

**EXECUTIVE FUNCTION AND PHYSICAL ACTIVITY IN PRESCHOOL CHILDREN FROM LOW-
INCOME SETTINGS IN SOUTH AFRICA**

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PEER-REVIEWED PUBLICATIONS

Results from this thesis have been published in the articles references below. Sections of the publications can be found in this thesis, specifically in Chapters 4 (A) and Chapters 8 and 9 (B).

- A. Howard, S. J., Cook, C. J., Everts, L., Melhuish, E., Scerif, G., Norris, S., ... & Draper, C. E. (2019). Challenging socioeconomic status: A cross-cultural comparison of early executive function. *Developmental science*, e12854.

- B. Cook, C. J., Howard, S. J., Scerif, G., Twine, R., Kahn, K., Norris, S. A., & Draper, C. E. (2019). Associations of physical activity and gross motor skills with executive function in preschool children from low-income South African settings. *Developmental science*, e12820.

ABSTRACT

Executive function (EF), that shows rapid development in the preschool years, is foundational for cognitive development. Previous research has found aspects of physical development including gross motor skills and physical activity to be related to EF. However, evidence for these relationships in the preschool years, as well as in low- and middle-income countries is lacking. Therefore, this study aimed to investigate the relationships between EF (and related components of cognitive development) with physical activity and gross motor skills (GMS) in a sample of preschool children from urban and rural low-income settings in South Africa.

Cognitive and physical outcomes were measured in a sample of preschool children (N=129; M_{age} = 50.7±8.3 months; 52.7% girls) from urban (Soweto) and rural (Bushbuckridge) low-income settings in South Africa. Cognitive components included EF, self-regulation (Early Years Toolbox, EYT), attention (adapted visual search task) and school readiness (Early Childhood Development Criteria Test). Physical outcomes included objectively measured physical activity (accelerometry), gross motor skills (Test for Gross Motor Development 2) and anthropometric measurements (height and weight).

On average, children from both settings showed higher than expected scores for EF and self-regulation (based on Australian norms for the EYT), adequate gross motor proficiency and high volumes of physical activity (M_{total physical} = 476 minutes per day). In contrast, a high proportion of children, particularly in the rural setting, demonstrated below average scores for school readiness. Investigations into the relationships revealed that EF was positively associated with self-regulation, attention and school readiness. Positive associations were also found between GMS and physical activity and, and physical activity and body mass index (BMI). And finally, that GMS, but not physical activity, was positively associated with all components of cognitive development.

This study is the first to provide evidence for the importance of EF and the link between motor and cognitive development in preschool children from South African, low-income settings. Another key finding was that there may be factors promoting early EF skills in these settings but that these skills, although associated, are not transferring to school readiness. The lack of (or negative) associations between physical activity and cognition presents another key finding, further research is needed to identify whether there are specific amounts and types of physical activity that specifically benefit cognitive development.

CONTENTS PAGE

LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF APPENDICES	xiii
LIST OF ABBREVIATIONS	xiv
CHAPTER 1: INTRODUCTION	1
CHAPTER 2: LITERATURE REVIEW	4
2.1 Introduction	4
2.2 Executive function	5
2.3 Components of cognitive development related to EF	13
2.4 Components of physical development related to EF	18
2.5 Relationships between components of cognitive and physical development	24
2.6 Aims and objectives	30
CHAPTER 3: METHODS	32
3.1 Study settings	32
3.2 Sample details	37
3.3 Data collection: Measures	39
3.4 Data collection: Procedure	56
3.5 Statistical analyses	57
3.6 Ethics	57
CHAPTER 4: DESCRIBING COGNITIVE AND PHYSICAL OUTCOMES	59
4.1 Introduction	59
4.2 Methods	61
4.3 Results	62
4.4 Discussion	76
4.5 Conclusion	88
CHAPTER 5: EXPLORING ASSOCIATIONS BETWEEN COMPONENTS OF COGNITIVE DEVELOPMENT	89
5.1 Introduction	89

5.2 Methods	91
5.3 Results	92
5.4 Discussion	95
5.5 Conclusion	97
CHAPTER 6: MODELLING THE ASSOCIATIONS OF EXECUTIVE FUNCTION AND SELF-REGULATION WITH SCHOOL READINESS _____	99
6.1 Introduction	99
6.2 Methods	101
6.3 Results	102
6.4 Discussion	105
6.5 Conclusion	108
CHAPTER 7: ASSOCIATIONS OF PHYSICAL ACTIVITY AND GROSS MOTOR SKILLS WITH ADIPOSITY _____	110
7.1 Introduction	110
7.2 Methods	112
7.3 Results	113
7.4 Discussion	115
7.5 Conclusion	118
CHAPTER 8: ASSOCIATIONS BETWEEN PHYSICAL ACTIVITY AND GMS WITH COMPONENTS OF COGNITIVE DEVELOPMENT _____	119
8.1 Introduction	119
8.2 Methods	121
8.3 Results	123
8.4 Discussion	131
8.5 Conclusion	139
CHAPTER 9: CONCLUSION _____	141
9.1 Summary of findings	141
9.2 Implications and recommendations	143
9.3 Strengths and limitations	149
9.4 Future research directions	152
9.5 Conclusion.....	153
REFERENCES _____	155

LIST OF TABLES

Table number	Table heading	Page number
3.1	Summary of the variables measured	53
4.1	Participant characteristics	60
4.2	Performance on each executive function task on the EYT	61
4.3	Scores for teacher-rated self-regulation	63
4.4	Selective attention scores	64
4.5	School readiness total score and percentile scores for each subtest	65
4.6	Average time spent per day in each physical activity intensity	67
4.7	Average time spent in physