681
Infected with intestinal protozoa[g]	-1.07	-7.03 to 4.89	0.726	-0.81	-2.70 to 1.08	0.402	-0.04	-0.23 to 0.14	0.641
Infected with soil-transmitted helminths[h]	-5.86	-12.84 to 1.11	0.099	0.05	-1.87 to 1.96	0.960	-0.07	-0.31 to 0.16	0.553
Age in years	-4.65	-8.04 to -1.25	0.007	1.48	0.41 to 2.54	0.007	-0.18	-0.29 to -0.07	<0.001
BMI in kg m^{-2}	0.12	-0.69 to 0.94	0.764	-0.13	-0.39 to 0.12	0.313	-0.001	-0.03 to 0.03	0.893
SES[i]	0.57	-0.57 to 1.71	0.325	-0.37	-0.73 to -0.02	0.039	-0.004	-0.04 to 0.03	0.815
Score of self-reported physical activity[j]	1.27	0.25 to 2.32	0.016	-0.34	-0.66 to 0.03	0.031	-0.01	-0.04 to 0.03	0.677
Grip strength in kg	1.16	0.29 to 2.04	0.009	-0.1	-0.37 to 0.18	0.495	0.004	-0.02 to 0.03	0.787
VO_2 max in ml kg^{-1} min^{-1}	0.77	0.12 to 1.42	0.021	-0.16	-0.37 to 0.04	0.114	0.004	-0.02 to 0.02	0.693
Intervention condition									
Intervention condition[k]	2.93	-5.01 to 10.86	0.469	-1.05	-0.69 to 2.78	0.237	0.34	0.03 to 0.65	0.032

* In the mixed linear regression models, cases were excluded listwise from the analyses if they had missing data in one or several of the covariates. Thus, all mixed linear regression analyses were based on data of children with complete data records across all variables: n=521

[a] B represents the estimate of the beta coefficient

[b] Adjusted estimates of mean change in the respective outcome from baseline to post-intervention: Unstandardized Beta coefficients, 95% confidence interval, and p-value

[c] All p-values are calculated using mixed linear regression, adjusting for clustering of school classes.

[d] Gender, (0=boys, 1=girls)

[e] Stunting is defined as HAZ score ≤-2 (1=stunted, 0=normal)

[f] Anemic is defined as hemoglobin concentration in blood ≤114 g/l, (1=anemic, 0=normal)

[g] Infected with one or two intestinal parasite species (*Cryptosporidium* spp. and/or *Giardia intestinalis*), (1=infected, 0=not infected)

[h] Infected with one or two soil-transmitted helminth species (*Ascaris lumbricoides* and/or *Trichuris trichiura*), (1=infected, 0=not infected)

[i] Socioeconomic status (SES) measured by ownership and housing related questions on a scale from 0 to 9 points (0=lowest score, 9=highest score)

[j] Score of self-reported physical activity for the past 7 days on a scale from 0 to 7 (0=lowest score, 7=highest score)

[k] School children from the intervention group took part in a 20-week physical activity intervention program, as described in Table 5.3 and Fig 2 (1=intervention group, 0=control group)

Effect of the physical activity intervention on error percentage

Model 2 of the mixed linear regression analyses (see Table 5.3) suggests that after having adjusted for clustering effects of school classes, baseline levels of E% and potential confounders, the physical activity intervention had no significant effect on E% at post-intervention (B=-1.05, 95% CI:-0.69 to 2.78, p=0.237). The mixed linear regression model further shows that baseline E% was significantly and positively associated with E% at post-intervention (p<0.001). Children's E% was 0.47% lower at post-intervention per additional percent at baseline. For every year younger a child was, children made 1.48% fewer errors. Whereas girls made 1.86% fewer errors than boys, children with higher SES and self-reported physical activity scores made fewer errors. The mean E% decreased by 0.37 percent per additional SES point and decreased by 0.34 percent per additional day of self-reported physical activity.

Effect of the physical activity intervention on EoYR academic results

Most importantly, Model 3 of the mixed linear regression analyses (see Table 5.3) shows that after accounting for clustering effects of school classes and controlling for baseline levels of academic performance as well as confounding factors, the physical activity intervention significantly predicted the EoYR at post-intervention (B=0.34, 95% CI: 0.03 to 0.65, p=0.032). However, as can be seen on a descriptive level (Table 5.2), this intervention effect was primarily based on EoYR remaining stable in the IG, whereas scores decreased in the CG. Additionally, the mixed linear regression shows that baseline EoYR were statistically significantly and positively associated with the post-intervention EoYR (p<0.001). Children's school grades were 0.47 grades higher at post-intervention per additional grade at baseline. Girls had 0.35 grades higher EoYR than boys. Finally, for every year younger a child was, children had 0.18 grades higher EoYR at post-intervention.

5.7 Discussion

The most important finding of the present study is that a 20-week physical activity intervention had a positive effect on children's EoYR. Indeed, the academic performance remained stable in children in the IG, whereas a decrease by half a grade was observed in the CG. Yet, no effects of the physical activity intervention were found on selective attention.

Our results are in line with previous studies showing maintenance and/or a smaller decline of academic performance in children participating in a physical activity intervention, compared to those experiencing no change in physical activity levels (Mullender-Wijnsma et al., 2015, Keeley and Fox, 2009). Our findings thus indicate that physical activity promotion may be a strategy to maintain academic performance with increasing demands. Other studies found enhancing effects within this domain (Donnelly et al., 2016). For example, Hollar et al. (2010) reported improved reading and mathematics skills after a 1-year physical activity intervention, in combination with a nutrition intervention in elementary school children from low-income families. Similarly, Chaya et al. (2012) found that a 3-month physical activity intervention, including yoga and physical education lessons, had a positive impact on cognitive performance (arithmetic, coding, and vocabulary) in socioeconomically disadvantaged Indian school children. Szabo-Reed et al. (2017) reported that moderate to vigorous physical activity lessons were significantly associated with more on-task time behavior.

In the present study, a possible explanation for the decreased academic performance in the CG could be the transition of language of instruction, also referred to as the "fourth-grade slump" (Sanacore and Palumbo, 2008). The baseline results refer to the final grades of grade three learners and the post-intervention results refer to the final grades from grade four. In South Africa, most schools offer mother-tongue instruction for the first three grades of school, while the transition to English as the language of instruction occurs in grade four (Taylor and von Fintel, 2016). Children undergo a shift from "learning to read" to "reading to learn", in conjunction with a change in the language of instruction. Cummins (1992) argues that only after the mastery of the first language a child will have the necessary skills to transition to a second language. Thus, our findings are in line with previous studies (Hirsch, 2003, Sanacore and Palumbo, 2008), which show that academic performance is decreasing in South African school children progressing from grade three to grade four. Hence, one interpretation of the present study's results could be that increasing in-school physical activity levels in third grade schooling holds promise to counteract a negative tendency of academic performance as transitioning to English language instruction.

Our findings further suggest that self-perceived physical activity, cardiorespiratory fitness, and grip strength were independently associated with selective attention. The first finding accorded well with previous studies showing that higher physical fitness levels are associated with better cognitive performance. For instance, our results are similar to a study conducted by London et al. (2011), in which overall physical fitness predicted academic performance. In a recent review, Donnelly et al. (2016) stated that increased cardiovascular fitness and physical activity has been associated with improved cognitive function, brain structure and function, and academic performance. Although cardiorespiratory fitness and physical activity are not identical concepts (Caspersen et al., 1985), physical activity can be considered as a proxy measure for physical fitness, particularly as fitness is a potential outcome of regular physical activity participation (Silva et al., 2013). Hence, our findings correspond with earlier studies showing that a positive relationship exists between physical activity and cognitive performance and academic performance (Keeley and Fox, 2009). However, as attention remained unchanged, this cognitive domain cannot explain why a decline in academic performance was observed in the CG only. Although children with higher physical fitness levels and higher self-reported physical activity seem to have an advantage in paying attention compared to their less fit peers, this does not necessarily guarantee the maintenance of academic performance. Evidence from longitudinal studies suggests that physical activity has an indirect effect on academic performance through a pathway of executive function (i.e., top-down control of behavior, especially in non-routine situations) (Donnelly et al., 2016). The direct effect of physical activity on this higher-order cognitive function is well documented (Diamond, 2013) and has been attributed to morphological changes (i.e., angiogenesis, neurogenesis, and synaptogenesis) in brain regions that are important for learning (Hillman et al., 2008). Another pathway that has been discussed as a potential mechanism underlying executive function benefits is the exercise-induced psychological stimulation that contributes to the improvement of self-control ability, which may impact on academic performance (Audiffren and Andre, 2015). Although speculative, it seems that changes in higher-order cognitive functions rather than attention may have contributed to the maintenance of academic performance in the IG. This suggests that physical activity, and therefore physical fitness, may positively affect important brain areas that stimulate cognition and as a result give fit children an advantage compared with their less fit peers (Mullender-Wijnsma et al., 2015).

In contrast, Spitzer et al. (2013) and Adsiz et al. (2012) found that a physical activity program has the potential to enhance selective attention. Hence, study results seem to vary considerably, most likely due to differences in the mode of assessment of selective attention, the setting in which the study took place, or the nature and intensity of the physical activity intervention. In the present study, the intervention might not have resulted in a positive effect because the intervention period was relatively short (total of 20 weeks) and because of the context in which the intervention took place (e.g., large class sizes, heterogeneous student population in terms of age and academic performance). These factors have complicated the implementation of the intervention and may have hindered the detection of subtle effects.

To our knowledge no study has examined the effect of a physical activity program on socioeconomically underprivileged children's selective attention, only acute effects have been reported (Tine and Butler, 2012). Given these findings, new research is needed to deepen the understanding of whether and how a physical activity might be associated with SES.

Our findings further show that older children have significantly lower scores for selective attention and academic performance. This may be explained by the fact that disadvantaged communities do not have the financial means to promote children with special needs or learning disabilities (Fleisch, 2008). Children suffering from attention deficit hyperactivity disorder (ADHD), fetal alcohol syndrome, reading difficulties, or neglect, might not get the required academic support and, subsequently, they might not be able to keep up with their peers. Learners with inadequate grades are retained up to three years until they become too old and automatically progress to the next grade (Fleisch, 2008, Spaull, 2013). Moreover, girls seemed to achieve better academic results compared to boys and achieve higher scores for selective attention. This is in line with a meta-analysis by Voyer and Voyer (2014), in which a consistent female advantage with regards to school grades was found for all subject content areas.

Our study has several limitations. First, academic performance was operationalized by the average end of the year grade (achieved at the end of grade three and four), which corresponds to the summary of four subjects (i.e., mathematics, home language, additional language, and life skills). While the objectivity of school grades can be questioned as a reliable outcome in empirical research (e.g., due to attributions or stereotypes of the teachers and/or different standards between classes/schools) (Malouff and Thorsteinsson, 2016), this measure has a high ecological validity because sufficiently high grades are needed for academic promotion, and the present study showed that selective attention and the academic performance scores were moderately correlated ($r > 0.30$).

Second, allocation to the intervention and control condition was done school-wise. We are aware that random allocation at class level is the 'gold' standard, but this was difficult to achieve in the present study. For instance, one component of the physical activity intervention was the creation of a "physical activity friendly" school environment. Thus, changes in the infrastructure were performed, which cannot be isolated for learners from specific classes. Nevertheless, we considered school class as random factor in our multivariate regression analyses to account for the variation in academic performance and intervention implementation between schools and classes.

Third, we used an indirect measurement of VO_2 max to assess aerobic fitness and children might not have performed to their best abilities due to lack of motivation. However, this standardized test was chosen because it is well-suited for a resource-constrained setting due to its ease of application (Léger et al., 1988).

Fourth, physical activity was assessed with a single self-reported item about children's physical activity levels. While it can be questioned whether children are able to accurately respond to this item, previous data from the present study have shown that children with higher physical activity levels indeed report higher health-related quality of life (Salvini et al., 2017), have lower blood pressure scores, and are less likely to be overweight or obese (Gerber et al., 2018).

Fifth, the physical activity intervention module was well perceived by the children and teachers alike. Yet, the level of the teacher's compliance and adherence toward a high intervention quality varied considerably. For instance, some of the teachers in the intervention schools did not have a high motivation to be physically active. Furthermore, the length of the intervention was relatively short. Hence, it may be that a longer intervention period is needed to positively impact selective attention among primary school children.

Sixth, as acknowledged previously, the present study took place in disadvantaged communities (quintile three schools). Consequently, variation in SES was limited, which might have resulted in an underestimation of SES as a predictor of selective attention and academic performance.

Seventh, on a descriptive level, baseline differences were apparent between the IG and CG in academic performance, although these schools were similar in size and student population. Such baseline differences pose a challenge with respect to data analyses, as the impact of the intervention could be interpreted as a regression to the mean. In other words, since learners of the CG had higher scores at baseline, there was also more scope for a decrease compared to peers from the IG.

These shortcomings should be addressed in future research by either using study designs that allow a class-wise group assignment or by controlling more systematically for academic performance when schools are selected to ensure that no between-school differences exist in children's EoYR prior to the beginning of the intervention program.

5.8 Conclusion

Participation in a 20-week physical activity intervention implemented in disadvantaged schools in Port Elizabeth, South Africa, was positively associated with children's academic performance. Our findings suggest that such a physical activity intervention has the potential to counteract decrease in academic performance. Hence, reintegration of physical education into the curriculum might have beneficial effects for children's academic performance. Yet, this conclusion needs to be interpreted with caution because the intervention period was relatively short, compliance was uneven, and there were differences in academic performance between the IG and CG at baseline. Future research is needed in disadvantaged schools with a physical activity intervention being carried out over an extended period of time and allocation procedures used that minimize the risk of baseline group differences.

Acknowledgments

This study has been funded by the Swiss National Science Foundation (SNSF; project no. IZLSZ3 149015) and the National Research Foundation (NRF; project no. 87397) in South Africa. The funders had no role in the study design, data collection and analysis, preparation of the manuscript, or decision to publish. We are thankful to the children and parents or guardians for their willingness to participate in this study. Special thanks are addressed to the education authorities of the schools, including the indispensable support and collaboration of the teaching staff, community volunteers, and the respective school health services. Thanks are also due to Mrs. Leyli Zondie and Mrs. Lindsey Beyleveld and her team of the Department of Medical Laboratory Sciences at the Nelson Mandela University. Furthermore, we are grateful to all the participating Master- and Honors-students for their dedicated contribution to the long and intensive data collection.

Compliance with Ethical Standards

All authors have no financial or no other relationships that could appear to have influenced the submitted work.

5.9 References

Adsiz, E., Dorak, F., Ozsaker, M. & Vurgun, N. 2012. The influence of physical activity on attention in Turkish children. *Healthmed,* 6**,** 1384-1389.

Andersen, L. B. 2011. Physical activity, fitness and health in children. *Scand J Med Sci Sports,* 21**,** 155-6.

Anthony, E. K., King, B. & Austin, M. J. 2011. Reducing child poverty by promoting child well-being: Identifying best practices in a time of great need. *Child Youth Serv Rev,* 33**,** 1999-2009.

Audiffren, M. & Andre, N. 2015. The strength model of self-control revisited: Linking acute and chronic effects of exercise on executive functions. *J Sport Health Sci,* 4**,** 30-46.

Biddle, S. J. & Asare, M. 2011. Physical activity and mental health in children and adolescents: a review of reviews. *Br J Sports Med,* 45**,** 886-95.

Bloom, B., Dey, A. N. & Freeman, G. 2006. Summary health statistics for U.S. children: National Health Interview Survey, 2005. *Vital Health Stat 10***,** 1-84.

Brickenkamp, R. & Zillmer, E. 1998. *The d2 test of attention,* Seattle, Hogrefe & Huber Publishers.

Brown, H. E., Pearson, N., Braithwaite, R. E., Brown, W. J. & Biddle, S. J. 2013. Physical activity interventions and depression in children and adolescents : a systematic review and meta-analysis. *Sports Med,* 43**,** 195-206.

Caspersen, C. J., Powell, K. E. & Christenson, G. M. 1985. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep,* 100**,** 126-31.

Chaya, M. S., Nagendra, H., Selvam, S., Kurpad, A. & Srinivasan, K. 2012. Effect of yoga on cognitive abilities in schoolchildren from a socioeconomically disadvantaged background: a randomized controlled study. *J Altern Complement Med,* 18**,** 1161-7.

Chomitz, V. R., Slining, M. M., McGowan, R. J., Mitchell, S. E., Dawson, G. F. & Hacker, K. A. 2009. Is there a relationship between physical fitness and academic achievement? Positive results from public school children in the northeastern United States. *J Sch Health,* 79**,** 30-7.

Coe, D. P., Pivarnik, J. M., Womack, C. J., Reeves, M. J. & Malina, R. M. 2006. Effect of physical education and activity levels on academic achievement in children. *Med Sci Sports Exerc,* 38**,** 1515-9.

Cummins, J. 1992. Bilingual Education and English Immersion: The Ramírez Report in Theoretical Perspective. *Bilig Res J,* 16**,** 91-104.

de Onis, M., Onyango, A. W., Borghi, E., Siyam, A., Nishida, C. & Siekmann, J. 2007. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ,* 85**,** 660-7.

Diamond, A. 2013. Executive functions. *Annu Rev Psychol,* 64**,** 135-68.

Dobbins, M., Husson, H., DeCorby, K. & LaRocca, R. L. 2013. School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6 to 18. *Cochrane Database Syst Rev***,** CD007651.

Dollman, J., Norton, K. & Norton, L. 2005. Evidence for secular trends in children's physical activity behaviour. *Br J Sports Med,* 39**,** 892-7; discussion 897.

Donnelly, J. E., Hillman, C. H., Castelli, D., Etnier, J. L., Lee, S., Tomporowski, P., Lambourne, K. & Szabo-Reed, A. N. 2016. Physical Activity, Fitness, Cognitive Function, and Academic Achievement in Children: A Systematic Review. *Med Sci Sports Exerc,* 48**,** 1197-222.

Europe, C. o. 1983. *Testing physical fitness: Eurofit experimental battery,* Strasbourg, Council of Europe.

Filmer, D. & Pritchett, L. H. 2001. Estimating wealth effects without expenditure data - or tears: an application to educational enrollments in states of India. *Demography,* 38**,** 115-132.

Fleisch, B. 2008. *Primary education in crisis: why South African schoolchildren underachieve in reading and mathematics,* Cape Town, Juta & Co.

Gall, S., Müller, I., Walter, C., Seelig, H., Steenkamp, L., Pühse, U., du Randt, R., Smith, D., Adams, L., Nqweniso, S., Yap, P., Ludyga, S., Steinmann, P., Utzinger, J. & Gerber, M. 2017. Associations between selective attention and soil-transmitted helminth infections, socioeconomic status, and physical fitness in disadvantaged children in Port Elizabeth, South Africa: An observational study. *PLoS Negl Trop Dis,* 11.

Gerber, M., Müller, I., Walter, C., du Randt, R., Adams, L., Gall, S., Joubert, N., Nqweniso, S., Smith, D., Steinmann, P., Probst-Hensch, N., Utzinger, J. & Pühse, U. 2018. Physical activity and dual disease burden among South African primary schoolchildren from disadvantaged neighbourhoods. *Prev Med,* 112**,** 104-110.

Hall, K. & Giese, S. 2009. Addressing quality through school fees and school funding. *S Afr Child Gauge***,** 35-40.

Hillman, C. H., Erickson, K. I. & Kramer, A. F. 2008. Be smart, exercise your heart: exercise effects on brain and cognition. *Nat Rev Neurosci,* 9**,** 58-65.

Hirsch, J. 2003. Reading comprehension requires knowledge - of words and the world: Scientific insights into the fourth-grade slump and the nation's stagnant comprehension scores. *American Educator,* 27**,** 10-18.

Hollar, D., Messiah, S. E., Lopez-Mitnik, G., Hollar, T. L., Almon, M. & Agatston, A. S. 2010. Effect of a two-year obesity prevention intervention on percentile changes in body mass index and academic performance in low-income elementary school children. *Am J Public Health,* 100**,** 646-53.

Inchley, J., Currie, D., Young, T., Samdal, O., Torsheim, T. & Auguston, L., et al. 2016. Growing up unequal: gender and socioeconomic differences in young people's health and well-being. Health Behaviour in School-aged Children (HBSC) study: International report from the 2013/2014 survey. *Health Policy for Children and Adolescents.*

Janssen, I. & Leblanc, A. G. 2010. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int J Behav Nutr Phys Act,* 7**,** 40.

Katz, N., Chaves, A. & Pellegrino, J. 1972. A simple device for quantitative stool thick-smear technique in Schistosomiasis mansoni. *Rev Inst Med Trop Sao Paulo,* 14**,** 397-400.

Keeley, T. J. H. & Fox, K. R. 2009. The impact of physical activity and fitness on academic achievement and cognitive performance in children. *Int Rev Sport Exerc Psychol,* 2**,** 198-214.

Knopp, S., Mgeni, A. F., Khamis, I. S., Steinmann, P., Stothard, J. R., Rollinson, D., Marti, H. & Utzinger, J. 2008. Diagnosis of soil-transmitted helminths in the era of preventive chemotherapy: effect of multiple stool sampling and use of different diagnostic techniques. *PLoS Negl Trop Dis,* 2**,** e331.

Kohl, H. W., 3rd, Craig, C. L., Lambert, E. V., Inoue, S., Alkandari, J. R., Leetongin, G., Kahlmeier, S. & Lancet Physical Activity Series Working, G. 2012. The pandemic of physical inactivity: global action for public health. *Lancet,* 380**,** 294-305.

Léger, L. A., Mercier, D., Gadoury, C. & Lambert, J. 1988. The multistage 20 meter shuttle run test for aerobic fitness. *J Sports Sci,* 6**,** 93-101.

London, R. A. & Castrechini, S. 2011. A longitudinal examination of the link between youth physical fitness and academic achievement. *J Sch Health,* 81**,** 400-8.

Lu, C. L., Black, M. M. & Richter, L. M. 2016. Risk of poor development in young children in low-income and middle-income countries: an estimation and analysis at the global, regional, and country level. *Lancet Glob Health,* 4**,** E916-E922.

Ludyga, S., Gerber, M., Brand, S., Holsboer-Trachsler, E. & Pühse, U. 2016. Acute effects of moderate aerobic exercise on specific aspects of executive function in different age and fitness groups: A meta-analysis. *Psychophysiology,* 53**,** 1611-1626.

Malouff, J. M. & Thorsteinsson, E. B. 2016. Bias in grading: A meta-analysis of experimental research findings. *Aust J Educ,* 60**,** 245-256.

Mullender-Wijnsma, M. J., Hartman, E., de Greeff, J. W., Bosker, R. J., Doolaard, S. & Visscher, C. 2015. Improving academic performance of school-age children by physical activity in the classroom: 1-year program evaluation. *J Sch Health,* 85**,** 365-71.

Owen, C. G., Nightingale, C. M., Rudnicka, A. R., Sattar, N., Cook, D. G., Ekelund, U. & Whincup, P. H. 2010. Physical activity, obesity and cardiometabolic risk factors in 9- to 10-year-old UK children of white European, South Asian and black African-Caribbean origin: the Child Heart And health Study in England (CHASE). *Diabetologia,* 53**,** 1620-30.

Pühse, U. & Gerber, M. 2005. *International comparison of physical education. Concepts, problems, prospects,* Aachen, Meyer & Meyer.

Salvini, M., Gall, S., Müller, I., Walter, C., du Randt, R., Steinmann, P., Utzinger, J., Pühse, U. & Gerber, M. 2017. Physical activity and health-related quality of life among schoolchildren from disadvantaged neighbourhoods in Port Elizabeth, South Africa. *Qual Life Res***,** 1-12.

Sanacore, J. & Palumbo, A. 2008. Understanding the Fourth-Grade Slump: Our Point of View. *The Educational Forum,* 73**,** 67-74.

Sibley, B. A. & Etnier, J. L. 2003. The relationship between physical activity and cognition in children: A meta-analysis. *Pediatr Exerc Sci,* 15**,** 243-256.

Silva, G., Andersen, L. B., Aires, L., Mota, J., Oliveira, J. & Ribeiro, J. C. 2013. Associations between sports participation, levels of moderate to vigorous physical activity and cardiorespiratory fitness in childrenand adolescents. *J Sports Sci,* 31**,** 1359-67.

Spaull, N. 2013. Poverty & privilege: primary school inequality in South Africa. *Int J Educ Dev,* 33**,** 436-447.

Speich, B., Croll, D., Furst, T., Utzinger, J. & Keiser, J. 2016. Effect of sanitation and water treatment on intestinal protozoa infection: a systematic review and meta-analysis. *Lancet Infect Dis,* 16**,** 87-99.

Spitzer, U. S. & Hollmann, W. 2013. Experimental observations of the effects of physical exercise on attention, academic and prosocial performance in school settings. *Trends Neurosci Educ,* 2**,** 1-6.

Strong, W. B., Malina, R. M., Blimkie, C. J., Daniels, S. R., Dishman, R. K., Gutin, B., Hergenroeder, A. C., Must, A., Nixon, P. A., Pivarnik, J. M., Rowland, T., Trost, S. & Trudeau, F. 2005. Evidence based physical activity for school-age youth. *J Pediatr,* 146**,** 732-7.

Szabo-Reed, A. N., Willis, E. A., Lee, J., Hillman, C. H., Washburn, R. A. & Donnelly, J. E. 2017. Impact of three years of classroom physical activity bouts on time-on-task behavior. *Med Sci Sports Exerc,* 49**,** 2343-2350.

Taylor-Robinson, D. C., Maayan, N., Soares-Weiser, K., Donegan, S. & Garner, P. 2015. Deworming drugs for soil-transmitted intestinal worms in children: effects on

nutritional indicators, haemoglobin, and school performance. *Cochrane Database Syst Rev,* 7**,** CD000371.
Taylor, S. & von Fintel, M. 2016. Estimating the impact of language of instruction in South African primary schools: A fixed effects approach. *Econ Educ Rev,* 50**,** 75-89.
Tine, M. T. & Butler, A. G. 2012. Acute aerobic exercise impacts selective attention: an exceptional boost in lower-income children. *J Educ Psychol,* 32**,** 821-834.
Tomporowski, P. D., Davis, C. L., Miller, P. H. & Naglieri, J. A. 2008. Exercise and Children's Intelligence, Cognition, and Academic Achievement. *Educ Psychol Rev,* 20**,** 111-131.
Tomporowski, P. D., McCullick, B., Pendleton, D. M. & Pesce, C. 2015. Exercise and children's cognition: The role of exercise characteristics and a place for metacognition. *J Sport Health Sci,* 4**,** 47-55.
United States Department of Health and Human Services 2008. *2008 physical activity guidelines for americans,* Washington, U.S. Government Printing Office.
Utzinger, J., Becker, S. L., Knopp, S., Blum, J., Neumayr, A. L., Keiser, J. & Hatz, C. F. 2012. Neglected tropical diseases: diagnosis, clinical management, treatment and control. *Swiss Med Wkly,* 142**,** w13727.
Van Deventer, K. J. 2009. Perspectives of teachers on the implementation of Life Orientation in Grades R–11 from selected Western Cape schools. *S Afr J Educ,* 29.
Voyer, D. & Voyer, S. D. 2014. Gender differences in scholastic achievement: a meta-analysis. *Psychol Bull,* 140**,** 1174-204.
Walter, C. M. 2011. In-school physical activity patterns of primary school learners from disadvantaged schools in South Africa. *Afr J Phys Health Educ Recreat Dance* 17**,** 780-789.
WHO. 2007. *Growth reference 5-19 years* [Online]. Available: http://www.who.int/growthref/en/ [Accessed].
Yap, P., Müller, I., Walter, C., Seelig, H., Gerber, M., Steinmann, P., Damons, B. P., Smith, D., Gall, S., Bänninger, D., Hager, T., Htun, N. S., Steenkamp, L., Gresse, A., Probst-Hensch, N., Utzinger, J., Du Randt, R. & Pühse, U. 2015. Disease, activity and schoolchildren's health (DASH) in Port Elizabeth, South Africa: a study protocol. *BMC Public Health,* 15**,** 1285.
Yap, P., Wu, F. W., Du, Z. W., Hattendorf, J., Chen, R., Jiang, J. Y., Kriemler, S., Krauth, S. J., Zhou, X. N., Utzinger, J. & Steinmann, P. 2014. Effect of deworming on physical fitness of school-aged children in Yunnan, China: a double-blind, randomized, placebo-controlled trial. *PLoS Negl Trop Dis,* 8**,** e2983.

Chapter 6 Article IV

6.1 Changes in self-reported physical activity predict health-related quality of life among South African schoolchildren: findings from the DASH intervention trial

Stefanie Gall[1*], Larissa Adams[2], Nandi Joubert[2], Sebastian Ludyga[1], Ivan Müller[1,3,4], Siphesihle Nqweniso[2], Uwe Pühse[1], Rosa du Randt[2], Harald Seelig[1], Danielle Smith[2], Peter Steinmann[3,4], Jürg Utzinger[3,4], Cheryl Walter[2], Markus Gerber[1]

[1] Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland

[2] Department of Human Movement Science, Nelson Mandela University, Port Elizabeth, South Africa

[3] University of Basel, Basel, Switzerland

[4] Swiss Tropical and Public Health Institute, Basel, Switzerland

[*]Corresponding author

E-mail: stefanie.gall@unibas.ch

This article was submitted to **Frontiers in Public Health** (August 2019)

6.2 Abstract

Introduction: Regular physical activity is associated with multiple health benefits for children. Evidence from cross-sectional studies suggests that physical activity is positively associated with health-related quality of life (HRQoL). The promotion of physical activity, and hence HRQoL, through a school-based intervention is therefore an important endeavor, particularly in disadvantaged areas of low- and middle-income countries, including South Africa.

Methods: We designed a multicomponent physical activity intervention that was implemented over a 20-week period in 2015 in eight disadvantaged primary schools of Port Elizabeth, South Africa. Overall, 758 children aged 8-13 years participated. HRQoL was measured with the 27-item KIDSCREEN questionnaire. Self-reported physical activity was assessed with a single item of the Health-Behavior of School-Aged Children test, and cardiorespiratory fitness with the 20-m shuttle run test. Post-intervention scores were predicted with mixed linear regression models, taking into consideration the clustered nature of the data.

Results: Higher baseline levels as well as increasing levels of self-reported physical activity predicted all dimensions of children's HRQoL. Baseline levels and increases in cardiorespiratory fitness predicted children's self-perceived physical wellbeing (one of the HRQoL subscales). Participation in the multicomponent physical activity intervention did not affect children's HRQoL.

Conclusion: Higher and increasing self-reported physical activity predict all assessed HRQoL dimensions, which underlines that the promotion of regular physical activity among children living in disadvantaged settings is an important public health measure. Policy makers should encourage schools to create physical activity friendly environments, while schools should implement regular physical education as proposed by the school curriculum.

Keywords: Intervention, mental health, physical activity, psychosocial wellbeing, schoolchildren, South Africa

6.3 Introduction

Physical activity is a cornerstone for people's health and wellbeing (Ortega et al., 2008). With regard to children and adolescents, previous research has shown that regular physical activity is positively associated with cardiovascular health (Ekelund et al., 2007), stronger bones (Gabel et al., 2017), better weight control (Janssen and Leblanc, 2010), lower depressive symptoms (Korczak et al., 2017), improved sleep (Lang et al., 2016), positive cognitive development and academic achievement (Esteban-Cornejo et al., 2015). Additionally, physical activity is associated with more favourable overall physical and mental wellbeing (Wu et al., 2017). There is also evidence from cross-sectional studies that children who regularly engage in physical activities report higher health-related quality of life (HRQoL) (Salvini et al., 2017, Breslin et al., 2012, Gerber et al., 2016). Although different definitions of HRQoL exist in the literature (Karimi and Brazier, 2016, Ferrans et al., 2005), in the present study, HRQoL is considered as a multidimensional construct that comprises of physical, mental, emotional, social, and behavioural aspects of wellbeing and functioning (Ravens-Sieberer et al., 2006a). Among children, low HRQoL is a predictor of poor childhood development, including lower educational attainment (Patel et al., 2007). HRQoL is therefore an important target variable in child research and for health interventions (Ravens-Sieberer et al., 2006b, Freire and Ferreira, 2016).

Several pathways have been proposed on how regular physical activity might impact HRQoL (Wu et al., 2017). These pathways include the release of neurotransmitters that improve mood (Dishman and O'Connor, 2009), the strengthening of social ties with peers and adults (Daley et al., 2006), and healthy, sufficient sleep (Lang et al., 2016). Furthermore, physical activity has the potential to promote stress resilience (Gerber et al., 2016) by decreasing the release of stress hormones when being exposed to psychosocial stress (Mücke et al., 2018). Evidence also suggests that regular physical activity has a favourable impact on brain functioning (Ludyga et al., 2018), which in turn contributes to children's psychosocial wellbeing (Lubans et al., 2016).

Against this background, the World Health Organization (WHO) recommends at least 60 min of moderate-to-vigorous intensity physical activity (MVPA) for children and young people (aged 5-17 years) (WHO, 2010). Yet, this recommendation is not met all over the world. For instance, a report comparing 38 countries from six continents found that worldwide, only four out of 10 children and youth meet this physical activity guideline (Tremblay et al., 2016). The situation is particularly critical in low- and middle-income countries (LMICs), including South Africa (Draper et al., 2018), where many children only have limited access to safe physical activity environments (McHunu and Le Roux, 2010).

Schools are considered an appropriate platform for the promotion of physical activity, since a large number of children are reached and a considerable amount of children's daily physical activity can be acquired during school hours (Meyer et al., 2013). As shown in previous research, schools can contribute to children's physical literacy through quality physical education lessons (McLennan and Thompson, 2015). It has also been shown that multi-dimensional physical activity interventions have a positive effect on children's body mass index (BMI) (Müller et al., 2019) and have the potential to positively influence children's academic achievements (Gall et al., 2018). However, equivocal results were reported in studies examining the impact of school-based physical activity interventions on HRQoL. Although many studies found that there were significant positive effects of a physical activity intervention on HRQoL (Ha et al., 2015, Casey et al., 2014, Hartmann et al., 2010), others did not detect such effects (Kriemler et al., 2010, Resaland et al., 2019, Meyer et al., 2014). In their meta-analysis, Wu et al. (Wu et al., 2017) identified 31 studies, in which researchers explored the relationship between physical activity, sedentary behaviour, and HRQoL in the general population of children and adolescents. Of these, 21 studies were cross-sectional, whereas 7 studies used a longitudinal design and 3 studies examined the effects of a school-based physical activity intervention. Importantly, none of the identified studies pertained to children from an African country. Among longitudinal studies, 6 found that higher levels of physical activity predicted higher HRQoL over time (Omorou et al., 2016, Gopinath et al., 2011, Vella et al., 2014, Gopinath et al., 2012, Wang et al., 2008, Chen et al., 2005). The only study that did not yield a significant relationship used a very long (22-year) follow-up period (Herman et al., 2010). Taken together, the school-based intervention trials provided mixed findings. Whereas a school-community program in Australia improved HRQoL among adolescent girls (Casey et al., 2014), no (or a very limited) impact of a daily physical education intervention was observed in Swiss primary schoolchildren (Hartmann et al., 2010, Kriemler et al., 2010).

The empirical evidence with regard to the prospective association between physical activity and HRQoL is growing. Nevertheless, to date, research on children from African countries is completely missing. Additionally, little is known about the potential of school-based interventions (Rafferty et al., 2016, Wu et al., 2017). This is particularly true for studies in resource-poor settings, where opportunities for physical activity inside and outside the school environment are lacking. Nevertheless, a few studies suggest that increased physical activity might be particularly beneficial for children living in disadvantaged settings. For instance, Crews et al. (Crews et al., 2004) found that aerobic exercise training had a positive impact on psychological wellbeing among Hispanic children living in low socioeconomic districts in the United States of America. To our knowledge, only two cross-sectional studies have been conducted in South Africa, investigating the relationship between schoolchildren's physical activity and HRQoL (Van Hout et al., 2013, Salvini et al., 2017). Van Hout et al. (Van Hout et al., 2013) found that those children who participated in sportive activities at least twice a week, reported better quality of life than their inactive peers. Similarly, Salvini et al. (Salvini et al., 2017) showed that schoolchildren who reported that they were active on at least 6 days a week for a minimum of 60 min per day, perceived higher HRQoL than their peers with lower physical activity levels.

In light of these findings and in view of the absence of physical education lessons in most South African schools in disadvantaged areas (Silva et al., 2018), the current paper examines whether and to what extent (i) participation in a school-based physical activity intervention vs. a control condition; (ii) baseline levels of physical activity and cardiorespiratory fitness; and (iii) changes in physical activity and cardiorespiratory fitness, predict children's HRQoL over time. Exploring the effect of physical activity on different aspects of physical, psychological, and social functioning of HRQoL among schoolchildren will help to establish an evidence-base for public health policy decision makers, and to judge whether the promotion of physical education and physically active lifestyles is worthwhile. Based on the literature reviewed above, we hypothesized that a multi-dimension physical activity intervention could have a positive effect on children's HRQoL. Given the mixed results observed in intervention studies, we further assumed that children's overall physical activity and fitness levels (as assessed at baseline), as well as positive changes in these two variables would have an even stronger impact on HRQoL.

6.4 Methods

Study design

Data presented in this paper are based on a cluster-randomized controlled trial that served to evaluate the potential impact of several school-based health promotion measures to improve the health and wellbeing of primary schoolchildren in disadvantaged settings in the Nelson Mandela Bay district, Port Elizabeth region, South Africa. In brief, trial schools were randomized based on a computer-generated number list either to one of four interventions or to a control condition. As described previously (Gall et al., 2018, Müller et al., 2019, Yap et al., 2015), schools were randomly allocated to one of the following intervention combinations: (i) physical activity alone; (ii) physical activity plus health and hygiene education; (iii) physical activity plus health and hygiene education plus nutrition education; and (iv) health and hygiene education plus nutrition education. Four schools served as control group and did not receive any intervention. Table 6.1 provides specific information regarding the intervention combinations and the socio-demographic background of the students at baseline in each of the participating schools.

The physical activity intervention component was thus carried out in three of the eight schools. The physical activity intervention lasted for 20 (school) weeks. The physical activity component contained four elements: (i) two 40 min physical education lessons per week; (ii) one weekly 40 min moving-to-music lesson; (iii) regular in-class physical activity breaks; and (iv) improving school environments to promote physical activity, including the implementation of physical play structures (jungle gyms, monkey bars, and over- and under bars) and colourful painted games. Prior to the intervention, workshops were held in which lessons and games were demonstrated and class management techniques were shared. The class teachers, supported by an experienced physical education coach, held the two physical education lessons. The lessons were pre-made and structured progressively, approximately 40 min in duration and contained four parts: (i) warm-up (5-10 min); (ii) fitness component (10-15 min); (iii) modified invasion games (10-15 min); and (iv) cool-down and stretching activities (5-10 min). The aerobic dancing-to-music lessons lasted 40 min and were conducted by student-dancers from the Nelson Mandela University after school to the entire grade (ranging from 80 to 160 learners at one time). The lessons were structured to contain a fast-paced dance to form the warm-up component, followed by an aerobic dancing-to-music sequence as the main component, and concluded with a slow-paced routine to music for the cool-down component. Baseline assessment took place between January and March 2015, whereas the post-intervention assessment was carried out between May and June 2016.

Table 6.1 Intervention measures and baseline demographics at the eight primary schools in Port Elizabeth, South Africa

Condition	**School**	**Children**	**Gender**		**Age**		**BMI**		**SES**	
			Male	Female						
		N	N	N	M	SD	M	SD	M	SD
Physical activity	1	75	38	37	9.5	1.0	18.1	4.0	8.8	0.5
Physical activity + health education	2	85	39	46	9.1	0.6	16.9	2.5	7.9	2.0
Physical activity + health education + nutrition	3	150	80	70	9.9	0.9	16.3	2.1	6.7	2.1
Health education + nutrition	4	71	38	33	9.7	1.0	18.0	3.3	7.5	1.6
Control	5	76	37	39	9.8	0.8	15.5	2.0	6.6	2.2
Control	6	97	47	50	9.0	0.8	17.2	2.7	8.7	0.9
Control	7	121	66	55	9.5	0.9	17.3	3.1	6.5	2.8
Control	8	83	40	43	9.2	0.7	17.1	3.0	8.2	1.3

Ethics statement

The study was approved by the ethics committee of Northwestern and Central Switzerland (EKNZ; reference no. 2014-179, approval date: 17 June 2014), the Nelson Mandela University (NMU) Ethics Committee (study number H14-HEA-HMS002, approval date: 4 July 2014) and the ethics review boards of the Eastern Cape Department of Education (approval date: 3 August 2014), and the Eastern Cape Department of Health (approval date: 7 November 2014). The study is registered at ISRCTN registry under controlled-trials.com (unique identifier: ISRCTN68411960, registration date: 1 October 2014). Prior to beginning the data assessment, written informed consent was obtained from the parents/legal guardians of children, while children assented orally. All procedures were in line with the ethical principles described in the Declaration of Helsinki.

Participants and procedures

Eight primary schools participated in the Disease Activity and Schoolchildren's Health (DASH) study. Schools were selected according to geographic location, representation of the target communities, and commitment shown by school principals to support the project activities. The detailed inclusion criteria can be found in the study protocol (Yap et al., 2015). Participation in the study was voluntary and children could withdraw at any time and without any further obligation.

The initial sample at baseline consisted of 1,009 children (508 girls, 501 boys, mean age at baseline=9.5 years, standard deviation (SD)=0.9 years). For the present data analyses, 190 children were excluded because they left the study between the baseline assessment and post-intervention. Moreover, 61 children were excluded due to missing baseline data in at least one of the covariates (i.e., age, gender, BMI, and socioeconomic status). Thus, the final sample for the current analyses consisted of 758 children (373 girls, 385 boys). Hereof, 448 belonged to the control group (220 girls, 228 boys, mean age at baseline=9.4 years, SD=0.9 years), whereas 310 obtained the physical activity intervention component (153 girls, 157 boys, mean age at baseline=9.6 years, SD=0.9 years). We performed a series of univariate analyses of variance (ANOVAs) (for metric study variables) and $\chi 2$-tests (for categorical variables), in order to compare those 758 children who were included in the present analyses with those who dropped out or were excluded due to missing data. Nevertheless, these analyses revealed that no significant differences ($p > 0.05$) existed between these two groups in any of the covariates, the predictor or outcome variables. Moreover, included/excluded students were similarly represented in the intervention and control condition.

Measures

The same indicators were assessed before the start, and after completion of the intervention. The data assessment was carried out class-wise during official school hours by trained research officers. SES was assessed with a 9-item self-report questionnaire about housing characteristics, ownership of durable assets (e.g., washing machine), and household-level living standards. Scores of the SES index range from 1 to 9, with higher scores being indicative of higher family SES. Evidence for the validity of similar SES scales has been reported in previous studies (Filmer and Pritchett, 2001). To assess self-perceived wellbeing, children completed the 27-item KIDSCREEN (The Kidscreen Group, 2006). Answers were given on a 5-point Likert scale ranging from ‘never’ to ‘always’. This instrument is composed of five subscales labelled physical wellbeing, psychological wellbeing, autonomy and parent relation, peers and social support, and school environment. To obtain an overall estimate of children’s HRQoL, we calculated the mean across all five KIDSCREEN dimensions. Additionally, we calculated the 10-item overall HRQoL index, as suggested in the KIDSCREEN manual (Ravens-Sieberer et al., 2007). The reliability and validity of the KIDSCREEN has been documented previously (Ravens-Sieberer et al., 2010). Following the official scoring guidelines, for each dimension, raw scores were transformed into Rasch person parameter estimates using the available IBM SPSS statistics software version 25 (IBM Corp; Armonk, NY, United State of America) syntax for each dimension. The calculated Rasch scores had a scale mean of 50 and a SD of 10 (The Kidscreen Group, 2006), with higher scores reflecting better wellbeing and HRQoL. To assess physical activity behavior, the children were asked to answer a single-item question taken from the Health-Behavior of School-Aged Children (HBSC) survey (Inchley et al., 2016): “Over the past 7 days (1 week), on how many days were you physically active for a total of at least 60 min (1 hour) a day?” Answering options ranged from 0 to 7 days. Previous studies showed that this question has acceptable validity when compared with physical activity assessed by accelerometers (Prochaska et al., 2001, Galan et al., 2013); it has previously been used in studies measuring physical activity and HRQoL (Galan et al., 2013). Finally, to assess children’s cardiorespiratory fitness, the 20-m shuttle run test was employed (Léger et al., 1988). A 20 m flat course was laid out and marked with 10-15 color coded cones. Children ran back and forth according to a sound signal on the premeasured running court and they were accompanied by a trained researcher officer. The pre-recorded sound signal started at a speed of 8.5 km/h and steadily increase by 0.5 km/h every minute. If a child was unable to cross the marked 2 m line at the moment of the sound signal for two consecutive intervals, the child was asked to stop and only the fully completed laps were noted.

All children underwent a clinical examination by a registered medical nurse to identify any health problems. Children who did not pass the health examination were excluded from the maximal exercise test. The 20-m shuttle run test has a moderate-to-high mean criterion-related validity for estimating cardiorespiratory fitness (Mayorga-Vega et al., 2015).

6.5 Statistical analysis

Data were double entered and validated using EpiData version 3.1 (EpiData Association; Odense, Denmark). Statistical analyses were performed with IBM SPSS statistics version 25 for Windows (IBM Corp.; Armonk, NY, United States of America) and STATA version 13.0 (STATA Corp.; College Station, TX, United States of America). For metric study variables, univariate ANOVAs were utilized to test differences between the intervention and control group at baseline and at post-intervention, whereas $\chi 2$ tests were employed for examining differences in categorical variables. To examine whether intervention allocation (physical activity vs. control condition), baseline levels of physical activity and cardiorespiratory fitness, and changes in physical activity and cardiorespiratory fitness from baseline to post-intervention predicted HRQoL, a series of mixed linear regression analyses were performed, with random intercepts for school classes, in order to adjust for cluster effects. These analyses were carried out with the multilevel mixed effects linear regression procedure (covariance structure = independent) in STATA. Separate analyses were carried out for the five KIDSCREEN subscales and the two overall HRQoL indices. Before testing the effect of the condition (physical activity vs. control), all regression analyses were controlled for children's age, gender, BMI, SES, and baseline KIDSCREEN scores. Change scores were calculated by subtracting baseline scores from post-intervention scores. For all regression analyses, we display the unstandardized Beta coefficients and the 95% confidence intervals (CIs). Statistical significance was set at $p < 0.05$ across all analyses. Based on a detailed missing data inspection, we found no evidence of systematic missing data pattern. Hence, we decided not to impute missing data, and to perform the regression analyses with data of children who had complete data records.

6.6 Results

Descriptive statistics

Table 6.3 provides an overview of the descriptive statistics and group differences at baseline and at post-intervention assessment, for all study variables. Our study sample consisted of 758 children from eight primary schools in Port Elizabeth. At baseline, children were aged between 8 and 12 years, 50.8% were boys.

Table 6.2 Means and standard deviations at baseline and post-intervention in wellbeing, physical activity and cardiorespiratory fitness, and differences between intervention and control group

	Control group (n=448)		*Intervention group (n=310)*		ANOVAs	
Baseline	M	SD	M	SD	F	η2
Age	9.4	0.9	9.6	0.9	7.0**	.009
BMI	17.1	3.0	16.9	2.9	0.6	.001
Socioeconomic status[a]	7.5	2.1	7.5	2.0	0.3	.000
Self-reported physical activity	3.1	2.4	4.0	2.5	29.1***	.037
Cardiorespiratory fitness	36.5	17.4	35.0	17.0	1.3	.002
Physical wellbeing (KIDSCREEN 27)	50.0	13.6	51.2	13.0	1.5	.002
Psychological wellbeing (KIDSCREEN 27)	37.3	8.3	39.5	8.8	11.6**	.015
Autonomy and parent relations (KIDSCREEN 27)	49.9	12.6	48.8	12.2	1.2	.002
Social support and peers (KIDSCREEN 27)	48.0	11.8	49.9	11.8	4.7*	.006
School environment (KIDSCREEN 27)	53.8	12.1	57.4	12.6	16.1***	.021
Overall HRQoL: Mean across dimensions (KIDSCREEN 27)	47.8	8.8	49.4	8.6	5.9**	.008
Overall HRQoL: 10-item overall index (KIDSCREEN 10)	50.1	12.8	51.9	15.2	3.0	.004
Post-intervention	M	SD	M	SD	F	η2
Age	10.6	0.9	10.9	0.9	13.3**	.012
BMI	18.1	3.6	17.8	3.6	1.9	.003
Self-reported physical activity	4.7	2.3	4.3	2.2	4.3*	.006
Cardiorespiratory fitness	35.1	18.6	34.8	21.1	0.0	.000
Physical wellbeing (KIDSCREEN 27)	46.7	9.7	46.5	9.1	0.1	.000
Psychological wellbeing (KIDSCREEN 27)	48.1	11.8	46.3	11.1	4.6*	.006
Autonomy and parent relations (KIDSCREEN 27)	46.6	10.5	46.4	9.6	0.1	.000
Social support and peers (KIDSCREEN 27)	48.0	11.2	46.6	10.4	2.9	.004
School environment (KIDSCREEN 27)	53.3	12.2	51.6	11.6	3.8	.005
Overall HRQoL: Mean across dimensions (KIDSCREEN 27)	48.6	8.2	47.5	7.2	3.4	.004

	Control group (n=448)		Intervention Group (n=310)		χ2 tests	
Overall HRQoL: 10-item overall index (KIDSCREEN 10)	47.7	11.1	46.1	9.5	3.9*	.005
Categorical variables	N	%	N	%	χ^2	ϕ
Gender					0.0	.002
Girls	220	49.1	153	49.4		
Boys	228	50.9	157	50.6		

Notes. HRQoL = Health-related quality of life. [a]Socio-economic status was only assessed at baseline.
**p*<.05. ***p*<.01. ****p*<.001.

Differences between intervention and control group at baseline and post-intervention

Table 6.3 shows the descriptive statistics separately for children assigned to the intervention and control group. Based on univariate ANOVAs, the intervention and control group significantly differed with regard to age, self-reported physical activity, and three of the KIDSCREEN subscales (psychological wellbeing, social support and peers, and school environment). The intervention group was slightly older, had higher self-reported physical activity, higher psychological wellbeing, higher scores in the domain social support and peers, school environment, and in the overall mean index compared to the control group. At post-intervention, significant group differences disappeared except for the difference in age, self-reported physical activity, psychological wellbeing, and overall HRQoL (10 item).

Prediction of HRQoL

Prediction of post-intervention scores

Table 6.4 summarizes the results of the mixed linear regression analyses, highlighting variables that acted as predictors of children's HRQoL. In Model 1, the dependent variable was the HRQoL scores at post-intervention, and analyses were computed separately for the five KIDSCREEN subscales and the two overall HRQoL indices.

With regard to the covariates, higher age was associated with lower overall HRQoL (mean across dimensions and 10-item index) and lower scores for physical wellbeing and psychological wellbeing at post-intervention. Girls reported better physical wellbeing at post-intervention, rated the school environment more positively, and reported better overall HRQoL (mean across dimensions and 10-item index). Students with higher SES reported higher scores for physical wellbeing, autonomy and parent relations, had a more positive perception of the school environment, and scored higher in the overall HRQoL (mean across dimensions). Except for psychological wellbeing, baseline scores in HRQoL significantly predicted the respective KIDSCREEN scales at post-intervention.

Condition (physical activity intervention vs. control condition) was not associated with the outcomes. Baseline levels and change of physical activity predicted all KIDSCREEN subscales (physical wellbeing, psychological wellbeing, autonomy and parent relations, social support and peers, and school environment) as well as the overall HRQoL (mean across dimensions). The positive association between the predictor and outcomes indicates that higher baseline physical activity levels predicted better HRQoL scores at post-intervention. The findings also show that increases in self-reported physical activity were associated with better HRQoL at post-intervention. Whereas this pattern was found consistently across all KIDSCREEN subscales, no significant association was observed for the overall 10-item HRQoL index. Moreover, baseline levels of, and improvements in, cardiorespiratory fitness predicted one domain, namely better physical wellbeing at post-intervention.

Table 6.3 Multiple mixed linear regression analyses to predict post-intervention scores in children's health-related quality of life

Prediction of KIDSCREEN post-intervention scores (*N*=758)																					
Model 1*	Physical wellbeing			Psychological wellbeing			Autonomy and parent relations			Social support and peers			School environment			Overall HRQoL: Mean across dimensions			Overall HRQoL: 10-item index		
	B[a]	**Estimate**[b] **(95% CI)**	**p-value**[c]	**B**[a]	**Estimate**[b] **(95% CI)**	**p-value**[c]	**B**[a]	**Estimate**[b] **(95% CI)**	**p-value**[c]	**B**[a]	**Estimate**[b] **(95% CI)**	**p-value**[c]	**B**[a]	**Estimate**[b] **(95% CI)**	**p-value**[c]	**B**[a]	**Estimate**[b] **(95% CI)**	**p-value**[c]	**B**[a]	**Estimate**[b] **(95% CI)**	**p-value**[c]
Age	-0.91	-1.68 to -0.14	0.021	-2.29	-3.24 to -1.33	0.000	-0.24	-1.06 to 0.58	0.567	-0.69	-1.58 to 0.2	0.127	-0.88	-1.85 to 0.09	0.074	-1.03	-1.64 to -0.41	0.001	-1.37	-2.21 to -0.53	0.001
Gender (1=male, 2=female)	1.98	0.48 to 3.48	0.009	1.17	-0.68 to 3.02	0.214	1.53	-0.06 to 3.13	0.059	-0.07	-1.82 to 1.67	0.933	4.66	2.76 to 6.56	0.000	1.68	0.48 to 2.88	0.006	1.78	0.16 to 3.4	0.031
BMI	0.17	-0.07 to 0.42	0.161	0.18	-0.12 to 0.48	0.250	0.21	-0.05 to 0.47	0.113	0.20	-0.08 to 0.48	0.168	0.02	-0.28 to 0.32	0.892	0.18	-0.01 to 0.37	0.070	0.18	-0.08 to 0.44	0.182
Socioeconomic status	0.38	0.05 to 0.71	0.024	0.23	-0.18 to 0.64	0.275	0.37	0.01 to 0.72	0.041	0.29	-0.09 to 0.67	0.134	0.61	0.2 to 1.02	0.004	0.40	0.14 to 0.67	0.003	0.27	-0.09 to 0.63	0.143
Baseline score of KIDSCREEN dimension	0.10	0.04 to 0.15	0.000	0.02	-0.08 to 0.12	0.697	0.17	0.1 to 0.23	0.000	0.19	0.12 to 0.25	0.000	0.15	0.08 to 0.22	0.000	0.24	0.17 to 0.31	0.000	0.21	0.15 to 0.26	0.000
Condition (1=control, 2=intervention)	-0.23	-2.6 to 2.15	0.853	-1.96	-5.04 to 1.12	0.212	-0.07	-2.73 to 2.6	0.960	-1.81	-3.95 to 0.32	0.096	-1.72	-4.24 to 0.79	0.178	-1.25	-3.28 to 0.78	0.226	-1.78	-4.67 to 1.11	0.227
Baseline physical activity	0.52	0.12 to 0.93	0.012	0.70	0.19 to 1.2	0.007	0.59	0.15 to 1.02	0.008	0.87	0.4 to 1.34	0.000	0.55	0.05 to 1.06	0.033	0.57	0.25 to 0.9	0.001	0.27	-0.18 to 0.71	0.238
Change in physical activity[d]	0.46	0.17 to 0.74	0.002	0.43	0.07 to 0.79	0.018	0.42	0.12 to 0.73	0.007	0.60	0.26 to 0.93	0.000	0.64	0.28 to 1	0.001	0.49	0.26 to 0.71	0.000	0.26	-0.05 to 0.57	0.106
Baseline cardiorespiratory fitness	0.09	0.04 to 0.15	0.000	0.04	-0.02 to 0.1	0.227	0.01	-0.04 to 0.07	0.634	-0.02	-0.07 to 0.04	0.593	0.00	-0.06 to 0.07	0.892	0.02	-0.02 to 0.06	0.255	0.03	-0.03 to 0.08	0.348
Change in cardiorespiratory fitness[d]	0.06	0.01 to 0.1	0.010	0.01	-0.04 to 0.06	0.715	-0.02	-0.07 to 0.02	0.337	-0.01	-0.06 to 0.04	0.634	-0.03	-0.08 to 0.03	0.352	0.00	-0.04 to 0.03	0.908	0.00	-0.04 to 0.05	0.874

Notes: (next page)

*In the mixed linear regression models, cases were excluded listwise from the analysis if they had missing data in one or several of the covariates. Thus. all mixed linear regression analyses were based on data of children with complete data records across all variables: N=758.

[a]B represents the estimate of the beta coefficient

[b]Adjusted estimates of mean change in the respective outcome from baseline to post-intervention: Unstandardized Beta coefficients, 95% confidence interval, and p-value

[c]All p-values are calculated using mixed linear regression, adjusting for clustering of school classes.

[d]To obtain change scores for physical activity and cardiorespiratory fitness, baseline scores were subtracted from post-intervention scores. Thus, higher change scores reflect stronger increases in physical activity and cardiorespiratory fitness.

[e]To obtain change scores for the KIDSCREEN overall index and subdimensions, baseline scores were subtracted from post-intervention scores. Thus, higher change scores reflect stronger increases in self-perceived wellbeing.

*p<.05. **p<.01. ***p<.001.

6.7 Discussion

The key findings of the present study highlight that assignment to the intervention or control condition did not affect the HRQoL among schoolchildren from the Port Elizabeth area in South Africa. Importantly, however, our analyses revealed that baseline levels and levels of self-reported physical activity positively (and consistently across all investigated dimensions) predicted children's HRQoL perceptions. Additionally, baseline levels and increases in cardiorespiratory fitness made a significant contribution to the prediction of children's self-perceived physical wellbeing.

The observation that higher self-reported physical activity levels result in higher HRQoL in our study population is important and in line with previous research. This finding might be attributed to several factors. Gopinath et al. (Gopinath et al., 2012) found that physically active adolescents reported higher HRQoL over a 5-year period and argued that participation in sports or games has a positive effect on the development of social reinforcement and social functioning. Physical activity contributes to the feeling of being socially accepted and popular, which are important concepts of self-perceived wellbeing (Breslin et al., 2012). Higher levels of physical activity might be further associated with better quality of sleep, which in turn has a positive effect on children's behavioural and emotional health (Lang et al., 2016). Studies also show that children who are physically active can better cope with stress (Gerber et al., 2016) and have an enhanced physical self-concept (Lindwall and Lindgren, 2005). Previous research has also shown that children who engage in regular physical activity report fewer depressive symptoms (Korczak et al., 2017). Omorou et al. (Omorou et al., 2016) found a cumulative and bidirectional association between physical activity and HRQoL for adolescents in France over a 2-year period. The authors concluded that physical activity and sedentary behaviour are important components in improving adolescents' wellbeing as well as preventing non-communicable diseases. Vella et al. (Vella et al., 2014) found a protective effect of sport participation on HRQoL in children aged 8-10 years. They found that the maintenance of sport participation results in elevated HRQoL. a Based on a systematic review, Lubans et al. (Lubans et al., 2016) concluded that it is still unclear what kind of neurobiological and behavioural mechanism might be at play when it comes to the effects of physical activity on HRQoL. Yet, they emphasized that participation in physical activity can improve physical self-perceptions and enhance self-esteem in young people (Ekeland et al., 2005).

Contrary to our working hypothesis, baseline levels of, and improvements in, cardiorespiratory fitness predicted only one HRQoL domain, namely physical wellbeing. This observation might be explained as follows. First, similar to our study, Morales et al. (Morales et al., 2013) observed that in comparison to other HRQoL domains, there is a particularly close relationship between cardiorespiratory fitness and physical wellbeing. This is not unexpected because low cardiorespiratory fitness is an independent marker of cardiovascular risk (Myers et al., 2015), and thus a physical health marker. Second, even though cardiorespiratory fitness is seen as a proxy for physical activity, it is depending on genetic factors, whereas physical activity is a behavioural component (Bouchard et al., 1997). Third, in a study with Swedish adults, Lindwall et al. (Lindwall et al., 2012) observed that self-reported physical activity is more closely associated with mental health outcomes than objectively assessed cardiorespiratory fitness. The authors argued that psychological processes, such as perceived control over one's health and body, might play a more important role than improved cardiovascular change. Fourth, both physical activity and HRQoL are self-reported and may therefore suffer from reporting bias and share common method variance (Byrne, 2010). Nevertheless, it is important to mention that numerous researchers found positive associations between cardiorespiratory fitness and HRQoL (Evaristo et al., 2019). For instance, Andersen et al. (Andersen et al., 2017) reported that cardiorespiratory fitness is positively associated with higher scores on all five KIDSCREEN-27 domains in a cross-sectional analysis. Hence, cardiorespiratory fitness should be seen as an important target variable for public health interventions.

With regard to the investigated covariates, our results suggest that higher age was associated with lower overall HRQoL (10-item index, mean across dimensions), lower physical wellbeing, and lower psychological wellbeing at post-intervention. This is in line with prior research (Palacio-Vieira et al., 2008) and can be explained through the physical as well as social transition from childhood to adulthood. Subjective wellbeing can be impaired through an imbalance of hormones and new physiological processes (Bisegger et al., 2005). Bisegger et al. (Bisegger et al., 2005) argued that puberty is physically more radical for girls than for boys and this can contribute to a decreased psychological wellbeing. Yet, in our study sample, girls reported better physical wellbeing at post-intervention and rated the school environment more positively than boys. The finding that girls perceive the school environment more positively could be attributed to the fact that girls see the school as a social place and a "sanctuary". Our observation that girls perceive their overall HRQoL and their physical health more positively than boys is contrary to most studies with European children. We hypothesize that underlying social concepts might be different in the South African context. One study by Chen et al. (Chen et al., 2014) found that a higher BMI is linked to lower HRQoL, while Griffiths et al. (Griffiths et al., 2010) reported that excess weight may impact HRQoL due to low self-image and low self-confidence. In our study sample, BMI was not statistically significantly associated with HRQoL. This might be due to cultural differences, since being overweight is seen more positively in the local culture, as it indicates wealth and happiness (Armstrong et al., 2014). Finally, we found that children with higher SES rated the HRQoL subscale physical wellbeing, autonomy and parent relations, school environment, and overall HRQoL (mean across dimensions) more positively than their peers with lower SES. This finding accords well with a study carried out in seven European countries, in which children with lower SES reported lower HRQoL (von Rueden et al., 2006).

Our observation that a multi-dimensional physical activity intervention had no effect on children’s HRQoL is in line with the equivocal findings reported in recent reviews. In their systematic review of school-based physical activity interventions, Rafferty et al. (Rafferty et al., 2016) evaluated 11 studies. Hereof, only 3 studies reported a positive effect on children’s wellbeing. In a recent school-based physical activity trial, Resaland et al. (Resaland et al., 2019) observed no significant effect of the intervention on HRQoL. However, it remained unclear whether the intervention indeed resulted in increased overall physical activity. In their review, Wu et al. (Wu et al., 2017) suggested that there is a dose-response relation between physical activity, sedentary behaviour, and HRQoL, indicating that there is a linear relationship between higher physical activity levels (or less time spent being sedentary) and better HRQoL.

The lack of impact of our intervention on children’s HRQoL may be due to limited exposure and intensity of our program. Our intervention lasted for 20 weeks, including two physical education and one moving-to-music lesson per week. Moreover, we observed that overall physical activity levels increased in the control group, whereas self-reported levels of physical activity remained stable in the intervention group. Hence, it is conceivable that unrelated changes in the physical activity behaviour in control schools have superimposed the effects of our intervention.

Although our study provides new insights with regard to the effect of regular physical activity on HRQoL in South African schoolchildren, our findings must be considered in light of several limitations. First, physical activity was assessed with a relatively simple single-item instrument. Of note, this item was successfully employed in large-scale studies with children and adolescents in a European context (HBSC study), in which meaningful relationships were found between physical activity and health-related outcomes (Haugland et al., 2003). Second, no objective physical activity measurements were obtained, which would have required the use of accelerometers (Scott et al., 2015). Accelerometry data have the potential to differentiate between intensities of physical activity and should be considered in future research. Nevertheless, although the precision of physical activity data might have been limited due to the simplicity of our instrument, it is noteworthy that it was self-reported physical activity that performed best as predictor of children's HRQoL (and not cardiorespiratory fitness). Third, our impression was that the quality of the intervention implementation depended to some extent on the motivation and skills of the teachers. For future research, we therefore suggest to more systematically assess the quality of intervention implementation, and to consider this as a moderating factor. Fourth, we acknowledge that in our study there was only one school in each intervention program, and some students received physical activity alone, some students in combination with other intervention components (health and hygiene and/or nutrition), and some students not at all. While this can be seen as a limitation, we included random intercepts for school classes, in order to adjust for cluster effects. As highlighted by Geiser (Geiser, 2010), using a mixed model approach (and taking into consideration the hierarchical structure of clustered data) is important because (i) clustered samples violate some of the assumption of independence of observations which is made in traditional regression analyses, and (ii) in many studies, variables at different level (e.g., individual, class, and intervention condition) are relevant for the prediction of an outcome variable. Fifth, although the 20 m shuttle run test is a frequently used procedure to assess children's cardiorespiratory fitness, a recent meta-analysis has revealed that compared to children, the criterion-related validity of Léger's protocol was statistically higher for adults (r = 0.94, 95% CI 0.87-1.00). Yet, the protocol performed quite well in children (r = 0.78, 95% CI 0.72-0.85).

6.8 Conclusion

Higher physical activity and positive change in physical activity was prospectively associated with better HRQoL in a sample of South African children attending primary schools from disadvantaged neighbourhoods. In view of our findings, we suggest that South African policy makers might reflect on how children's overall physical activity can be increased and how schools can be supported to provide physical activity-friendly environments that promote intramural physical activity. Concerted efforts are required to implement high quality physical education in schools in disadvantaged settings in order to sustainably increase children's physical literacy and to promote physically active lifestyles.

6.9 Author Contributions

Conceptualization: Cheryl Walter, Ivan Müller, Uwe Pühse, Jürg Utzinger, Markus Gerber.

Data curation: Stefanie Gall, Harald Seelig, Markus Gerber.

Formal analysis: Stefanie Gall, Markus Gerber.

Funding acquisition: Cheryl Walter, Rosa du Randt, Ivan Müller, Uwe Pühse, Jürg Utzinger, Markus Gerber.

Methodology: Cheryl Walter, Ivan Müller, Harald Seelig, Peter Steinmann, Markus Gerber.

Project administration: Ivan Müller.

Supervision: Ivan Müller, Uwe Pühse, Harald Seelig, Markus Gerber.

Writing – original draft: Stefanie Gall, Markus Gerber.

Writing – review & editing: Cheryl Walter, Rosa du Randt, Larissa Adams, Nandi Joubert, Ivan Müller, Siphesihle Nqweniso, Uwe Pühse, Harald Seelig, Danielle Smith, Peter Steinmann, Jürg Utzinger, Markus Gerber.

6.10 Conflict of interest

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

6.11 Funding

This study has been funded by the Swiss National Science Foundation (SNSF; project no. IZLSZ3 149015) and the National Research Foundation (NRF; project no. 87397) in South Africa. The funders had no role in the study design, data collection and analysis, preparation of the manuscript, or decision to publish.

6.12 Acknowledgments

We are grateful to the children and parents/guardians for their participation in our study. Special thanks are addressed to the education authorities of the schools, including the indispensable support and collaboration of the teaching staff, community volunteers, and the respective school health services. Furthermore, we are grateful to all the participating Master- and Honours-students for their dedicated contribution to the long and intensive data collection.

6.13 Data Availability Statement

The datasets for this manuscript are not publicly available. Requests to access the datasets should be directed to the Ethics Committee of Northwestern and Central Switzerland (EKNZ), Ms. Nienke Jones (e-mail: nienke.jones@bs.ch; Tel.: +41 61 268-1354).

6.14 References

Andersen, J. R., Natvig, G. K., Aadland, E., Moe, V. F., Kolotkin, R. L., Anderssen, S. A. & Resaland, G. K. 2017. Associations between health-related quality of life, cardiorespiratory fitness, muscle strength, physical activity and waist circumference in 10-year-old children: the ASK study. *Qual Life Res,* 26**,** 3421-3428.

Armstrong, M. E. G., Lambert, M. I., Sharwood, K. A. & Lambert, E. V. 2014. Obesity and overweight in South African primary school children—the Health of the Nation Study. *JEMDSA,* 11**,** 52-63.

Bisegger, C., Cloetta, B., von Rueden, U., Abel, T., Ravens-Sieberer, U. & European Kidscreen, G. 2005. Health-related quality of life: gender differences in childhood and adolescence. *Soz Praventivmed,* 50**,** 281-91.

Bouchard, C., Malina, R. M. & Perusse, L. 1997. *Genetics of fitness and physical activity,* Champaign, Human Kinetics.

Breslin, G., Gossrau-Breen, D., McCay, N., Gilmore, G., McDonald, L. & Hanna, D. 2012. Physical activity, gender, weight status, and wellbeing in 9- to 11-year-old children: a cross sectional survey. *J Phys Act Health,* 9**,** 394-401.

Byrne, B. M. 2010. *Structural equation modeling with AMOS. Basic concepts, applications, and programming,* New York, Taylor & Francis.

Casey, M. M., Harvey, J. T., Telford, A., Eime, R. M., Mooney, A. & Payne, W. R. 2014. Effectiveness of a school-community linked program on physical activity levels and health-related quality of life for adolescent girls. *BMC Public Health,* 14**,** 649.

Chen, G., Ratcliffe, J., Olds, T., Magarey, A., Jones, M. & Leslie, E. 2014. BMI, health behaviors, and quality of life in children and adolescents: a school-based study. *Pediatrics,* 133**,** e868-74.

Chen, X., Sekine, M., Hamanishi, S., Yamagami, T. & Kagamimori, S. 2005. Associations of lifestyle factors with quality of life (QOL) in Japanese children: a 3-year follow-up of the Toyama Birth Cohort Study. *Child Care Health Dev,* 31**,** 433-9.

Crews, D. J., Lochbaum, M. R. & Landers, D. M. 2004. Aerobic physical activity effects on psychological well-being in low-income Hispanic children. *Percept Mot Skills,* 98**,** 319-24.

Daley, A. J., Copeland, R. J., Wright, N. P., Roalfe, A. & Wales, J. K. 2006. Exercise therapy as a treatment for psychopathologic conditions in obese and morbidly obese adolescents: a randomized, controlled trial. *Pediatrics,* 118**,** 2126-34.

Dishman, R. K. & O'Connor, P. J. 2009. Lessons in exercise neurobiology: the case of endorphins. *Ment Health Phys Act,* 2**,** 4-9.

Draper, C. E., Tomaz, S. A., Bassett, S. H., Burnett, C., Christie, C. J., Cozett, C., de Milander, M., Krog, S., Monyeki, A., Naidoo, N., Naidoo, R., Prioreschi, A., Walter, C., Watson, E. & Lambert, E. V. 2018. Results from South Africa's 2018 report card on physical activity for children and youth. *J Phys Act Health,* 15**,** S406-S408.

Ekeland, E., Heian, F. & Hagen, K. B. 2005. Can exercise improve self esteem in children and young people? A systematic review of randomised controlled trials. *Br J Sports Med,* 39**,** 792-8; discussion 792-8.

Ekelund, U., Anderssen, S. A., Froberg, K., Sardinha, L. B., Andersen, L. B., Brage, S. & European Youth Heart Study, G. 2007. Independent associations of physical activity and cardiorespiratory fitness with metabolic risk factors in children: the European youth heart study. *Diabetologia,* 50**,** 1832-1840.

Esteban-Cornejo, I., Tejero-Gonzalez, C. M., Sallis, J. F. & Veiga, O. L. 2015. Physical activity and cognition in adolescents: A systematic review. *J Sci Med Sport,* 18**,** 534-9.

Evaristo, S., Moreira, C., Lopes, L., Oliveira, A., Abreu, S., Agostinis-Sobrinho, C., Oliveira-Santos, J., Povoas, S., Santos, R. & Mota, J. 2019. Muscular fitness and cardiorespiratory fitness are associated with health-related quality of life: Results from labmed physical activity study. *J Exerc Sci Fit,* 17**,** 55-61.

Ferrans, C. E., Zerwic, J. J., Wilbur, J. E. & Larson, J. L. 2005. Conceptual model of health-related quality of life. *J Nurs Scholarsh,* 37**,** 336-42.

Filmer, D. & Pritchett, L. H. 2001. Estimating wealth effects without expenditure data - or tears: an application to educational enrollments in states of India. *Demography,* 38**,** 115-132.

Freire, T. & Ferreira, G. 2016. Health-related quality of life of adolescents: relations with positive and negative psychological dimensions. *International Journal of Adolescence and Youth,* 23**,** 11-24.

Gabel, L., Macdonald, H. M., Nettlefold, L. & McKay, H. A. 2017. Physical activity, sedentary time, and bone strength from childhood to early adulthood: a mixed longitudinal HR-pQCT study. *J Bone Miner Res,* 32**,** 1525-1536.

Galan, I., Boix, R., Medrano, M. J., Ramos, P., Rivera, F., Pastor-Barriuso, R. & Moreno, C. 2013. Physical activity and self-reported health status among adolescents: a cross-sectional population-based study. *BMJ Open,* 3**,** e002644.

Gall, S., Adams, L., Joubert, N., Ludyga, S., Müller, I., Nqweniso, S., Pühse, U., du Randt, R., Seelig, H., Smith, D., Steinmann, P., Utzinger, J., Walter, C. & Gerber, M. 2018. Effect of a 20-week physical activity intervention on selective attention and academic performance in children living in disadvantaged neighborhoods: A cluster randomized control trial. *PLoS One,* 13**,** e0206908.

Geiser, C. 2010. *Data analysis with MPlus,* New York, Guilford Publications.

Gerber, M., Endes, K., Brand, S., Herrmann, C., Colledge, F., Donath, L., Faude, O., Hanssen, H., Pühse, U. & Zahner, L. 2016. In 6- to 8-year-old children, cardiorespiratory fitness moderates the relationship between severity of life events and health-related quality of life. *Qual Life Res*.

Gopinath, B., Baur, L. A., Wang, J. J., Hardy, L. L., Teber, E., Kifley, A., Wong, T. Y. & Mitchell, P. 2011. Influence of physical activity and screen time on the retinal microvasculature in young children. *Arterioscler Thromb Vasc Biol,* 31**,** 1233-9.

Gopinath, B., Hardy, L. L., Baur, L. A., Burlutsky, G. & Mitchell, P. 2012. Physical activity and sedentary behaviors and health-related quality of life in adolescents. *Pediatrics,* 130**,** e167-74.

Griffiths, L. J., Parsons, T. J. & Hill, A. J. 2010. Self-esteem and quality of life in obese children and adolescents: a systematic review. *Int J Pediatr Obes,* 5**,** 282-304.

Ha, A. S., Burnett, A., Sum, R., Medic, N. & Ng, J. Y. 2015. Outcomes of the rope skipping 'STAR' programme for schoolchildren. *J Hum Kinet,* 45**,** 233-40.

Hartmann, T., Zahner, L., Pühse, U., Puder, J. J. & Kriemler, S. 2010. Effects of a school-based physical activity program on physical and psychosocial quality of life in elementary school children: a cluster-randomized trial. *Pediatr Exerc Sci,* 22**,** 511-22.

Haugland, S., Wold, B. & Torsheim, T. 2003. Relieving the pressure? The role of physical activity in the relationship between school-related stress and adolescent health complaints. *Research Quarterly for Exercise and Sport,* 74**,** 127-135.

Herman, K. M., Hopman, W. M. & Craig, C. L. 2010. Are youth BMI and physical activity associated with better or worse than expected health-related quality of life in adulthood? The Physical Activity Longitudinal Study. *Qual Life Res,* 19**,** 339-49.
Inchley, J., Currie, D., Young, T., Samdal, O., Torsheim, T. & Auguston, L., et al. 2016. Growing up unequal: gender and socioeconomic differences in young people's health and well-being. Health Behaviour in School-aged Children (HBSC) study: International report from the 2013/2014 survey. *Health Policy for Children and Adolescents.*
Janssen, I. & Leblanc, A. G. 2010. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int J Behav Nutr Phys Act,* 7**,** 40.
Karimi, M. & Brazier, J. 2016. Health, health-related quality of life, and quality of life: what is the difference? *Pharmacoeconomics,* 34**,** 645-9.
Korczak, D. J., Madigan, S. & Colasanto, M. 2017. Children's physical activity and depression: a meta-analysis. *Pediatrics,* 139.
Kriemler, S., Zahner, L., Schindler, C., Meyer, U., Hartmann, T., Hebestreit, H., Brunner-La Rocca, H. P., van Mechelen, W. & Puder, J. J. 2010. Effect of school based physical activity programme (KISS) on fitness and adiposity in primary schoolchildren: cluster randomised controlled trial. *BMJ,* 340**,** c785.
Lang, C., Kalak, N., Brand, S., Holsboer-Trachsler, E., Pühse, U. & Gerber, M. 2016. The relationship between physical activity and sleep from mid adolescence to early adulthood. A systematic review of methodological approaches and meta-analysis. *Sleep Med Rev,* 28**,** 32-45.
Léger, L. A., Mercier, D., Gadoury, C. & Lambert, J. 1988. The multistage 20 meter shuttle run test for aerobic fitness. *J Sports Sci,* 6**,** 93-101.
Lindwall, M. & Lindgren, E. C. 2005. The effects of a 6-month exercise intervention programme on physical self-perceptions and social physique anxiety in non-physically active adolescent Swedish girls. *Psychol Sport Exerc,* 6**,** 643-658.
Lindwall, M., Ljung, T., Hadzibajramovic, E. & Jonsdottir, I. 2012. Self-reported physical activity and aerobic fitness are differently related to mental health. *Ment Health Phys Act,* 5**,** 28-34.
Lubans, D., Richards, J., Hillman, C., Faulkner, G., Beauchamp, M., Nilsson, M., Kelly, P., Smith, J., Raine, L. & Biddle, S. 2016. Physical activity for cognitive and mental health in youth: a systematic review of mechanisms. *Pediatrics,* 138**,** e20161642.
Ludyga, S., Gerber, M., Herrmann, C., Brand, S. & Pühse, U. 2018. Chronic effects of exercise implemented during school-break time on neurophysiological indices of inhibitory control in adolescents. *Trends Neurosci Educ,* 10**,** 1-7.
Mayorga-Vega, D., Aguilar-Soto, P. & Viciana, J. 2015. Criterion-related validity of the 20-m shuttle run test for estimating cardiorespiratory fitness: a meta-analysis. *J Sports Sci Med,* 14**,** 536-47.
McHunu, S. & Le Roux, K. 2010. Non-participation in sport by black learners with special reference to gender, grades, family income and home environment. *S Afr J Res Sport Phys Educ Rec,* 32**,** 85-98.
McLennan, N. & Thompson, J. 2015. *Quality Physical Education (QPE). Guidelines for policy-makers,* Paris, France, UNESCO publishing.
Meyer, U., Roth, R., Zahner, L., Gerber, M., Puder, J. J., Hebestreit, H. & Kriemler, S. 2013. Contribution of physical education to overall physical activity. *Scand J Med Sci Sports,* 23**,** 600-6.
Meyer, U., Schindler, C., Zahner, L., Ernst, D., Hebestreit, H., van Mechelen, W., Brunner-La Rocca, H. P., Probst-Hensch, N., Puder, J. J. & Kriemler, S. 2014. Long-term effect of a

school-based physical activity program (KISS) on fitness and adiposity in children: a cluster-randomized controlled trial. *PLoS One,* 9**,** e87929.
Morales, P. F., Sanchez-Lopez, M., Moya-Martinez, P., Garcia-Prieto, J. C., Martinez-Andres, M., Garcia, N. L. & Martinez-Vizcaino, V. 2013. Health-related quality of life, obesity, and fitness in schoolchildren: the Cuenca study. *Qual Life Res,* 22**,** 1515-23.
Mücke, M., Ludyga, S., Colledge, F. & Gerber, M. 2018. Influence of regular physical activity and fitness on stress reactivity as measured with the trier social stress test protocol: a systematic review. *Sports Med,* 48**,** 2607-2622.
Müller, I., Schindler, C., Adams, L., Endes, K., Gall, S., Gerber, M., Htun, N. S. N., Nqweniso, S., Joubert, N., Probst-Hensch, N., du Randt, R., Seelig, H., Smith, D., Steinmann, P., Utzinger, J., Yap, P., Walter, C. & Pühse, U. 2019. Effect of a multidimensional physical activity intervention on body mass index, skinfolds and fitness in South African children: results from a cluster-randomised controlled trial. *Int J Environ Res Public Health,* 16.
Myers, J., McAuley, P., Lavie, C. J., Despres, J. P., Arena, R. & Kokkinos, P. 2015. Physical activity and cardiorespiratory fitness as major markers of cardiovascular risk: their independent and interwoven importance to health status. *Prog Cardiovasc Dis,* 57**,** 306-14.
Omorou, A. Y., Langlois, J., Lecomte, E., Briancon, S. & Vuillemin, A. 2016. Cumulative and bidirectional association of physical activity and sedentary behaviour with health-related quality of life in adolescents. *Qual Life Res,* 25**,** 1169-78.
Ortega, F. B., Ruiz, J. R., Castillo, M. J. & Sjostrom, M. 2008. Physical fitness in childhood and adolescence: a powerful marker of health. *Int J Obes (Lond),* 32**,** 1-11.
Palacio-Vieira, J. A., Villalonga-Olives, E., Valderas, J. M., Espallargues, M., Herdman, M., Berra, S., Alonso, J. & Rajmil, L. 2008. Changes in health-related quality of life (HRQoL) in a population-based sample of children and adolescents after 3 years of follow-up. *Qual Life Res,* 17**,** 1207-15.
Patel, V., Flisher, A. J., Hetrick, S. & McGorry, P. 2007. Mental health of young people: a global public-health challenge. *Lancet,* 369**,** 1302-1313.
Prochaska, J. J., Sallis, J. F. & Long, B. 2001. A physical activity screening measure for use with adolescents in primary care. *Arch Pediatr Adolesc Med,* 155**,** 554-559.
Rafferty, R., Breslin, G., Brennan, D. & Hassan, D. 2016. A systematic review of school-based physical activity interventions on children's wellbeing. *Int Rev Sport Exerc Psychol,* 9**,** 215-230.
Ravens-Sieberer, U., Auquier, P., Erhart, M., Gosch, A., Rajmil, L., Bruil, J., Power, M., Duer, W., Cloetta, B., Czemy, L., Mazur, J., Czimbalmos, A., Tountas, Y., Hagquist, C., Kilroe, J. & European, K. G. 2007. The KIDSCREEN-27 quality of life measure for children and adolescents: psychometric results from a cross-cultural survey in 13 European countries. *Qual Life Res,* 16**,** 1347-56.
Ravens-Sieberer, U., Erhart, M., Rajmil, L., Herdman, M., Auquier, P., Bruil, J., Power, M., Duer, W., Abel, T., Czemy, L., Mazur, J., Czimbalmos, A., Tountas, Y., Hagquist, C., Kilroe, J. & European, K. G. 2010. Reliability, construct and criterion validity of the KIDSCREEN-10 score: a short measure for children and adolescents' well-being and health-related quality of life. *Qual Life Res,* 19**,** 1487-500.
Ravens-Sieberer, U., Erhart, M., Wille, N., Wetzel, R., Nickel, J. & Bullinger, M. 2006a. Generic health-related quality-of-life assessment in children and adolescents: methodological considerations. *Pharmacoeconomics,* 24**,** 1199-220.

Ravens-Sieberer, U., Gosch, A., Erhart, M., von Rueden, U., Nickel, J., Kurth, B. M., Duer, W., Fuerth, K. & Waters, E. 2006b. *The KIDSCREEN questionnaires. Quality of life questionnaires for children and adolescents. Handbook.,* Lengerich, Pabst Science Publishers.

Resaland, G. K., Aadland, E., Moe, V. F., Kolotkin, R. L., Anderssen, S. A. & Andersen, J. R. 2019. Effects of a physical activity intervention on schoolchildren's health-related quality of life: The active smarter kids (ASK) cluster-randomized controlled trial. *Prev Med Rep,* 13**,** 1-4.

Salvini, M., Gall, S., Müller, I., Walter, C., du Randt, R., Steinmann, P., Utzinger, J., Pühse, U. & Gerber, M. 2017. Physical activity and health-related quality of life among schoolchildren from disadvantaged neighbourhoods in Port Elizabeth, South Africa. *Qual Life Res*, 1-12.

Scott, J. J., Morgan, P. J., Plotnikoff, R. C. & Lubans, D. R. 2015. Reliability and validity of a single-item physical activity measure for adolescents. *J Paediatr Child Health,* 51**,** 787-93.

Silva, D. A. S., Chaput, J. P., Katzmarzyk, P. T., Fogelholm, M., Hu, G., Maher, C., Olds, T., Onywera, V., Sarmiento, O. L., Standage, M., Tudor-Locke, C. & Tremblay, M. S. 2018. Physical education classes, physical activity, and sedentary behavior in children. *Med Sci Sports Exerc,* 50**,** 995-1004.

The Kidscreen Group, E. 2006. *The KIDSCREEN questionnaires: Quality of life questionnaires for children and adolescents*.

Tremblay, M. S., Barnes, J. D., Gonzalez, S. A., Katzmarzyk, P. T., Onywera, V. O., Reilly, J. J., Tomkinson, G. R. & Global Matrix 2.0 Research, T. 2016. Global Matrix 2.0: Report Card Grades on the Physical Activity of Children and Youth Comparing 38 Countries. *J Phys Act Health,* 13**,** S343-S366.

Van Hout, R., Young, M., Bassett, S. & Hooft, T. 2013. Participation in sport and the perceptions of quality of life of high school learners in the Theewaterskloof Municipality , South Africa. *AJPHES,* 19**,** 612-622.

Vella, S. A., Cliff, D. P., Magee, C. A. & Okely, A. D. 2014. Sports participation and parent-reported health-related quality of life in children: longitudinal associations. *J Pediatr,* 164**,** 1469-74.

von Rueden, U., Gosch, A., Rajmil, L., Bisegger, C. & Ravens-Sieberer, U. 2006. Socioeconomic determinants of health related quality of life in childhood and adolescence: results from a European study. *J Epidemiol Community Health,* 60**,** 130-5.

Wang, H., Sekine, M., Chen, X., Yamagami, T. & Kagamimori, S. 2008. Lifestyle at 3 years of age and quality of life (QOL) in first-year junior high school students in Japan: results of the Toyama Birth Cohort Study. *Qual Life Res,* 17**,** 257-65.

WHO 2010. Global recommendations on physical activity for health. Geneva, Switzerland.

Wu, X. Y., Han, L. H., Zhang, J. H., Luo, S., Hu, J. W. & Sun, K. 2017. The influence of physical activity, sedentary behavior on health-related quality of life among the general population of children and adolescents: A systematic review. *PLoS One,* 12**,** e0187668.

Yap, P., Müller, I., Walter, C., Seelig, H., Gerber, M., Steinmann, P., Damons, B. P., Smith, D., Gall, S., Bänninger, D., Hager, T., Htun, N. S., Steenkamp, L., Gresse, A., Probst-Hensch, N., Utzinger, J., Du Randt, R. & Pühse, U. 2015. Disease, activity and schoolchildren's health (DASH) in Port Elizabeth, South Africa: a study protocol. *BMC Public Health,* 15**,** 1285.

7 Synthesis and discussion

This PhD project forms part of a larger study entitled: Disease, Activity and Schoolchildren's Health, or DASH for short, which was conducted between 2015 and 2016. The DASH study was a joint research project involving three institutions, namely: the Department of Human Movement Science at the Nelson Mandela University in Port Elizabeth, South Africa; the Swiss Tropical and Public Health Institute, an associate institute of the University of Basel; and the Department of Sport, Exercise and Health, from the University of Basel, in Switzerland. The DASH study investigated health markers, and the effect of a multi-component school-based health intervention, on approximately 1000 primary schoolchildren living in impoverished areas of Port Elizabeth, South Africa. This chapter summarises and discusses the main findings regarding cognition, health-related quality of life and the effect of a multi-component school-based physical activity intervention.

7.1 Synthesis

Before the implementation of a school-based health intervention programme, baseline assessments of physical fitness tests, cognition tests, anthropometric measurements, blood tests, as well as stool analyses were conducted with 1009 fourth grade schoolchildren (501 girls, 508 boys) from eight primary schools. Children filled out questionnaires about their health and well-being, their physical activity and their household-level living standards. A computer-generated random number list was used to allocate the eight schools to either a control or an intervention condition. The intervention took place for 20 weeks. The physical activity intervention consisted of two Physical Education lessons per week, weekly moving-to-music classes, daily in-class physical activity breaks and physical activity homework, as well as the creation of a low-cost physical activity-friendly school environment. The physical activity intervention was designed in accordance with CAPS of the Life Skills subject for Intermediate Phase, Grade 4 to 6 (South African Department of Basic Education, 2011b). Further components of the intervention included health and nutrition education classes, which were held on a weekly basis, also designed in accordance with the CAPS curriculum. The four control schools did not receive any intervention components during the duration of the study but were provided with all the material after the final testing phase. The Physical Education classes, as well as health and nutrition education lessons were presented by the responsible Life Skills teachers, whereas the weekly moving-to-music classes were implemented by Human Movement Science students from the Nelson Mandela University. Prior to the implementation of the intervention workshops were conducted, with the teachers responsible for teaching the Life Skills subject. The workshops were presented by experienced Physical Education teachers and Human Movement Science students from the Nelson Mandela University. The theoretical background of the lessons, general class management concepts and techniques, as well as pedagogical approaches in Physical Education were shared and discussed. Furthermore, practical implementation of the lessons was demonstrated and later practiced by the teachers. At the end of the workshop, teachers were given a resource package which contained various manuals explaining physical activity lessons, including Physical Education lesson plans for grade four and five, physical activity cards and exercise posters, as well as small equipment needed for the implementation of the lessons. Outcome measures were assessed at baseline, at mid-line (six months) and after the intervention (12 months), the midline results were not used for this PhD thesis. The anthelminthic drug Albendazole (400 mg) was provided in accordance with the WHO guidelines, to both the intervention and control schools at each measuring point (WHO, 2013).

7.1.1 Aim 1: To explore cross-sectional associations and possible determinants of selective attention and academic performance

At baseline 835 children (417 girls, 418 boys) aged 8-12 years were examined for physical fitness, soil-transmitted helminth infection, stunting, food security, household socio-economic conditions and selective attention. Additionally, children’s academic achievement scores were used as a proxy for academic achievement. Selective attention and academic achievement were negatively associated with soil-transmitted helminth infections and age. Whereas higher selective attention was associated with higher cardiorespiratory fitness and muscular strength. Academic achievement was associated with higher socio-economic status and cardiorespiratory fitness but not muscular fitness, in terms of handgrip strength. Girls scored higher academic grades compared to boys. No significant associations were seen among stunting, food security or BMI.

7.1.2 Aim 2: To investigate cross-sectional associations between health-related quality of life, self-reported physical activity and cardiorespiratory fitness

A complete data set pertaining to health-related quality of life (HRQoL) was obtained from 832 children (417 girls, 415 boys). Children with higher self-reported physical activity reached higher scores across all five HRQoL dimensions, compared to their peers with lower physical activity levels. A small but significant group differences across all dimensions of HRQoL between low and high self-reported physical activity were observed. Cardiorespiratory fitness was not associated with HRQoL.

7.1.3 Aim 3: To evaluate the effect of a 20-week school-based physical activity intervention program on academic performance, selective attention and health-related quality of life

The physical activity intervention had a buffering effect on academic achievement. School grades among the intervention group remained stable compared to the control group where we observed a decrease in academic achievement. Selective attention was not associated with the physical activity intervention and HRQoL was only weakly associated with the intervention. The only significant association within the five dimensions of HRQoL, was for social support and peers, showing that children reported lower scores in this dimension after the physical activity intervention.

7.2 General discussion

The next section will first discuss findings pertaining to socio-economic status, stunting and soil-transmitted helminth infections that could not be reported in full length in the publications. The data included in the section on soil-transmitted helminth infections refers to two publications that are not part of this PhD project but seem relevant in light of the associations between cognition and soil-transmitted helminths. The second part discusses the content and the findings in connection with the multi-component physical activity intervention.

7.2.1 Socio-economic status

Higher socio-economic status was associated with higher academic achievement scores (Gall et al., 2017) and higher socio-economic status predicted fewer errors, but not concentration performance in the selective attention test (Gall et al., 2018). To date, the strength of the relations between socio-economic status, attention and academic achievement and possible moderators still remain highly unclear. Research from high income countries indicates that children who live in disadvantaged environments are at risk for school failure and that environmental stressors may interfere with regulatory processes such as working memory and attention (Bronfenbrenner, 1999, St John et al., 2019, Liu et al., 2019, Ferguson et al., 2001). In line with this Pienaar et al. (2014) report that South African learners from disadvantaged schools (quintile 1-3) attained lower academic achievement compared to their more advantaged peers (quintile 4-5). Interestingly, a study by Howard et al. (2020) found that a subsample of the most highly disadvantaged South African pre-schoolers outperformed middle- and high socio-economic status Australian pre-schoolers on two of three executive functions. These results might indicate that the negative effects of environmental stress is moderated by children's reactivity to adversity (Obradović, 2016), or in other words that certain conditions induced from living in disadvantaged neighbourhoods, require children to be vigilant, autonomous and adaptive, which in turn may support certain cognitive functions (Mittal et al., 2015). Furthermore, robust and reliable findings of the executive function, socio-economic gradients (children from higher socio-economic families perform better than their peers from lower socio-economic families) have mainly been presumed on the basis of results in high income countries. Therefore, cross-cultural studies as well as more studies in low- and middle-income countries are needed to investigate the relation, and possible mediators, between socio-economic status and cognitive processes (Howard et al., 2020).

7.2.2 Soil-transmitted helminth infections and stunting

At baseline, the stool samples of 835 children were analysed. Results showed that 31% of the children were infected with *Trichuris trichiura* and/or *Ascaris lumbricoides*, and thereof, 16% were infected with both species. No hookworm infections were found. Stunting was observed in 12% of the children (Gall et al., 2017). Stunted and infected children had lower school grades and lower scores in the selective attention test. This was expected based on existing literature, as multiple studies show that early childhood malnutrition negatively affect cognition (Alderman et al., 2006) and are negatively associated with learning and literacy/numeracy development (Miller et al., 2016, Kang et al., 2018).

Previous findings indicate that helminth infections are negatively associated with learning (Ezeamama et al., 2005), poorer general intelligence (Jardim-Botelho et al., 2008) and worse school performance (Liu et al., 2015). The mechanisms of adverse effects on cognition and mental function of infected children are not well understood (Dickson et al., 2000) but a recent meta-analysis by Pabalan et al. (2018) concludes that the non-treatment of soil-transmitted helminth infection is related to disadvantages in cognitive function and educational attainment. This is especially relevant for a highly prevalent exposure such as endemic settings, where reinfection is rapid. Also, multi-species and polyparasitic infections may cause further disadvantages for cognitive function and educational loss (Pabalan et al., 2018). However, for this study we did not measure the effect of deworming on academic achievement or selective attention. Yet, our study administered anthelmintic treatment after each measurement point, based on WHO guidelines (WHO, 2013). The mean infection intensities for *A. lumbricoides* were 9554 eggs per gram of stool (EPG) in May 2015, 4317 EPG in October 2015 and 1684 EPC in May 2016. For *T. trichiura* we measured 664 EPG, 331 EPG and 87 EPG respectively (Müller et al., 2017). Conclusively, repeated deworming shrank the risk of soil-transmitted helminthiasis.

Spatial clustering revealed that infections were most prevalent among two of the eight schools from the DASH study (Müller et al., 2016). The prevalence of *T. trichiura* and *A. lumbricoides* at school 2 was 65% and 72% respectively, and at school 1 65% and 60%, which was significantly higher than in other schools, see Figure 7.1 (Müller et al., 2016).

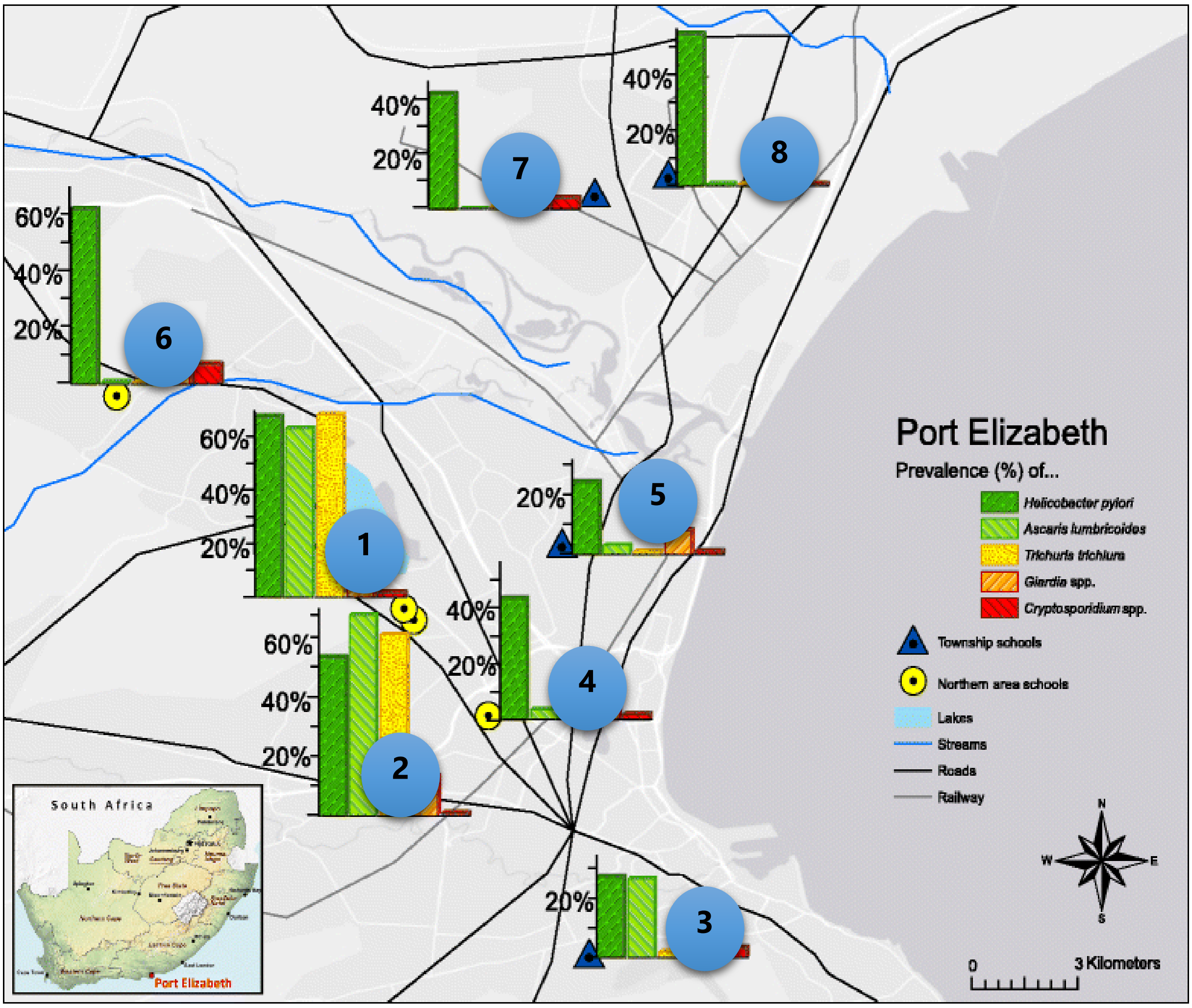


Figure 7.1 Prevalence of helminth, intestinal protozoan and Helicobacter pylori infection in eight primary schools in Port Elizabeth, South Africa, in early 2015 (adapted from Müller et al., 2016).

Dialogues with local health and education authorities revealed that preventive chemotherapy (with either Albendazole or Mebendazole) against soil-transmitted helminth infections has been neglected in recent years. According to national guidelines the following testing and treatment strategies should be adhered to: i) prevalence of less than 20% of soil-transmitted helminth infection means individual testing and treatment (this was seen in schools 4-8), ii) annual deworming if the prevalence ranges between 20% - 50% (seen in school 3), iii) biannual treatment of all learners if the prevalence exceeds 50% (seen in school 1&2) (Müller et al., 2017).

Furthermore, the high spatial heterogeneity of the data suggests that the entire local population is at risk of being infected, which in turn should be tackled with appropriate intervention strategies. Such strategies could entail the strengthening of hygiene awareness and improvement of related behaviour such as hand washing with soap along with improved water and sanitation infrastructure, collectively known as WASH interventions - in schools and households alike (Strunz et al., 2014).

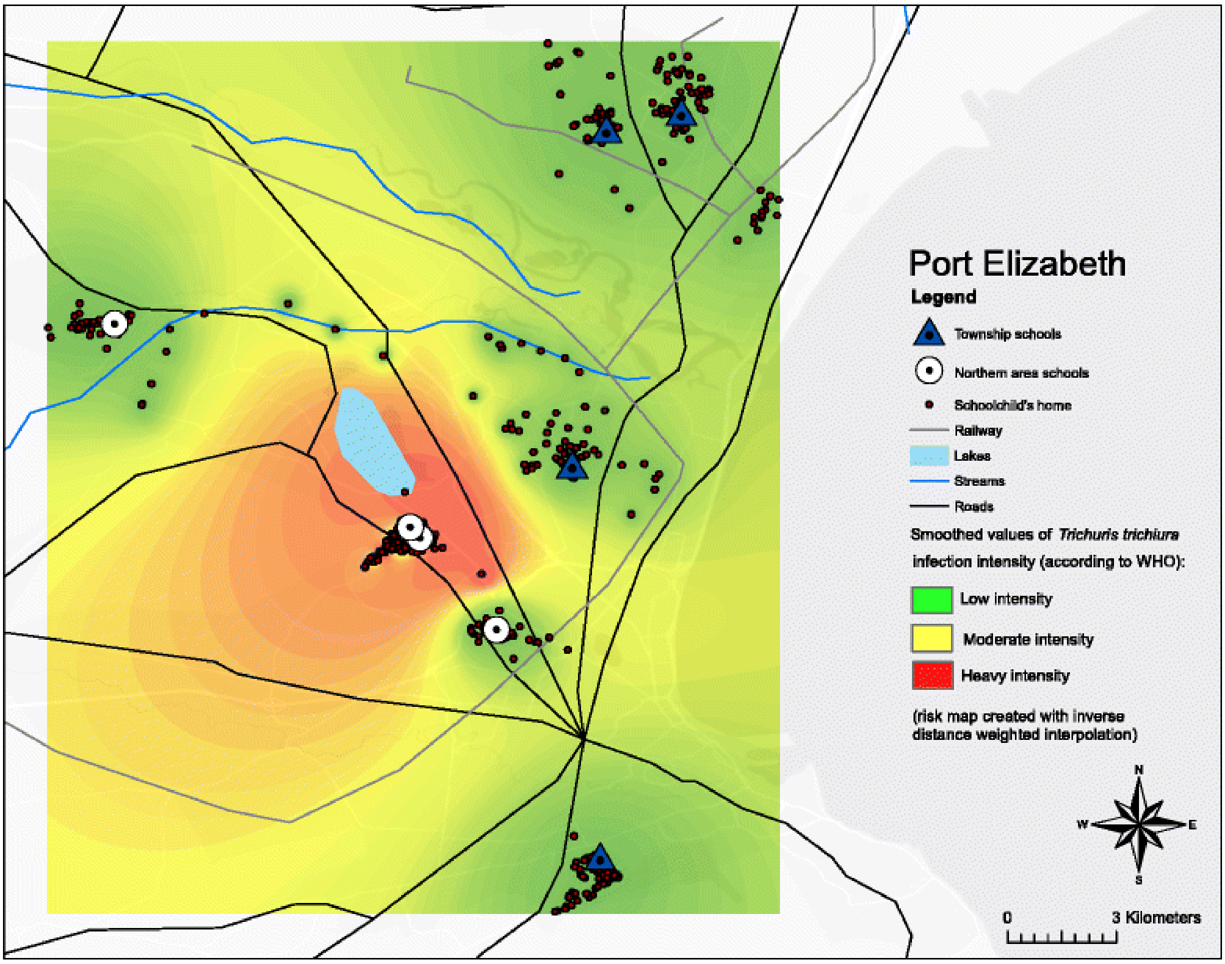


Figure 7.2 *Trichuris trichiura* infection intensities (stratified according to WHO guidelines) in the Northern part of Port Elizabeth, South Africa, in February 2015, smoothed and based on 648 geographical coordinates of schoolchildren's homes (Müller et al. 2016)

7.2.3 School-based health intervention content

The present study used a multi-component health intervention programme since they have been found to be more effective in achieving health and educational outcomes, compared to classroom-only or single-focus intervention approaches (Mukamana and Johri, 2016). The intervention package consisted of four main components: i) physical activity ii) health education iii) nutritional intervention and iv) deworming. The next paragraph will solely elaborate on the physical activity intervention component, since the other interventions were not considered within this dissertation.

7.2.4 Physical activity intervention

The physical activity intervention consisted of five elements, namely: i) two Physical Education lessons per week, ii) weekly moving-to-music classes, iii) daily in-class physical activity breaks and iv) physical activity homework as well as v) the creation of a low-cost physical activity-friendly school environment. The evidence that these five components positively affect the physical activity levels and academic performance of children was largely confirmed by literature (Lee et al., 2019, Heath et al., 2012). For example, a recent meta-analysis by Norris et al. (2019) showed that in-class physical activity had a positive impact on both physical activity and educational outcomes. The integration of weekly moving-to-music classes was based on the notion that South African culture is deeply rooted in music and dance (Edwards, 2010). Furthermore, research has demonstrated that different forms of dance can be a relevant and fun activity for diverse groups of young people (Beaulac et al., 2010). Dance interventions have also proved to be a cost effective way to increase moderate-to-vigorous intensity physical activity in children from lower socio-economic settings (Romero, 2012). Active homework has been shown to improve physical activity (Duncan et al., 2019). Though, Williams et al. (2013) emphasise that the homework exercises should be enjoyable and focus on skill-, fitness-, and intellectual development. They argue that in most Physical Education programmes students are given little time to develop skills, and without skills physical activity is less enjoyable. An unsupportive physical environment that has insufficient places for safe and active leisure and play, has been identified as one of the key factors that prevent young people in disadvantaged communities from participating in physical activity (Beaulac et al., 2009). Also, a study by Kan et al. (2019) showed that in Bangladesh a schoolyard intervention positively influenced children's well-being due to the increased opportunities for exploration of the environment, physical activity and interaction with peers. Therefore, the creation of a physical activity friendly environment through various colourful painted games, and structures such as jungle gyms seemed relevant and appropriate. Concerning the Physical Education lessons, research has identified that lack of teacher involvement might have negative effects on the implementation and fidelity as a consequence (Naylor et al., 2015). In order to address these issues, specific workshops with the Life Skills teachers were held in which lessons were demonstrated and afterwards practiced by the teachers themselves. Furthermore, class management concepts and techniques for Physical Education lessons were shared. At the end of the workshop, teachers were given ready-made lesson plans and equipment. As pointed out in the introduction, many Life Skills teachers are lacking the qualifications, experience and self-confidence to teach the subject (Stroebel et al., 2017). Not surprisingly, none of the Life Skills teachers involved in our study were specifically trained in Physical Education. We therefore assigned a 'teacher coach' to assist for one of the two Physical Education lessons per week. At the end of the intervention, teachers were asked if in future they would be willing to teach Physical Education similar to the DASH lessons. Their responses were mainly positive and included answers such as, "*Yes, I learnt more innovative games and ways to implement Physical Education, inside and outside of the class.*" and "*Yes because this will keep our children in shape and it also helped in their concentration in class.*" Negative responses included "*Due to time constraints, it is not always possible*". Considering these responses, our health intervention seemed to have made a positive impact and seems promising. In line with Stroebel et al. (2019), one way of addressing the challenges pertaining to the subject Physical Education is to equip in-service teachers with the essential knowledge and skills to teach Physical Education proficiently. This can be done through Short Learning Programmes (SLPs) offered within their Continuous Professional Development (CPD).

7.2.5 School-based health interventions

The present study investigated the effect of a multi-component physical activity intervention on primary schoolchildren's academic achievement, selective attention and health-related quality of life. We found a buffering effect on school grades, but no effect on selective attention or health-related quality of life.

Research largely agrees that physical activity-related changes in brain function and cognition (such as attention, information processing, memory and executive functions) exist. It is also widely acknowledged that higher levels of fitness or increased physical activity seem to be predictive of better cognitive performance. However, the assumption that participation in physical activity will favourably affect the way that children think and learn in school settings has yet to be validated (Donnelly et al., 2016). Existing study results vary considerably, most likely due to differences in the mode of assessments, the inclusion of covariates such as socio-economic status, as well as the length and the nature of the physical activity intervention. Our study contributes to the evidence of the benefits of physical activity and physical fitness on cognition in primary schoolchildren from a low socio-economic setting.

Findings in the recent literature regarding health-related quality of life and intervention studies have been equivocal. The meta-analysis by Rafferty et al. (2016) evaluated eleven physical activity intervention studies, with only three studies reporting a positive effect on children's wellbeing. The meta-analysis by Rodriguez-Ayllon et al. (2019) reports a small overall positive effect of physical activity on mental health in children and adolescents aged 6-18 years. However, when they performed the analyses separately for children and adolescents, the results were significant for adolescents but not for children. They argue that the little or no effects observed are mainly due to poorly designed physical activity interventions. It was concluded that physical activity interventions can improve adolescents' mental health, but additional studies are needed to confirm the effects of physical activity on children's mental health.

Contrary to our expectations, the physical activity intervention in our study did not have an effect on children's HRQoL. The lack of impact of our intervention on children's HRQoL may be due to limited exposure and intensity of our program which only lasted for 20 weeks. Furthermore, physical activity intensity was not controlled for during the intervention. Even though, a review including mainly cross-sectional data from Wu et al. (2017) suggested that there is a linear relationship between higher physical activity levels (or less time spent being sedentary) and better health-related quality of life, it is still largely unknown how much physical activity is needed to improve health-related quality of life in children. Considering this, further studies that investigate the dose-response relationship between physical activity and health-related quality of life should be conducted.

7.3 Strengths and limitations

The DASH study is one of very few studies that investigated health indicators and the effect of a multi-component school-based health intervention in low- and middle-income countries, including a sample of primary schoolchildren from socio-economically disadvantaged settings. The study is therefore filling a research gap. A further strength was the relatively high number of study participants. At baseline, 1009 schoolchildren were examined and the loss of follow up was not higher than 20%, which makes the study findings robust. The measurements at each assessment were carried out by a small group of researchers to minimize inter-observer variation and data was double entered. In addition, the longitudinal study design allowed for the tracking of primary schoolchildren and provided more in-depth data. Furthermore, the collaboration between international and local partners ensured local relevance and brought together a wide range of expertise, which further strengthened the study. The fact that the intervention also entailed a small part of capacity building (in terms of teacher workshop and change in school environment) is also considered as a strength. Through workshops and the close collaboration between teachers and coaches, the Life Skill teachers gained skills, knowledge and self-confidence to implement Physical Education lessons. Furthermore, the teachers perceived the intervention as positive and expressed their interest in pursuing the physical activity programme long-term. The fact that annual or biannual deworming had been neglected by local health authorities was detected through the analysis of the fourth grade schoolchildren participating in the study and made schools aware of the importance of such interventions.

The study nevertheless has some limitations that should be considered. First, the intervention allocation was done on a school level, rather than at class-level or even on an individual student level. This was difficult to implement in the present study since one component of the physical activity intervention was the creation of a physical activity friendly school environment. Thus, changes in the infrastructure were performed, which cannot be isolated for learners from specific classes. However, we considered school class as random factor in our multivariate regression analyses. Furthermore, the school-based allocation minimised contamination and therefore comparability of the results was ensured (Keogh-Brown et al., 2007). Second, academic performance was operationalised by the average end of the year grade, which corresponds to the summary of four subjects (Mathematics, Home Language, Additional Language, and Life Skills). While the objectivity of school grades can be questioned as a reliable outcome in empirical research (due to the usage of different standards between classes and schools) (Malouff and Thorsteinsson, 2016), this measure has a high ecological validity because adequate grades are needed for academic promotion and thus school success. Third, information about HRQoL is exclusively based on self-reports. As shown previously children's self-reports may differ considerably from data obtained through teachers or parents (Achenbach et al., 2002). Fourth, physical activity was measured with a single-item question from the Health-Behaviour of School-Aged Children (HBSC) survey. This question has acceptable validity when compared with physical activity assessed by accelerometers (Prochaska et al., 2001, Galan et al., 2013). Fifth, the present study took place in quintile three schools and consequently the variation in socio-economic status was limited, which might have resulted in an underestimation of socio-economic status as a predictor of cognition. Sixth, the measurement of cardiorespiratory fitness/ VO_2max through the 20m shuttle run test might have been influenced by factors such as motivation. One approach could have been to wear heart rate monitors and exclude children below a certain threshold, however, due to operational circumstances this was not possible. Seventh, the physical activity intensity during Physical Education classes and moving-to-music classes was not measured. Therefore, we had no control over unfavourable teaching-to-activity ratio. This limitation was described by Uys et al. (2016), who reported that low-intensity interventions are not effective to improve physical performance. However, using heart-rate monitors during the physical activity intervention was unfeasible. Eighth, the motivation and level of compliance toward a high-quality physical activity lessons varied considerably among the teachers and low motivation and compliance might have compromised the intervention. Ninth, the length of the intervention (twice 10 weeks) was relatively short and maybe a longer intervention period is needed to positively impact selective attention and health-related quality of life among primary school children.

8 Conclusion

The DASH study showed that the physical activity intervention was positively associated with children's academic performance and that higher physical activity and positive change in physical activity were prospectively associated with better health-related quality of life. Furthermore, low physical fitness and soil-transmitted helminth infections are negatively associated with selective attention. Based on our findings, there is an urgent need to increase children's overall physical activity as well as implementing regular deworming and the strengthening of hygiene awareness and practices. South African policy makers should invest in school infrastructure such as the provision of physical activity facilities and school environments that promote physical activity and play, as well as improved water and sanitation facilities. Furthermore, the subject Physical Education should be strengthened. There is a great need for theoretical and practical knowledge as well as training in the implementation of Physical Education for in-service as well as pre-service Life Skills and Life Orientation teachers. One way of addressing this challenge would be to reintroduce Physical Education as a stand-alone subject in the school curriculum. This can be done through Higher Education Institutions offering the subject as a major, or as a specialised learning area. The need for skilled and creative Physical Education specialists, who can work within lower resourced settings, should especially be addressed. Many public schools in South Africa are still confronted with difficult circumstances such as limited availability of facilities and equipment, large classes, and learners of different developmental levels. In depth knowledge and experience to present creative and practical Physical Education lessons, as well as the knowledge and skills to assess performance in movement skills within the framework of the curriculum, would benefit both teachers and learners alike (Stroebel et al., 2019, Stroebel et al., 2017). Quality Physical Education lessons will increase the physical literacy and the physical activity levels of students, which in turn will have positive effects on children's concentration, their academic performance and their physical and psychological wellbeing. Furthermore, creating healthy active habits during childhood carries forward into adulthood (Telama et al., 2014) and might have a protective effect on non-communicable diseases that are linked with inactivity (Aspinall and Munro, 2019), one of the major global threats to health currently.

9 Perspectives

The DASH study undertook a first attempt to increase health literacy in primary schoolchildren from disadvantaged communities. Changes in cardiorespiratory fitness or in self-reported physical activity were not observed, when comparing the intervention to the control group. The absence of improvements within the intervention condition could be due to the relatively short duration of the intervention, the summer school breaks or due to the motivation of the teachers. For future research, we therefore suggest, to assess the quality of intervention implementation more systematically, and to consider this as a moderating factor, as well as implementing the intervention consecutively during a longer period of time. In accordance with a longer intervention, school holidays should be taken into consideration and physical activity homework with specific exercises should be given to the children. Physical activity measurements were based on self-reports. Discrepancies between self-reported and objectively assessed physical activity in children has been observed repeatedly and the results from a meta-analysis revealed that indirectly measured physical activity is overestimated when compared to objectively assessed data with accelerometers (Adamo et al., 2009). Therefore, the objective measurement of physical activity is recommended for future research. Another shortcoming of the DASH study is the limited variance in socio-economic status because our study population only included children from quintile three schools. It would be interesting to compare children from quintile one to five, as well as children from rural and urban schools.

The DASH intervention package was well received at schools and teachers were enthusiastic to continue with the programme. Next steps were taken, and the existing DASH lessons were revised and expanded in accordance with the South African curriculum. The aim is to provide Life Skills and Life Orientation teachers (grades 1 to 7) with ready-made lesson plans, which include Physical Education, moving to music, nutrition and health and hygiene lessons. A follow-up project called *KaziBantu* (which means 'active people' in Swahili and Xhosa) has been brought to life and funded by the Novartis Foundation since October 2017. The aim of the *KaziBantu* project on the one hand is to assess the efficacy and effectiveness of the ready-made lessons plans (*KaziKidz* programme) on health indicators such as mental wellbeing, stress, cognitive performance, hyperglycaemia, obesity, hypertension, physical activity levels and nutrition in school-aged children from disadvantaged areas in Port Elizabeth, South Africa. On the other hand, *KaziBantu* aims to implement a teacher's health promotion programme called *KaziHealth*. *KaziHealth* consists of a behaviour change model that targets health behaviours related to activity, diet and stress management, on non-communicable disease and mental health outcomes. This specially tailored school-based programme has been designed to educate, contribute and enact a positive transformation towards healthy schools, leading to healthy communities. Furthermore, in order to address the need for the reskilling of in-service teachers such as teachers from the DASH study, the *KaziBantu* project is in the process of creating a short learning programme (SLP). The SLP will provide knowledge and practical tips on how to implement the *KaziKidz* toolkit within difficult circumstances faced in areas of South African, such as limited availability of facilities and equipment, large class sizes with learners of different developmental levels. The SLP will be accredited by the South African Qualifications Authority (SAQA) and the South African Council for Educators (SACE) within the existing continuous professional development programme.

10 References

Achenbach, T. M., Dumenci, L. & Rescorla, L. A. 2002. Ten-year comparisons of problems and competencies for national samples of youth: Self, parent, and teacher reports. *J Emot Behav Disord,* 10**,** 194-203.

Adamo, K. B., Prince, S. A., Tricco, A. C., Connor-Gorber, S. & Tremblay, M. 2009. A comparison of indirect versus direct measures for assessing physical activity in the pediatric population: a systematic review. *Int J Pediatr Obes,* 4**,** 2-27.

Alderman, H., Hoddinott, J. & Kinsey, B. 2006. Long term consequences of early childhood malnutrition. *Oxford Econ Pap,* 58**,** 450-474.

American College of Sports, M., Riebe, D., Ehrman, J. K., Liguori, G. & Magal, M. 2018. *ACSM's guidelines for exercise testing and prescription*.

Andersen, J. R., Natvig, G. K., Aadland, E., Moe, V. F., Kolotkin, R. L., Anderssen, S. A. & Resaland, G. K. 2017. Associations between health-related quality of life, cardiorespiratory fitness, muscle strength, physical activity and waist circumference in 10-year-old children: the ASK study. *Qual Life Res,* 26**,** 3421-3428.

Andersen, L. B., Harro, M., Sardinha, L. B., Froberg, K., Ekelund, U., Brage, S. & Anderssen, S. A. 2006. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet,* 368**,** 299-304.

Archer, R. & Bouillon, A. 1982. *The South African game: sport and racism,* London, Zed Press.

Aspinall, S. & Munro, A. 2019. Knowledge and global health: reducing the burden of non-communicable diseases using physical activity. *Brit J Sport Med,* 53**,** 845-846.

Aubert, S., Barnes, J. D., Abdeta, C., Abi Nader, P., Adeniyi, A. F., Aguilar-Farias, N., Andrade Tenesaca, D. S., Bhawra, J., Brazo-Sayavera, J., Cardon, G., Chang, C. K., Delisle Nystrom, C., Demetriou, Y., Draper, C. E., Edwards, L., Emeljanovas, A., Gaba, A., Galaviz, K. I., Gonzalez, S. A., Herrera-Cuenca, M., Huang, W. Y., Ibrahim, I. A. E., Jurimae, J., Kamppi, K., Katapally, T. R., Katewongsa, P., Katzmarzyk, P. T., Khan, A., Korcz, A., Kim, Y. S., Lambert, E., Lee, E. Y., Lof, M., Loney, T., Lopez-Taylor, J., Liu, Y., Makaza, D., Manyanga, T., Mileva, B., Morrison, S. A., Mota, J., Nyawornota, V. K., Ocansey, R., Reilly, J. J., Roman-Vinas, B., Silva, D. A. S., Saonuam, P., Scriven, J., Seghers, J., Schranz, N., Skovgaard, T., Smith, M., Standage, M., Starc, G., Stratton, G., Subedi, N., Takken, T., Tammelin, T., Tanaka, C., Thivel, D., Tladi, D., Tyler, R., Uddin, R., Williams, A., Wong, S. H. S., Wu, C. L., Zembura, P. & Tremblay, M. S. 2018. Global matrix 3.0 physical activity report card grades for children and youth: results and analysis from 49 countries. *J Phys Act Health,* 15**,** S251-S273.

Australian Government Department of Health 2019. Australian 24-hour movement guidelines for children (5-12 years) and young people (13-17 years): an integration of physical activity, sedentary behaviour, and sleep. Canberra.

Bailey, R. 2006. Physical education and sport in schools: a review of benefits and outcomes. *J Sch Health,* 76**,** 397-401.

Barnard, S. & McCaughtry, N. 2007. Teaching Physical Education in Urban Schools. *J Phys Educ Recreat Dance,* 7**,** 16.

Beaulac, J., Bouchard, D. & Kristjansson, E. 2009. Physical activity for adolescents living in a disadvantaged neighbourhood: Views of parents and adolescents on needs, barriers, facilitators, and programming. *Leisure/Loisir,* 33**,** 537-561.

Beaulac, J., Olavarria, M. & Kristjansson, E. 2010. A community-based hip-hop dance program for youth in a disadvantaged community in Ottawa: implementation findings. *Health Promot Pract,* 11**,** 61S-9S.

Biddle, S. J. & Asare, M. 2011. Physical activity and mental health in children and adolescents: a review of reviews. *Br J Sports Med,* 45**,** 886-95.

Blair, C. 2010. Stress and the development of self-regulation in context. *Child Dev Perspect,* 4**,** 181-188.

Blair, C. & Raver, C. C. 2012. Child development in the context of adversity: experiential canalization of brain and behavior. *Am Psychol,* 67**,** 309-18.

Blair, C. & Razza, R. P. 2007. Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Dev,* 78**,** 647-63.

Blair, S. N., Cheng, Y. & Holder, J. S. 2001. Is physical activity or physical fitness more important in defining health benefits? *Med Sci Sports Exerc,* 33**,** S379-99; discussion S419-20.

Bouchard, C., Daw, E. W., Rice, T., Perusse, L., Gagnon, J., Province, M. A., Leon, A. S., Rao, D. C., Skinner, J. S. & Wilmore, J. H. 1998. Familial resemblance for VO2max in the sedentary state: the HERITAGE family study. *Med Sci Sports Exerc,* 30**,** 252-8.

Brand, S., Kalak, N., Gerber, M., Clough, P. J., Lemola, S., Pühse, U. & Holsboer-Trachsler, E. 2016. During early and mid-adolescence, greater mental toughness is related to increased sleep quality and quality of life. *J Health Psychol,* 21**,** 905-15.

Brand, S., Kalak, N., Gerber, M., Clough, P. J., Lemola, S., Sadeghi Bahmani, D., Pühse, U. & Holsboer-Trachsler, E. 2017. During early to mid adolescence, moderate to vigorous physical activity is associated with restoring sleep, psychological functioning, mental toughness and male gender. *J Sports Sci,* 35**,** 426-434.

Bronfenbrenner, U. 1999. Environments in developmental perspective: theoretical and operational models. *Measuring environment across the life span: Emerging methods and concepts.* Washington, DC, US: American Psychological Association.

Brown, H. E., Pearson, N., Braithwaite, R. E., Brown, W. J. & Biddle, S. J. 2013. Physical activity interventions and depression in children and adolescents : a systematic review and meta-analysis. *Sports Med,* 43**,** 195-206.

Carter, N. D., Khan, K. M., McKay, H. A., Petit, M. A., Waterman, C., Heinonen, A., Janssen, P. A., Donaldson, M. G., Mallinson, A., Riddell, L., Kruse, K., Prior, J. C. & Flicker, L. 2002. Community-based exercise program reduces risk factors for falls in 65- to 75-year-old women with osteoporosis: randomized controlled trial. *CMAJ,* 167**,** 997-1004.

Caspersen, C. J., Powell, K. E. & Christenson, G. M. 1985. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep,* 100**,** 126-31.

Cesa, C. C., Sbruzzi, G., Ribeiro, R. A., Barbiero, S. M., de Oliveira Petkowicz, R., Eibel, B., Machado, N. B., Marques, R., Tortato, G., dos Santos, T. J., Leiria, C., Schaan, B. D. & Pellanda, L. C. 2014. Physical activity and cardiovascular risk factors in children: meta-analysis of randomized clinical trials. *Prev Med,* 69**,** 54-62.

Christie, P. & Collins, C. 1990. Bantu education: Apartheid ideology and labour reproduction. *In:* Kallaway, P. (ed.) *Apartheid and education: the educaiton of Black South Africans.* Johannesburg: Ravan.

Chudley, A. E. 2017. Fetal alcohol spectrum disorder-high rates, high needs, high time for action. *JAMA Pediatr,* 171**,** 940-941.

Conger, R. D. & Donnellan, M. B. 2007. An interactionist perspective on the socioeconomic context of human development. *Annu Rev Psychol,* 58**,** 175-99.

Cook, S., Auinger, P. & Huang, T. T. 2009. Growth curves for cardio-metabolic risk factors in children and adolescents. *J Pediatr,* 155**,** S6 e15-26.

Cotman, C. W., Berchtold, N. C. & Christie, L. A. 2007. Exercise builds brain health: key roles of growth factor cascades and inflammation. *Trends Neurosci,* 30**,** 464-72.

Damon, A., Glewwe, P., Wisniewski, S. & Sun, B. 2016. Education in developing countries – what policies and programmes affect learning and time in school? Stockholm: Elanders Sverige AB.

Daskalopoulou, C., Stubbs, B., Kralj, C., Koukounari, A., Prince, M. & Prina, A. M. 2017. Physical activity and healthy ageing: A systematic review and meta-analysis of longitudinal cohort studies. *Ageing Res Rev,* 38**,** 6-17.

de Greeff, J. W., Bosker, R. J., Oosterlaan, J., Visscher, C. & Hartman, E. 2018. Effects of physical activity on executive functions, attention and academic performance in preadolescent children: a meta-analysis. *J Sci Med Sport,* 21**,** 501-507.

De Waal, T. G. 2004. Curriculum 2005: challenges facing teachers in historically disadvantaged schools in the Western Cape. *MA thesis, University of the Western Cape.* Cape Town.

Deci, E. L. & Ryan, R. M. 2000. The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychol Inq,* 11**,** 227-268.

Dhar, A. K. & Barton, D. A. 2016. Depression and the link with cardiovascular disease. *Front Psychiatry,* 7**,** 33.

Dickson, R., Awasthi, S., Williamson, P., Demellweek, C. & Garner, P. 2000. Effects of treatment for intestinal helminth infection on growth and cognitive performance in children: systematic review of randomised trials. *BMJ,* 320**,** 1697-701.

Ding, K., Tarumi, T., Zhu, D. C., Tseng, B. Y., Thomas, B. P., Turner, M., Repshas, J., Kerwin, D. R., Womack, K. B., Lu, H., Cullum, C. M. & Zhang, R. 2018. Cardiorespiratory fitness and white matter neuronal fiber integrity in mild cognitive impairment. *J Alzheimers Dis,* 61**,** 729-739.

Dishman, R. K. & O'Connor, P. J. 2009. Lessons in exercise neurobiology: the case of endorphins. *Ment Health Phys Act,* 2**,** 4-9.

Dobbins, M., Husson, H., DeCorby, K. & LaRocca, R. L. 2013. School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6 to 18. *Cochrane Database Syst Rev***,** CD007651.

Doherty, A. & Forés Miravalles, A. 2019. Physical Activity and Cognition: Inseparable in the Classroom. *Front Educ,* 4.

Donnelly, J. E., Hillman, C. H., Castelli, D., Etnier, J. L., Lee, S., Tomporowski, P., Lambourne, K. & Szabo-Reed, A. N. 2016. Physical activity, fitness, cognitive function, and academic achievement in children: a systematic review. *Med Sci Sports Exerc,* 48**,** 1197-222.

Draper, C. E., Tomaz, S. A., Bassett, S. H., Burnett, C., Christie, C. J., Cozett, C., de Milander, M., Krog, S., Monyeki, A., Naidoo, N., Naidoo, R., Prioreschi, A., Walter, C., Watson, E. & Lambert, E. V. 2018. Results from South Africa's 2018 report card on physical activity for children and youth. *J Phys Act Health,* 15**,** S406-S408.

du Plessis, D. J. 2013. A critical reflection on urban spatial planning practices and outcomes in post-Apartheid South Africa. *Urban Forum,* 25**,** 69-88.

Du Toit, D., Van der Merwe, N. & Rossouw, J. P. 2007. Return of Physical Education to the curriculum : problems and challenges facing schools in South African communities. *Afr J Phys Health Educ Recreat Dance* 13**,** 241-253.

Duncan, S., Stewart, T., McPhee, J., Borotkanics, R., Prendergast, K., Zinn, C., Meredith-Jones, K., Taylor, R., McLachlan, C. & Schofield, G. 2019. Efficacy of a compulsory homework programme for increasing physical activity and improving nutrition in children: a cluster randomised controlled trial. *Int J Behav Nutr Phys Act,* 16**,** 80.

Edwards, S. 2010. Dance for health : a disclosure. *Afr J Phys Health Educ Recreat Dance,* 16**,** 129-146.

Eime, R. M., Young, J. A., Harvey, J. T., Charity, M. J. & Payne, W. R. 2013. A systematic review of the psychological and social benefits of participation in sport for children and adolescents: informing development of a conceptual model of health through sport. *Int J Behav Nutr Phys Act,* 10**,** 98.

Erickson, K. I., Voss, M. W., Prakash, R. S., Basak, C., Szabo, A., Chaddock, L., Kim, J. S., Heo, S., Alves, H., White, S. M., Wojcicki, T. R., Mailey, E., Vieira, V. J., Martin, S. A., Pence, B. D., Woods, J. A., McAuley, E. & Kramer, A. F. 2011. Exercise training increases size of hippocampus and improves memory. *Proc Natl Acad Sci U S A,* 108**,** 3017-22.

Evans, G. W. 2004. The environment of childhood poverty. *Am Psychol,* 59**,** 77-92.

Ezeamama, A. E., Friedman, J. F., Acosta, L. P., Bellinger, D. C., Langdon, G. C., Manalo, D. L., Olveda, R. M., Kurtis, J. D. & McGarvey, S. T. 2005. Helminth infection and cognitive impairment among Filipino children. *Am J Trop Med Hyg,* 72**,** 540-548.

Farah, M. J., Noble, K. G. & Hurt, H. 2004. Poverty, privilege, and brain development: empirical findings and ethical implications. *Neuroethics: defining the issues in theory, practice, and policy.* Oxford: Oxford University Press.

Ferguson, P., Jimerson, S. R. & Dalton, M. J. 2001. Sorting out successful failures: exploratory analyses of factors associated with academic and behavioral outcomes of retained students. *Psychol Schools,* 38**,** 327-341.

Fisher, A., Reilly, J. J., Kelly, L. A., Montgomery, C., Williamson, A., Paton, J. Y. & Grant, S. 2005. Fundamental movement skills and habitual physical activity in young children. *Med Sci Sports Exerc,* 37**,** 684-8.

Fleisch, B. 2008. *Primary education in crisis: why South African schoolchildren underachieve in reading and mathematics,* Cape Town, Juta & Co.

Fox, K. R., Cooper, A. & McKenna, J. 2004. The school and promotion of children's health-enhancing physical activity: Perspectives from the United Kingdom. *J Teach Phys Educ,* 23**,** 338-358.

Gabel, L., Macdonald, H. M., Nettlefold, L. & McKay, H. A. 2017. Physical activity, sedentary time, and bone strength from childhood to early adulthood: a mixed longitudinal HR-pQCT study. *J Bone Miner Res,* 32**,** 1525-1536.

Galan, I., Boix, R., Medrano, M. J., Ramos, P., Rivera, F., Pastor-Barriuso, R. & Moreno, C. 2013. Physical activity and self-reported health status among adolescents: a cross-sectional population-based study. *BMJ Open,* 3**,** e002644.

Gall, S., Adams, L., Joubert, N., Ludyga, S., Müller, I., Nqweniso, S., Pühse, U., du Randt, R., Seelig, H., Smith, D., Steinmann, P., Utzinger, J., Walter, C. & Gerber, M. 2018. Effect of a 20-week physical activity intervention on selective attention and academic performance in children living in disadvantaged neighborhoods: A cluster randomized control trial. *PLoS One,* 13**,** e0206908.

Gall, S., Müller, I., Walter, C., Seelig, H., Steenkamp, L., Pühse, U., du Randt, R., Smith, D., Adams, L., Nqweniso, S., Yap, P., Ludyga, S., Steinmann, P., Utzinger, J. & Gerber, M. 2017. Associations between selective attention and soil-transmitted helminth infections, socioeconomic status, and physical fitness in disadvantaged children in Port Elizabeth, South Africa: An observational study. *PLoS Negl Trop Dis,* 11.

Gerber, M., Endes, K., Brand, S., Herrmann, C., Colledge, F., Donath, L., Faude, O., Hanssen, H., Pühse, U. & Zahner, L. 2016. In 6- to 8-year-old children, cardiorespiratory fitness moderates the relationship between severity of life events and health-related quality of life. *Qual Life Res*.

Gerber, M., Endes, K., Herrmann, C., Colledge, F., Brand, S., Donath, L., Faude, O., Pühse, U., Hanssen, H. & Zahner, L. 2017. Fitness, stress, and body composition in primary schoolchildren. *Med Sci Sports Exerc,* 49**,** 581-587.

Gopinath, B., Hardy, L. L., Baur, L. A., Burlutsky, G. & Mitchell, P. 2012. Physical activity and sedentary behaviors and health-related quality of life in adolescents. *Pediatrics,* 130**,** e167-74.

Gunter, K. B., Almstedt, H. C. & Janz, K. F. 2012. Physical activity in childhood may be the key to optimizing lifespan skeletal health. *Exerc Sport Sci Rev,* 40**,** 13-21.

Guthold, R., Stevens, G. A., Riley, L. M. & Bull, F. C. 2020. Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants. *Lancet Child Adolesc Health,* 4**,** 23-35.

Guure, C. B., Ibrahim, N. A., Adam, M. B. & Said, S. M. 2017. Impact of physical activity on cognitive decline, dementia, and its subtypes: meta-analysis of prospective studies. *Biomed Res Int,* 2017**,** 9016924.

Haapala, E. A., Vaisto, J., Veijalainen, A., Lintu, N., Wiklund, P., Westgate, K., Ekelund, U., Lindi, V., Brage, S. & Lakka, T. A. 2017. Associations of objectively measured physical activity and sedentary time with arterial stiffness in pre-pubertal children. *Pediatr Exerc Sci,* 29**,** 326-335.

Haerens, L., Kirk, D., Cardon, G. & De Bourdeaudhuij, I. 2011. Toward the development of a pedagogical model for health-based physical education. *Quest,* 63**,** 321-338.

Haerens, L., Kirk, D., Cardon, G., De Bourdeaudhuij, I. & Vansteenkiste, M. 2010. Motivational profiles for secondary school physical education and its relationship to the adoption of a physically active lifestyle among university students. *Eur Phys Educ Rev,* 16**,** 117-139.

Hallal, P. C., Victora, C. G., Azevedo, M. R. & Wells, J. C. 2006. Adolescent physical activity and health: a systematic review. *Sports Med,* 36**,** 1019-30.

Hanson, S. K., Munthali, R. J., Micklesfield, L. K., Lobelo, F., Cunningham, S. A., Hartman, T. J., Norris, S. A. & Stein, A. D. 2019. Longitudinal patterns of physical activity, sedentary behavior and sleep in urban South African adolescents, Birth-To-Twenty Plus cohort. *BMC Pediatr,* 19**,** 241.

Haugen, T., Säfvenbom, R. & Ommundsen, Y. 2011. Physical activity and global self-worth: the role of physical self-esteem indices and gender. *Ment Health Phys Act,* 4**,** 49-56.

Heath, G. W., Parra, D. C., Sarmiento, O. L., Andersen, L. B., Owen, N., Goenka, S., Montes, F., Brownson, R. C. & Lancet Physical Activity Series Working, G. 2012. Evidence-based intervention in physical activity: lessons from around the world. *Lancet,* 380**,** 272-81.

Herrmann, C., Gerlach, E. & Seelig, H. 2015. Development and validation of a test instrument for the assessment of basic motor competencies in primary school. *Meas Phys Educ Exerc,* 19**,** 80-90.

Herrmann, C., Heim, C. & Seelig, H. 2019. Construct and correlates of basic motor competencies in primary school-aged children. *J Sport Health Sci,* 8**,** 63-70.

Hillman, C. H., Erickson, K. I. & Kramer, A. F. 2008. Be smart, exercise your heart: exercise effects on brain and cognition. *Nat Rev Neurosci,* 9**,** 58-65.

Hills, A. P., Dengel, D. R. & Lubans, D. R. 2015. Supporting public health priorities: recommendations for physical education and physical activity promotion in schools. *Prog Cardiovasc Dis,* 57**,** 368-74.

Holt, R. I. & Mitchell, A. J. 2015. Diabetes mellitus and severe mental illness: mechanisms and clinical implications. *Nat Rev Endocrinol,* 11**,** 79-89.

Hoskisson, R. E., Eden, L., Lau, C. M. & Wright, M. 2000. Strategy in emerging economies. *Acad Manage J,* 43**,** 249-267.

Howard, S. J., Cook, C. J., Everts, L., Melhuish, E., Scerif, G., Norris, S., Twine, R., Kahn, K. & Draper, C. E. 2020. Challenging socioeconomic status: a cross-cultural comparison of early executive function. *Dev Sci,* 23**,** e12854.

Howie, L. D., Lukacs, S. L., Pastor, P. N., Reuben, C. A. & Mendola, P. 2010. Participation in activities outside of school hours in relation to problem behavior and social skills in middle childhood. *J Sch Health,* 80**,** 119-25.

Institute of Medicine (U.S.) 2013. *Educating the student body: taking physical activity and physical education to school,* Washington, DC, The National Academies Press.

Jansen, J. D. 1999. The school curriculum since apartheid: intersections of politics and policy in the South African transition. *J Curriculum Stud* 31**,** 57-67.

Janssen, I. & Leblanc, A. G. 2010. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int J Behav Nutr Phys Act,* 7**,** 40.

Jardim-Botelho, A., Raff, S., Rodrigues Rde, A., Hoffman, H. J., Diemert, D. J., Correa-Oliveira, R., Bethony, J. M. & Gazzinelli, M. F. 2008. Hookworm, Ascaris lumbricoides infection and polyparasitism associated with poor cognitive performance in Brazilian schoolchildren. *Trop Med Int Health,* 13**,** 994-1004.

Joubert, J., Norman, R., Lambert, E. V., Groenewald, P., Schneider, M., Bull, F., Bradshaw, D. & South African Comparative Risk Assessment Collaborating, G. 2007. Estimating the burden of disease attributable to physical inactivity in South Africa in 2000. *S Afr Med J,* 97**,** 725-31.

Kang, Y., Aguayo, V. M., Campbell, R. K. & West, K. P., Jr. 2018. Association between stunting and early childhood development among children aged 36-59 months in South Asia. *Matern Child Nutr,* 14 Suppl 4**,** e12684.

Kanjee, A. & Chudgar, A. 2009. School money, funding the flaws. *Hum Sci Res Coun,* 7**,** 18-19.

Keogh-Brown, M. R., Bachmann, M. O., Shepstone, L., Hewitt, C., Howe, A., Ramsay, C. R., Song, F., Miles, J. N., Torgerson, D. J., Miles, S., Elbourne, D., Harvey, I. & Campbell, M. J. 2007. Contamination in trials of educational interventions. *Health Technol Assess,* 11**,** iii, ix-107.

Khan, M. & McGeown, S. 2019. P18 Designing for well-being: the influence of a schoolyard intervention on subjective well-being. *BMJ Open,* 9**,** A20-A21.

Kipping, R. R., Jago, R. & Lawlor, D. A. 2008. Obesity in children. Part 1: Epidemiology, measurement, risk factors, and screening. *BMJ,* 337**,** a1824.

Klaperski, S. 2018. Exercise, Stress and Health: The Stress-Buffering Effect of Exercise. *In:* Fuchs, R. & Gerber, M. (eds.) *Handbuch Stressregulation und Sport.* Berlin, Heidelberg: Springer Berlin Heidelberg.

Korczak, D. J., Madigan, S. & Colasanto, M. 2017. Children's physical activity and depression: a meta-analysis. *Pediatrics,* 139.

Kremer, P., Elshaug, C., Leslie, E., Toumbourou, J. W., Patton, G. C. & Williams, J. 2014. Physical activity, leisure-time screen use and depression among children and young adolescents. *J Sci Med Sport,* 17**,** 183-7.

Kriemler, S., Meyer, U., Martin, E., van Sluijs, E. M., Andersen, L. B. & Martin, B. W. 2011. Effect of school-based interventions on physical activity and fitness in children and adolescents: a review of reviews and systematic update. *Br J Sports Med,* 45**,** 923-30.

Lago-Ballesteros, J., Martins, J., Gonzalez-Valeiro, M. A. & Fernandez-Villarino, M. A. 2019. Parental assessment of physical education in the school curriculum: A brief report on the influence of past experiences as students. *PLoS One,* 14**,** e0219544.

Lang, C., Kalak, N., Brand, S., Holsboer-Trachsler, E., Pühse, U. & Gerber, M. 2016. The relationship between physical activity and sleep from mid adolescence to early adulthood. A systematic review of methodological approaches and meta-analysis. *Sleep Med Rev,* 28**,** 32-45.

Le Masurier, G. & Corbin, C. B. 2006. Top 10 Reasons for Quality Physical Education. *J Phys Educ Recreat Dance* 77**,** 44-53.

Lee, A., Lo, A. S. C., Keung, M. W., Kwong, C. M. A. & Wong, K. K. 2019. Effective health promoting school for better health of children and adolescents: indicators for success. *BMC Public Health,* 19**,** 1088.

Lightfoot, J. T., EJC, D. E. G., Booth, F. W., Bray, M. S., M, D. E. N. H., Kaprio, J., Kelly, S. A., Pomp, D., Saul, M. C., Thomis, M. A., Garland, T., Jr. & Bouchard, C. 2018. Biological/genetic regulation of physical activity level: consensus from GenBioPAC. *Med Sci Sports Exerc,* 50**,** 863-873.

Liu, C., Luo, R., Yi, H., Zhang, L., Li, S., Bai, Y., Medina, A., Rozelle, S., Smith, S., Wang, G. & Wang, J. 2015. Soil-transmitted helminths in southwestern China: a cross-sectional study of links to cognitive ability, nutrition, and school performance among children. *PLoS Negl Trop Dis,* 9**,** e0003877.

Liu, J., Peng, P. & Luo, L. 2019. The relation between family socioeconomic status and academic achievement in china: a meta-analysis. *Educ Psyc Rev*.

Lu, C., Black, M. M. & Richter, L. M. 2016. Risk of poor development in young children in low-income and middle-income countries: an estimation and analysis at the global, regional, and country level. *Lancet Glob Health,* 4**,** e916-e922.

Lubans, D., Richards, J., Hillman, C., Faulkner, G., Beauchamp, M., Nilsson, M., Kelly, P., Smith, J., Raine, L. & Biddle, S. 2016. Physical activity for cognitive and mental health in youth: a systematic review of mechanisms. *Pediatrics,* 138**,** e20161642.

Lubans, D. R., Morgan, P. J., Cliff, D. P., Barnett, L. M. & Okely, A. D. 2010. Fundamental movement skills in children and adolescents: review of associated health benefits. *Sports Med,* 40**,** 1019-35.

Maffeis, C. & Castellani, M. 2007. Physical activity: an effective way to control weight in children? *Nutr Metab Cardiovasc Dis,* 17**,** 394-408.

Malouff, J. M. & Thorsteinsson, E. B. 2016. Bias in grading: A meta-analysis of experimental research findings. *Aust J Educ,* 60**,** 245-256.

Maringira, G. & Gibson, D. 2019. Maintaining order in townships: gangsterism and community resilience in post-Apartheid South Africa. *AFr Con Peacebuild Rev,* 9**,** 55-74.

Martínez-Vizcaíno, V. & Sánchez-López, M. 2008. Relationship Between Physical Activity and Physical Fitness in Children and Adolescents. *Revista Española de Cardiología (English Edition),* 61**,** 108-111.

Mbeki, T. M. 1998. Statement on reconciliation and nation building. *National assembly.* Cape Town.

McCaughtry, N., Barnard, S., Martin, J., Shen, B. & Kulinna, P. H. 2006. Teachers' perspectives on the challenges of teaching physical education in urban schools: the student emotional filter. *Res Q Exerc Sport,* 77**,** 486-97.

McIntyre, D. & Gilson, L. 2002. Putting equity in health back onto the social policy agenda: experience from South Africa. *Soc Sci Med,* 54**,** 1637-56.

McMahon, E. M., Corcoran, P., O'Regan, G., Keeley, H., Cannon, M., Carli, V., Wasserman, C., Hadlaczky, G., Sarchiapone, M., Apter, A., Balazs, J., Balint, M., Bobes, J., Brunner, R., Cozman, D., Haring, C., Iosue, M., Kaess, M., Kahn, J. P., Nemes, B., Podlogar, T., Postuvan, V., Saiz, P., Sisask, M., Tubiana, A., Varnik, P., Hoven, C. W. & Wasserman, D. 2017. Physical activity in European adolescents and associations with anxiety, depression and well-being. *Eur Child Adolesc Psychiatry,* 26**,** 111-122.

McVeigh, J. A., Norris, S. A. & de Wet, T. 2004. The relationship between socio-economic status and physical activity patterns in South African children. *Acta Paediatr,* 93**,** 982-8.

Miller, A. C., Murray, M. B., Thomson, D. R. & Arbour, M. C. 2016. How consistent are associations between stunting and child development? Evidence from a meta-analysis of associations between stunting and multidimensional child development in fifteen low- and middle-income countries. *Public Health Nutr,* 19**,** 1339-47.

Mittal, C., Griskevicius, V., Simpson, J. A., Sung, S. & Young, E. S. 2015. Cognitive adaptations to stressful environments: When childhood adversity enhances adult executive function. *J Pers Soc Psychol,* 109**,** 604-621.

Morris, J. N., Heady, J. A., Raffle, P. A., Roberts, C. G. & Parks, J. W. 1953. Coronary heart-disease and physical activity of work. *Lancet,* 262**,** 1053-1057.

Mukamana, O. & Johri, M. 2016. What is known about school-based interventions for health promotion and their impact in developing countries? A scoping review of the literature. *Health Educ Res,* 31**,** 587-602.

Mulia, N., Schmidt, L., Bond, J., Jacobs, L. & Korcha, R. 2008. Stress, social support and problem drinking among women in poverty. *Addiction,* 103**,** 1283-93.

Müller, I. 2019. Epidemiology of infectious and non-communicable diseases and effect of health interventions on children's physical fitness in Port Elizabeth, South Africa. *PhD thesis.* Basel: Swiss Tropical and Public Health Institute.

Müller, I., Gall, S., Beyleveld, L., Gerber, M., Pühse, U., Du Randt, R., Steinmann, P., Zondie, L., Walter, C. & Utzinger, J. 2017. Shrinking risk profiles after deworming of children in Port Elizabeth, South Africa, with special reference to Ascaris lumbricoides and Trichuris trichiura. *Geospat Health,* 12**,** 601.

Müller, I., Yap, P., Steinmann, P., Damons, B. P., Schindler, C., Seelig, H., Htun, N. S., Probst-Hensch, N., Gerber, M., du Randt, R., Pühse, U., Walter, C. & Utzinger, J. 2016. Intestinal parasites, growth and physical fitness of schoolchildren in poor neighbourhoods of Port Elizabeth, South Africa: a cross-sectional survey. *Parasit Vectors,* 9**,** 488.

Naylor, P. J., Nettlefold, L., Race, D., Hoy, C., Ashe, M. C., Wharf Higgins, J. & McKay, H. A. 2015. Implementation of school based physical activity interventions: a systematic review. *Prev Med,* 72**,** 95-115.

Nixon, G. M., Thompson, J. M. D., Han, D. Y., Becroft, D. M. O., Clark, P. M., Robinson, E., Waldie, K. E., Wild, C. J., Black, P. N. & Mitchell, E. A. 2009. Falling asleep: the determinants of sleep latency. *Arc Dis Child,* 94**,** 686-689.

Norris, E., van Steen, T., Direito, A. & Stamatakis, E. 2019. Physically active lessons in schools and their impact on physical activity, educational, health and cognition outcomes: a systematic review and meta-analysis. *Br J Sports Med***,** bjsports-2018-100502.

O'Brien, L. M. 2011. The neurocognitive effects of sleep disruption in children and adolescents. *Sleep Med Clin,* 6**,** 109-116.

Obradović, J. 2016. Physiological responsivity and executive functioning: implications for adaptation and resilience in early childhood. *Child Dev Pers,* 10**,** 65-70.

Opel, N., Martin, S., Meinert, S., Redlich, R., Enneking, V., Richter, M., Goltermann, J., Johnen, A., Dannlowski, U. & Repple, J. 2019. White matter microstructure mediates the association between physical fitness and cognition in healthy, young adults. *Sci Rep,* 9**,** 12885.

Pabalan, N., Singian, E., Tabangay, L., Jarjanazi, H., Boivin, M. J. & Ezeamama, A. E. 2018. Soil-transmitted helminth infection, loss of education and cognitive impairment in school-aged children: A systematic review and meta-analysis. *PLoS Negl Trop Dis,* 12**,** e0005523.

Peltzer, K., Shisana, O., Zuma, K., Van Wyk, B. & Zungu-Dirwayi, N. 2009. Job stress, job satisfaction and stress-related illnesses among South African educators. *Stress and Health,* 25**,** 247-257.

Pienaar, A. E., Barhorst, R. & Twisk, J. W. 2014. Relationships between academic performance, SES school type and perceptual-motor skills in first grade South African learners: NW-CHILD study. *Child Care Health Dev,* 40**,** 370-8.

Pinto Pereira, S. M., Geoffroy, M. C. & Power, C. 2014. Depressive symptoms and physical activity during 3 decades in adult life: bidirectional associations in a prospective cohort study. *JAMA Psychiatry,* 71**,** 1373-80.

Poitras, V. J., Gray, C. E., Borghese, M. M., Carson, V., Chaput, J. P., Janssen, I., Katzmarzyk, P. T., Pate, R. R., Connor Gorber, S., Kho, M. E., Sampson, M. & Tremblay, M. S. 2016. Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Appl Physiol Nutr Metab,* 41**,** S197-239.

Prinsloo, E. 2007. Implementation of life orientation programmes in the new curriculum in South African schools: perceptions of principals and life orientation teachers. *S Afr J Educ,* 27**,** 155-170.

Prochaska, J. J., Sallis, J. F. & Long, B. 2001. A physical activity screening measure for use with adolescents in primary care. *Arch Pediatr Adolesc Med,* 155**,** 554-559.

Pudi, T. 2006. 'From OBE to C2005 to RNCS': Are we still on track? *Afr Educ Rev,* 3**,** 100-112.

Pühse, U. & Gerber, M. 2005. *International comparison of physical education. Concepts, problems, prospects,* Aachen, Meyer & Meyer.

Rafferty, R., Breslin, G., Brennan, D. & Hassan, D. 2016. A systematic review of school-based physical activity interventions on children's wellbeing. *Int Rev Sport Exerc Psychol,* 9**,** 215-230.

Rajput, D. I. & van Deventer, K. J. 2010. An epoch of controversy within physical education and sport in post-apartheid South Africa: a review. *Afr J Phys Health Educ Recreat Dance* 16**,** 147-165.

Reddy, S. P., Panday, S. & Swart, D. 2003. Umthenthe Uhlaba Usamila - the South African youth risk health behavior survey 2002. Cape Town: South African Medical Research Council.

Riley, M. R., Scaramella, L. V. & McGoron, L. 2014. Disentangling the associations between contextual stress, sensitive parenting, and children's social development. *Fam Relat,* 63**,** 287-299.

Rimm-Kaufman, S. E. & Pianta, R. C. 2000. An ecological perspective on the transition to kindergarten: A theoretical framework to guide empirical research. *J Appl Dev Psychol,* 21**,** 491-511.
Rodriguez-Ayllon, M., Cadenas-Sanchez, C., Estevez-Lopez, F., Munoz, N. E., Mora-Gonzalez, J., Migueles, J. H., Molina-Garcia, P., Henriksson, H., Mena-Molina, A., Martinez-Vizcaino, V., Catena, A., Lof, M., Erickson, K. I., Lubans, D. R., Ortega, F. B. & Esteban-Cornejo, I. 2019. Role of physical activity and sedentary behavior in the mental health of preschoolers, children and adolescents: a systematic review and meta-analysis. *Sports Med,* 49**,** 1383-1410.
Romero, A. J. 2012. A pilot test of the Latin active hip hop intervention to increase physical activity among low-income Mexican-American adolescents. *Am J Health Promot,* 26**,** 208-11.
Rosenkranz, M. A., Esnault, S., Christian, B. T., Crisafi, G., Gresham, L. K., Higgins, A. T., Moore, M. N., Moore, S. M., Weng, H. Y., Salk, R. H., Busse, W. W. & Davidson, R. J. 2016. Mind-body interactions in the regulation of airway inflammation in asthma: A PET study of acute and chronic stress. *Brain Behav Immun,* 58**,** 18-30.
Ross, R., Goodpaster, B. H., Koch, L. G., Sarzynski, M. A., Kohrt, W. M., Johannsen, N. M., Skinner, J. S., Castro, A., Irving, B. A., Noland, R. C., Sparks, L. M., Spielmann, G., Day, A. G., Pitsch, W., Hopkins, W. G. & Bouchard, C. 2019. Precision exercise medicine: understanding exercise response variability. *Br J Sports Med,* 53**,** 1141-1153.
Sibley, B. A. & Etnier, J. L. 2003. The relationship between physical activity and cognition in children: A meta-analysis. *Pediatr Exerc Sci,* 15**,** 243-256.
Silventoinen, K., Magnusson, P. K., Tynelius, P., Kaprio, J. & Rasmussen, F. 2008. Heritability of body size and muscle strength in young adulthood: a study of one million Swedish men. *Genet Epidemiol,* 32**,** 341-9.
Simoneau, J. A. & Bouchard, C. 1995. Genetic determinism of fiber type proportion in human skeletal muscle. *FASEB J,* 9**,** 1091-5.
South African Department of Basic Education 2011a. Curriculum and assessment policy statement (CAPS): Life Skills Foundation Phase Grades R-3. Pretoria, South Africa: SADBE.
South African Department of Basic Education 2011b. Curriculum and assessment policy statement (CAPS): Life Skills Intermediate Phase Grades 4-6. Pretoria, South Africa: SADBE.
Speich, B., Croll, D., Furst, T., Utzinger, J. & Keiser, J. 2016. Effect of sanitation and water treatment on intestinal protozoa infection: a systematic review and meta-analysis. *Lancet Infect Dis,* 16**,** 87-99.
St John, A. M., Kibbe, M. & Tarullo, A. R. 2019. A systematic assessment of socioeconomic status and executive functioning in early childhood. *J Exp Child Psychol,* 178**,** 352-368.
Statistics South Africa. 2016. *Mapping diversity: An exploration of our social tapestry* [Online]. Available: http://www.statssa.gov.za/?p=7678 [Accessed 19.11.2019].
Statistics South Africa. 2019. *Department: statistics of South Africa* [Online]. Available: http://www.statssa.gov.za [Accessed 19.11.2019].
Steyn, K. & Damasceno, A. 2006. Lifestyle and related risk factors for chronic diseases. *In:* Nd, Jamison, D. T., Feachem, R. G., Makgoba, M. W., Bos, E. R., Baingana, F. K., Hofman, K. J. & Rogo, K. O. (eds.) *Disease and Mortality in Sub-Saharan Africa.* Washington (DC): World Bank
The international bank for reconstruction and development/the World Bank.

Stroebel, L. C. E., Hay, J. & Bloemhoff, H. 2017. Needs and challenges of Foundation Phase life skills teachers in delivering physical education : Jack of all trades and master of none? *S Afr J Res Sport Phys,* 39**,** 163-177.

Stroebel, L. C. E., Hay, J. & Bloemhoff, H. J. 2016. Physical education in South Africa: have we come full circle? *S Afr J Res Sport Phys,* 38**,** 215-228.

Stroebel, L. C. E., Hay, J. & Bloemhoff, H. J. 2019. An approach to re-skilling of in-service teachers in Physical Education in South African schools. *S Afr J Educ,* 39**,** 1-12.

Ströhle, A. 2009. Physical activity, exercise, depression and anxiety disorders. *J Neural Transm* 116**,** 777-84.

Strunz, E. C., Addiss, D. G., Stocks, M. E., Ogden, S., Utzinger, J. & Freeman, M. C. 2014. Water, sanitation, hygiene, and soil-transmitted helminth infection: a systematic review and meta-analysis. *PLoS Med,* 11**,** e1001620.

Telama, R., Yang, X., Leskinen, E., Kankaanpaa, A., Hirvensalo, M., Tammelin, T., Viikari, J. S. & Raitakari, O. T. 2014. Tracking of physical activity from early childhood through youth into adulthood. *Med Sci Sports Exerc,* 46**,** 955-62.

Telama, R., Yang, X., Viikari, J., Valimaki, I., Wanne, O. & Raitakari, O. 2005. Physical activity from childhood to adulthood: a 21-year tracking study. *Am J Prev Med,* 28**,** 267-73.

Tomporowski, P. D., Davis, C. L., Miller, P. H. & Naglieri, J. A. 2008. Exercise and children's intelligence, cognition, and academic achievement. *Educ Psychol Rev,* 20**,** 111-131.

Tomporowski, P. D., McCullick, B., Pendleton, D. M. & Pesce, C. 2015. Exercise and children's cognition: The role of exercise characteristics and a place for metacognition. *J Sport Health Sci,* 4**,** 47-55.

UNESCO 2014. World-wide survey of school physical education. Paris: United Nations educational, scientific and cultural organization.

Utzinger, J., Becker, S. L., Knopp, S., Blum, J., Neumayr, A. L., Keiser, J. & Hatz, C. F. 2012. Neglected tropical diseases: diagnosis, clinical management, treatment and control. *Swiss Med Wkly,* 142**,** w13727.

Uys, M., Bassett, S., Draper, C. E., Micklesfield, L., Monyeki, A., de Villiers, A., Lambert, E. V. & Group, H. W. 2016. Results from South Africa's 2016 report card on physical activity for children and youth. *J Phys Act Health,* 13**,** S265-S273.

Valiente, C., Lemery-Chalfant, K., Swanson, J. & Reiser, M. 2008. Prediction of children's academic competence from their effortful control, relationships, and classroom participation. *J Educ Psychol,* 100**,** 67-77.

Van Deventer, K. J. 2009. Perspectives of teachers on the implementation of Life Orientation in Grades R–11 from selected Western Cape schools. *S Afr J Educ,* 29.

van Deventer, K. J. 2012. School physical education in four South African provinces: A survey. *S Afr J Res Sport Phys,* 34**,** 153-166.

Van Dusen, D. P., Kelder, S. H., Kohl, H. W., 3rd, Ranjit, N. & Perry, C. L. 2011. Associations of physical fitness and academic performance among schoolchildren. *J Sch Health,* 81**,** 733-40.

Vos, T., Abajobir, A. A., Abbafati, C., Abbas, K. M., Abate, K. H., Abd-Allah, F., Abdulle, A. M., Abebo, T. A., Abera, S. F., Aboyans, V., Abu-Raddad, L. J., Ackerman, I. N., Adamu, A. A., Adetokunboh, O., Afarideh, M., Afshin, A., Agarwal, S. K., Aggarwal, R., Agrawal, A., Agrawal, S., Kiadaliri, A. A., Ahmadieh, H., Ahmed, M. B., Aichour, A. N., Aichour, I., Aichour, M. T. E., Aiyar, S., Akinyemi, R. O., Akseer, N., Al Lami, F. H., Alahdab, F., Al-Aly, Z., Alam, K., Alam, N., Alam, T., Alasfoor, D., Alene, K. A., Ali, R., Alizadeh-Navaei, R., Alkerwi, A., Alla, F., Allebeck, P., Allen, C., Al-Maskari, F., Al-Raddadi, R., Alsharif, U., Alsowaidi, S., Altirkawi, K. A., Amare, A. T., Amini, E., Ammar, W., Amoako, Y. A., Andersen, H. H., Antonio, C. A. T., Anwari, P., Arnlov, J., Artaman, A., Aryal, K. K., Asayesh, H., Asgedom, S. W., Assadi, R., Atey, T. M., Atnafu, N. T., Atre, S. R., Avila-Burgos, L., Avokpaho, E. F. G. A., Awasthi, A., Quintanilla, B. P. A., Saleem, H. O. B., Bacha, U., Badawi, A., Balakrishnan, K., Banerjee, A., Bannick, M. S., Barac, A., Barber, R. M., Barker-Collo, S. L., Barnighausen, T., Barquera, S., Barregard, L., Barrero, L. H., Basu, S., Battista, B., Battle, K. E., Baune, B. T., Bazargan-Hejazi, S., Beardsley, J., Bedi, N., Beghi, E., Bejot, Y., Bekele, B. B., Bell, M. L., Bennett, D. A., Bensenor, I. M., Benson, J., Berhane, A., Berhe, D. F., Bernabe, E., Betsu, B. D., Beuran, M., et al. 2017. Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet,* 390**,** 1211-1259.

Walter, C. M. 2011. In-school physical activity patterns of primary school learners from disadvantaged schools in South Africa. *Afr J Phys Health Educ Recreat Dance* 17**,** 780-789.

Warburton, D. E., Charlesworth, S., Ivey, A., Nettlefold, L. & Bredin, S. S. 2010. A systematic review of the evidence for Canada's physical activity guidelines for adults. *Int J Behav Nutr Phys Act,* 7**,** 39.

Warburton, D. E., Nicol, C. W. & Bredin, S. S. 2006. Health benefits of physical activity: the evidence. *Can Med Assoc J,* 174**,** 801-9.

Watt, M. H., Eaton, L. A., Choi, K. W., Velloza, J., Kalichman, S. C., Skinner, D. & Sikkema, K. J. 2014. "It's better for me to drink, at least the stress is going away": perspectives on alcohol use during pregnancy among South African women attending drinking establishments. *Soc Sci Med,* 116**,** 119-25.

Whitehead, M. 2006. The concept of physical literacy. *Eur J Phys Ed,* 6**,** 127-138.

WHO 2010. Global recommendations on physical activity for health. Geneva, Switzerland.

WHO. Global action plan for the prevention and control of noncommunicable diseases 2013–2020. 2013. Wold Health Organisation, Geneva.

Williams, H. G., Pfeiffer, K. A., O'Neill, J. R., Dowda, M., McIver, K. L., Brown, W. H. & Pate, R. R. 2008. Motor skill performance and physical activity in preschool children. *Obesity,* 16**,** 1421-6.

Williams, J. F., Smith, V. C. & Committee On Substance, A. 2015. Fetal alcohol spectrum disorders. *Pediatrics,* 136**,** e1395-406.

Williams, S. M. & Hannon, J. C. 2013. Physical education homework that involves the family. *Strategies,* 26**,** 3-8.

Wirtz, P. H. & von Kanel, R. 2017. Psychological stress, inflammation, and coronary heart disease. *Curr Cardiol Rep,* 19**,** 111.

World Bank 2019. The human capital project. *In:* World Bank (ed.) *World development report 2019 : the changing nature of work*. Washington, DC: World Bank.

Wu, X. Y., Han, L. H., Zhang, J. H., Luo, S., Hu, J. W. & Sun, K. 2017. The influence of physical activity, sedentary behavior on health-related quality of life among the general population of children and adolescents: A systematic review. *PLoS One,* 12**,** e0187668.

Yang, P. Y., Ho, K. H., Chen, H. C. & Chien, M. Y. 2012. Exercise training improves sleep quality in middle-aged and older adults with sleep problems: a systematic review. *J Physiother,* 58**,** 157-63.

Zeng, N., Ayyub, M., Sun, H., Wen, X., Xiang, P. & Gao, Z. 2017. Effects of Physical Activity on Motor Skills and Cognitive Development in Early Childhood: A Systematic Review. *Biomed Res Int,* 2017**,** 2760716.

Zulu, B., Urbani, G., van der Merwe, A. & Walt, J. 2004. Violence as an impediment to a culture of teaching and learning in some South African schools. *S Afr J Educ,* 24.

11 Appendix

A Informed consent form in English

15 October 2014

Impact of disease burden and setting-specific interventions on schoolchildren's cardio-respiratory physical fitness and psychosocial health in Port Elizabeth, South Africa

Informed consent form

Project title: Impact of disease burden and setting-specific interventions on schoolchildren's cardio-respiratory physical fitness and psychosocial health in Port Elizabeth, South Africa

Statement by the researcher/person taking consent

I have accurately outlined the purpose, objectives and procedures of the study and given enough information including the potential benefits and risks to the parent/legal guardian of the potential participant.

I confirm that the parent/legal guardian of participant Mr/Ms: ________________________
School Nr.: ____________________ Telephone Nr.: ____________________ was given an opportunity to ask questions and that all questions have been answered correctly. I confirm that the participant has not been forced into giving consent, and consent has been given freely and voluntarily.

Name of researcher: ________________________ Place: ____________________

Date: ____________________ Signature: ________________________

Statement by the parent/legal guardian

I have read the letter of information of the study or it has been read to me in a language that I understand. I had the opportunity to ask questions about it and any questions I have asked have been answered to my satisfaction. I know the purpose, objectives and procedures, risk and benefits of the study. I understand that I can withdraw my child from the study at any time without further consequences. I have also an additional letter of information that I can keep for future reference.

Name of schoolchild:____

Name of parent/legal guardian: ____________________________________

Place:__________Date:__________Signature: ______________________

If participant is **illiterate**
I have witnessed the accurate reading of the consent form to the potential participant and the individual had the opportunity to ask questions. I confirm that the individual has given consent freely.

Name of witness: ____

Place:______________Date:__________Signature:____________________

Thumb print of participant:

Study doctor or responsible nurse of the study

The purpose, objectives and procedures of the study has been accurately outlined and enough information was given including the potential benefits and risks to the parent/legal guardian of the potential participant.

Name of the doctor / nurse: ____________________

Place:____________Date:____________Signature: ____________________

---------------------------- Thank you very much for your invested time! -----------------------------

B Clinical examination sheet

INDIVIDUAL SHEET FOR MONITORING

Test date (dd/mm): _______/_______/2015

ID: ☐ ☐ ☐ ☐ ☐

First name: __________________ Last name: __________________________

DONE BY INVESTIGATOR:

- Did you have something to eat at home this morning before school? ❑ yes ❑ no
- How many meals did you eat yesterday? _________
- Did you go to bed hungry last night? ❑ yes ❑ no
- Do you feel hungry after meals because the meals are too small? ❑ yes ❑ no

DONE BY NURSE / DOCTOR: Temperature: _________ °C

FUNCTIONAL SIGNS:

Fever	❑ yes ❑ no	Vertigo	❑ yes ❑ no
Nervousness	❑ yes ❑ no	Cough	❑ yes ❑ no
Headache	❑ yes ❑ no	Constipation	❑ yes ❑ no
Nausea	❑ yes ❑ no	Itching	❑ yes ❑ no
Vomiting	❑ yes ❑ no	Blood in the stool	❑ yes ❑ no
Diarrhea	❑ yes ❑ no	Problems with breathing	❑ yes ❑ no
Belly ache	❑ yes ❑ no	Allergy	❑ yes ❑ no

Gender: ❑ Female ❑ Male

- Menarche (to ask girls) ❑ yes ❑ no
  Starting date __________/__________ (mm/yyyy)

- Taking medication (last week): ❑ yes ❑ no
  If "yes", please specify the name or description of medication.
  Against worms:____
  Others: ____

- **PHYSICAL EXAMINATION:**

Conjunctiva ____
(0=normal, 1=moderately colored, 2=slightly colored, 3=pale or slightly colored)

Jaundice (0=no, 1=sub-jaundice, jaundice franc=2) ____________________________________

Splenomegaly (0-5) ____

Hepatomegaly (0-4) ____

Pulse____________________bpm Blood Pressure________________mmHg

Skin lesions (0=no, 1=presence, specify) ____

Pulmonary auscultation (0=no, 1=presence, specify) ____________________________________

Cardiac auscultation (0=no, 1=presence, specify) ______________________________________

- **Result of the Hemoglobin (Hb) test using HemoCue® Hb 301 system:**
  __________ g / mL

- **Result of the blood glucose test using Accu-Check® blood glucose monitoring system:** __________ mmol / L

  - If blood glucose is under 4 or over 7mmol/L

    How many hours ago did he /she eat? ____________ hours

    What did he/she eat? ____

CONCLUSION:

Included ______________________________

Excluded (pattern) ______________________________

Name of the nurse / doctor in block letters: ______________________________

Signature of the nurse / doctor: ____

C Physical fitness score sheet

PARTICIPANT EVALUATION FORM – FITNESS SCORE			
BIOGRAPHICAL INFORMATION			
ID	☐ ☐ ☐ ☐ ☐	**TEST DATE**	(dd / mm) : ____/____/ 2015
NAME		**SURNAME**	
BIRTHDAY	(dd / mm / yyyy): ____/____/20___		

PHYSICAL FITNESS COMPONENTS			
ANTHROPOMETRY			
HEIGHT *(cm)*		**WEIGHT (kg)**	
SKINFOLDS *(mm)*	***TRIAL 1***	***TRIAL 2***	***TRIAL 3***
TRICEPS			
SUBSCAPULAR			

PHYSICAL FITNESS TESTS						
				TRIAL 1		***TRIAL 2***
Station 1	*Flexibility*	Sit & Reach *(cm)*				
			CIRCLE DOMINANT HAND	***TRIAL 1***	***TRIAL 2***	***TRIAL 3***
Station 2	*Upper body strength*	Grip strength *(kg)*	Right hand			
			Left hand			
				TRIAL 1		***TRIAL 2***
Station 3	*Lower body strength*	Standing Broad Jump *(cm)*				
Station 4	*Coordination & speed*	Jump Sideward				
Cardiorespiratory fitness		Start Number				
		Laps				

D Questionnaire (English version)

Survey on the impact of disease burden on schoolchildren's physical fitness and psychosocial health in Port Elizabeth, South Africa

Questionnaire

SSAJRP-project

Version 7, 27 January 2015

‚Education is the most powerful weapon that can be used to change the world'. (Nelson Mandela)

SSAJRP
University of Basel, CH, and Nelson Mandela Metropolitan University, Port Elizabeth, ZA

Hello,

How are you? How do you feel? This is what we would like ***you*** to tell us and is the reason why we are doing this questionnaire with you. We are not looking for right or wrong answers. We simply want you to write the response that tells us your feelings.

Please read every question carefully. Whatever answer comes to your mind that best reflects your feelings, choose the box that fits that answer best and tick (☐) it. The entire questionnaire takes about 2 hours. After 1 hour, you have earned a 15 minute break.

Remember:

- This is not a test.
- There is no mark, and there are no wrong answers.
- Please answer all the questions, as honestly and accurately as you can.
- It is important that you answer all the questions.
- Make sure we can see your marks clearly.
- You do not have to show your answers to anybody.
- All answers remain secret.
- Neither your teacher nor the school principal gets to see the answers.
- Please only tick one box (☐) when answering the questions.
- If you have ticked something wrong, then cross out the field and mark the right place.
- If something is unclear, you can ask one of the investigators of course.

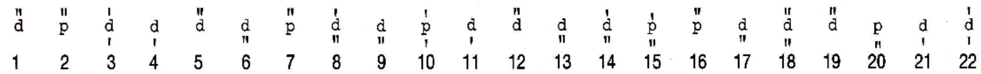
When you are done, please give the questionnaire directly to the investigator. Thank you!

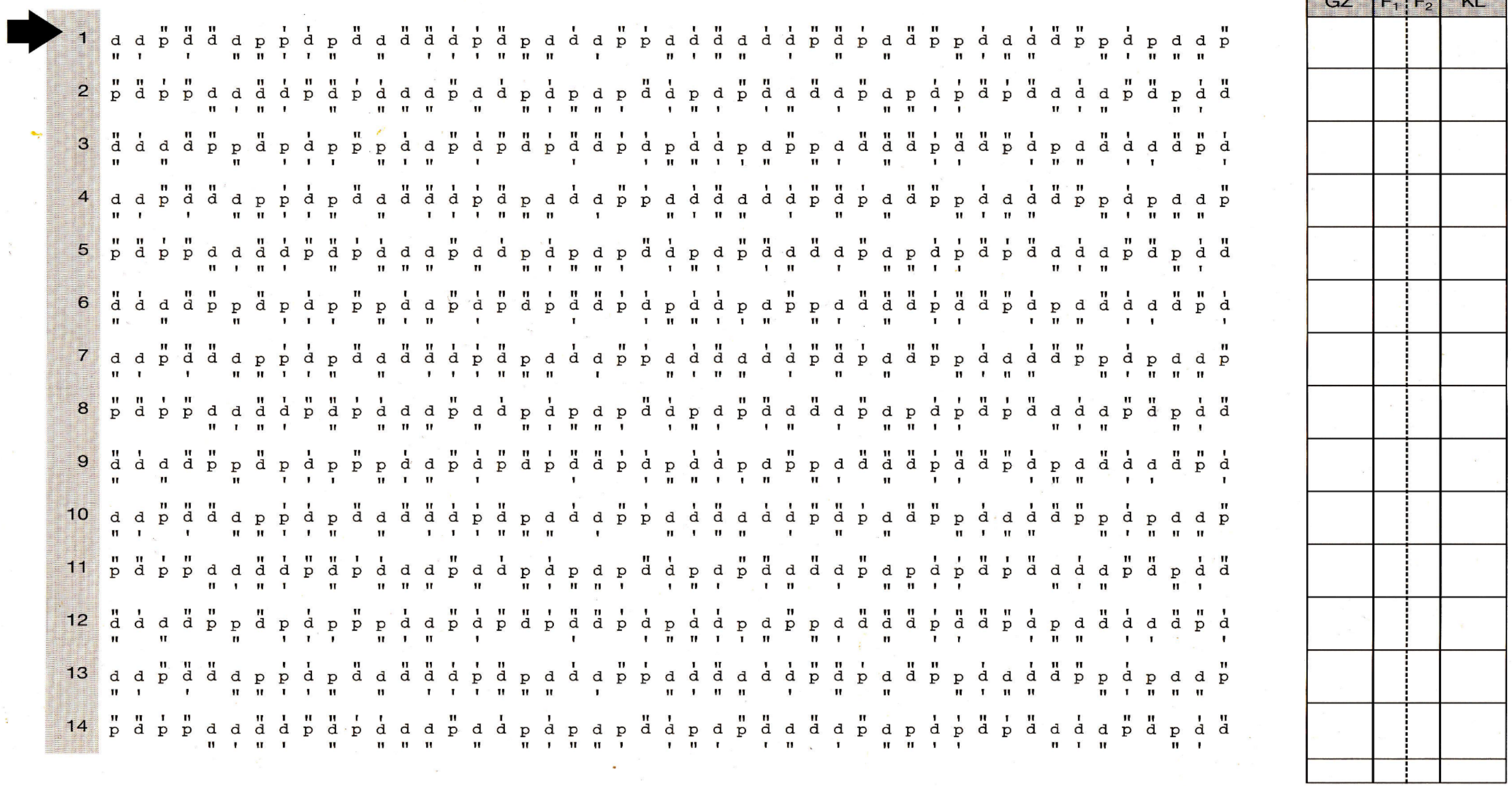
Port Elizabeth and Basel, January 2015; the SSAJRP-team

PART A
THE D2 TEST OF ATTENTION

At the beginning, we want to determine how well each of you **can focus** on a specific task (by means of the so-called d2 test). See the standard instructions for children which will be illustrated on the blackboard. The test sheet as you see below will be handed out to you prior to the execution of the test. The pure test execution time is 4 minutes and 40 seconds, the total time including instruction is about **8 minutes**.

Example: 

Exercise line: 



PART B
SOCIO-ECONOMIC AND DEMOGRAPHIC PROFILE

1. ID-Number (filled out by the researcher): ☐☐☐☐☐

2. First name: ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

3. Surname: ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

4. Age: (in completed years) ☐☐

5. Grade: ☐☐

6. Surname of the teacher: ☐☐☐☐☐☐☐☐☐☐☐☐☐☐

7. Ethnic group/race: ☐ 1. Black ☐ 2. Indian ☐ 3. Coloured ☐ 4. White

☐ 5. Mixed: ____________ & _____________

8. Home language: ☐ 1. Xhosa ☐ 2. Afrikaans ☐ 3. English ☐ 4. Other: ______________

9. Asset ownership: Do you have at home…

a.	**… a washing machine for clothes?**	☐Yes	☐No
b.	**… a fridge?**	☐Yes	☐No
c.	**… a freezer for food?**	☐Yes	☐No
d.	**… radios?**	☐Yes, how many: _______	☐No
e.	**… a land line phone / house phone?**	☐Yes	☐No
f.	**… a television?**	☐Yes, how many: _______	☐No
g.	**Do your parents have a cell phone?**	☐Yes, how many: _______	☐No
h.	**Does your family have a car?**	☐Yes, how many: _______	☐No
i.	**Does your family have a computer?**	☐Yes, how many: _______	☐No

Housing questions:

10. Do you live in a …

a. Shack in informal settlement ☐
b. Backyard shack/room ☐
c. Privately built house ☐
d. RDP house ☐
e. Council house ☐
f. Other, specify: ☐ ☐☐☐☐☐☐☐☐☐☐☐

11. How is your house made?

a. Zinc ☐
b. Bricks ☐
c. Wood ☐
d. Other, specify: ☐ | | | | | | | | | | | | |

12. How many bedrooms does your house have? | | |

13. Do you have a bathroom inside your house? ☐Yes ☐No

14. Do you have a toilet inside your house? ☐Yes ☐No

15. What type of toilet does your house have?

a. Flush toilet ☐
b. Pit toilet ☐
c. Bucket ☐
d. Communal toilet ☐

16. How does your family get water?

a. Taps inside house ☐
b. Tap in the yard ☐
c. Water tank ☐
d. Communal tap/tap shared with other families ☐

17. Does your house have electricity? ☐Yes ☐No

18. How does your family cook food? With ...

a. Electricity ☐
b. Gas ☐
c. Paraffin stove ☐
d. Fire ☐

Family questions:

19. How many other people live in your house with you? | | |

20. Who looks after you for most of the time?

a. Mother and father ☐
b. Mother only ☐
c. Father only ☐
d. Grandparents ☐
e. Brothers or sisters ☐
f. Other adults / guardians ☐

21. Who in your house has a job?

a. Both parents / guardians ☐
b. One parent or guardian ☐
c. None is employed ☐

22. Does any person in your house get a government grant?

☐Yes ☐No ☐ Don't know

PART C
BRIEF SELF-CONTROL SCALE (SCS)

Please choose the answer that best describes how you typically are.

	Never	Seldom	Sometimes	Often	Always
23. I am lazy.	☐	☐	☐	☐	☐
24. I say things that are strange and out of place.	☐	☐	☐	☐	☐
25. I do certain things that are bad for me, if they are fun.	☐	☐	☐	☐	☐
26. I refuse things that are bad for me.	☐	☐	☐	☐	☐
27. I am lacking self-discipline.	☐	☐	☐	☐	☐
28. I can't stop myself from doing something, even if I know it is wrong.	☐	☐	☐	☐	☐

PART D
SCHOOL BURNOUT INVENTORY (SBI)

Please choose the answer that best describes your situation at school. Think about the last week…

	Never	Seldom	Sometimes	Often	Always
29. I feel overstressed by my schoolwork.	☐	☐	☐	☐	☐
30. I feel a lack of motivation in my schoolwork.	☐	☐	☐	☐	☐
31. I think of giving up in my schoolwork.	☐	☐	☐	☐	☐
32. I feel that my schoolwork is weak.	☐	☐	☐	☐	☐
33. I sleep badly because of a matter related to my schoolwork.	☐	☐	☐	☐	☐
34. I feel that I am losing interest in my schoolwork.	☐	☐	☐	☐	☐
35. I am wondering whether my schoolwork has any meaning.	☐	☐	☐	☐	☐
36. I brood over matters related to my schoolwork a lot during my free time.	☐	☐	☐	☐	☐
37. I am not able to achieve so well in my school work.	☐	☐	☐	☐	☐
38. I learn things quickly in most school subjects.	☐	☐	☐	☐	☐

PART E
KIDSCREEN-27: Health Questionnaire for Children and Young People

Think about the last week...

39. In general, how would you say your health is?

a. Excellent ☐
b. Very good ☐
c. Good ☐
d. Fair ☐
e. Poor ☐

	Never	Seldom	Sometimes	Often	Always
40. Have you physically felt fit and well?	☐	☐	☐	☐	☐
41. Have you been physically active (e. g. running, playing)?	☐	☐	☐	☐	☐
42. Have you been able to run well?	☐	☐	☐	☐	☐
43. Have you felt full of energy?	☐	☐	☐	☐	☐
44. Has your life been enjoyable?	☐	☐	☐	☐	☐
45. Have you been in a good mood?	☐	☐	☐	☐	☐
46. Have you had fun?	☐	☐	☐	☐	☐
47. Have you felt sad?	☐	☐	☐	☐	☐
48. Have you felt so bad that you didn´t want to do anything?	☐	☐	☐	☐	☐
49. Have you felt lonely?	☐	☐	☐	☐	☐
50. Have you been happy with the way you are?	☐	☐	☐	☐	☐
51. Have you had enough time for yourself?	☐	☐	☐	☐	☐
52. Have you been able to do the things that you want to do in your free time?	☐	☐	☐	☐	☐

	Never	Seldom	Sometimes	Often	Always
53. Have your parent(s)/guardian(s) paid enough attention to you?	☐	☐	☐	☐	☐
54. Have your parent(s)/guardian(s) treated you fairly?	☐	☐	☐	☐	☐
55. Have you been able to talk to your parent(s)/guardian(s) when you wanted to?	☐	☐	☐	☐	☐
56. Have you had enough money to do the same things as your friends?	☐	☐	☐	☐	☐
57. Have you had enough money for your needs?	☐	☐	☐	☐	☐
58. Have you spent time with your friends?	☐	☐	☐	☐	☐
59. Have you had fun with your friends?	☐	☐	☐	☐	☐
60. Have you and your friends helped each other?	☐	☐	☐	☐	☐
61. Have you been able to rely on your friends?	☐	☐	☐	☐	☐
62. Have you been happy at school?	☐	☐	☐	☐	☐
63. Have you got on well at school?	☐	☐	☐	☐	☐
64. Have you been able to pay attention?	☐	☐	☐	☐	☐
65. Have you got along well with your teachers?	☐	☐	☐	☐	☐

PART F
Health Behaviours in School Age Children Survey

Physical activity can be done in sports, school activities, playing with friends or walking to school.

66. Over the past 7 days (1 week), on how many days were you physically active for a total of at least 60 minutes (1 hour) per day?

0 days	☐	4 days	☐
1 day	☐	5 days	☐
2 days	☐	6 days	☐
3 days	☐	7 days	☐

67. <u>OUTSIDE SCHOOL HOURS</u>: How OFTEN do you usually exercise in your free time so much that you get out of breath or sweat?

a. Every day ☐
b. 4 to 6 times a week ☐
c. 2 to 3 times a week ☐
d. Once a week ☐
e. Once a month ☐
f. Less than once a month ☐
g. Never ☐

68. How long does it usually take you to travel to school from your home?

a. Less than 5 minutes ☐
b. 5-15 minutes ☐
c. 15-30 minutes ☐
d. 30 minutes to 1 hour ☐
e. More than 1 hour ☐

69. On a typical day is the MAIN part of your trip TO school made by...? (Please circle one only)

a. Walking ☐
b. Bicycle ☐
c. Bus or train ☐
d. Car, taxi or motorbike ☐
e. Other means ☐

70. On a typical day is the MAIN part of your trip FROM school made by...? (Please circle one only)

a. Walking ☐
b. Bicycle ☐
c. Bus or train ☐
d. Car, taxi or motorbike ☐
e. Other means ☐

71. First and last name of the investigator: ____________________

____

Date of evaluation:

				2	**0**		

E Contributors

The author of this dissertation joined the DASH project as a master student in 2014. During this time, she helped with the development of the questionnaire found in Appendix D and she collected data during the baseline assessment from January to March 2015. One year later, the author joined the project as a research assistant and collected data in the end line assessment from May to June 2016. As of January 2017, the author started her doctorate, conducted data cleaning and statistical analyses, wrote the drafts of the manuscripts and published four papers as first author. The author was listed as a co-author in the study protocol, where she contributed to the methods and study design and reviewed the draft of the manuscript. In addition to the author, a large team consisting of experienced scientists, statisticians, teachers, nurses and students contributed to the success of the project. Their contributions to the project as well as the publications are specified below.

Prof. Dr. Uwe Pühse was the principal investigator and had the overall responsibility of the project together with Prof. Dr. Cheryl Walter. He secured funding, participated in the study design, monitored the process and ensured the integrity of any collaborative relationships. He supervised master students and reviewed the drafts of the manuscripts of all publications.

Prof. Dr. Cheryl Walter was the principal investigator and had the overall responsibility of the project together with Prof. Dr. Uwe Pühse. She participated in the study design, obtained permission from the Department of Health and Department of Education, established a trust relationship between the schools and the University. Furthermore, she recruited students and nurses to help with the data assessments and hosted international students. Moreover, she supervised master students and reviewed the drafts of the manuscripts of all publications.

Prof. Dr. Markus Gerber participated in the study design, established the methods and questionnaire, advised and supported in terms of structure and scope of this dissertation, advised and supported on statistical analyses in all four publications, critically revised the first versions of the manuscripts and reviewed the drafts of the manuscripts of all publications.

Prof. Dr. Rosa du Randt participated in the study design and advised on the methods. She helped writing the ethical proposal and advised on the setup of the study procedures. She reviewed the drafts of the manuscripts of all publications.

Dr. Ivan Müller led the project "Disease, activity and schoolchildren's health", including compiling of the study, applying for funding and writing the ethical proposal, developing the content of the multi-component physical activity intervention, conducting the sample size calculation, coordinating assessment periods and the implementation of the interventions and reviewing the drafts of the manuscripts of all publications. Furthermore, he supervised master students and he wrote the study protocol together with Dr. Peiling Yap.

Dr. Peiling Yap participated in the study design and supervised and supported the compiling of the study, advised on the setup of study procedures and methods, conducted sample size calculations, developed the content of the multi-component physical activity intervention and reviewed the first draft of the first publication. Furthermore, she wrote the study protocol together with Dr. Ivan Müller.

Dr. Harald Seelig participated in the study design, advised on the methods, data management and sample size calculations. He advised and supported on statistical analyses in all four publications as well as in the study protocol. Furthermore, he reviewed the drafts of the manuscripts of all publications.

Prof. Dr. Jürg Utzinger participated in the study design, advised on methods, and reviewed the drafts of the manuscripts of all publications.

Dr. Peter Steinmann participated in the study design, advised on methods, and reviewed the drafts of the manuscripts of all publications.

Dr. Liana Steenkamp advised and supported in the study design and supported the diagnostics in the lab.

Prof. Dr. Annelie Gresse advised and supported in the study design, the methods and in the development of the nutrition intervention.

Prof. Dr. Nicole Probst-Hensch participated in the study design, advised on methods, and reviewed the drafts of the study protocol.

Dr. Sebastian Ludyga supported and advised on statistical analyses and he reviewed the drafts of publication one and three.

Marina Salvini now Marina Mäder wrote the first draft of the second manuscript together with the author.

Danielle Smith obtained informed consent from schoolchildren, held workshops for coaches, students and teachers, collected and entered data. Furthermore, she wrote her master thesis and reviewed the draft of the study protocol, the first, third and fourth publication.

Siphesihle Nqweniso obtained informed consent from schoolchildren, held workshops for coaches, students and teachers, collected and entered data. Furthermore, she wrote her master thesis and reviewed the first, third and fourth publication.

Larissa Adams obtained informed consent from schoolchildren, held workshops for coaches, students and teachers, collected and entered data. Furthermore, she wrote her master thesis and reviewed the first, third and fourth publication.

Nandi Joubert helped with the data collection, wrote her master thesis and reviewed the draft of the third and fourth publication. Furthermore, she revised the grammar, punctuation and structure of this thesis.

Robyn Cody revised the grammar and punctuation of this thesis.

Further, a large team consisting of researchers, teachers, South African and Swiss students, nurses and coaches realized the implementation of the project. Schoolteachers implemented the nutrition, hygiene & health lessons and together with the coaches they conducted the physical education lessons. Human movement science students held the moving-to-music lessons. Swiss and South African students supported data collection (i.e. measured anthropometric data, assessed fitness and collected end of the year school grades etc.) and data entry. **Leyli Zondie** and **Lindsey Beyleveld** and her team provided diagnostic support in the laboratory. **Mr. Bruce Damons**, former principal of the Sapphire Road Primary, helped facilitate the collaboration with the teaching staff and the respective school health services. **Dominique Bänninger, Thomas Hager, Susanne Tschudi, Silvan Zwick, Marina Mäder, Benjamin Wegenstein** and **the author** collected data and wrote their master thesis in this project.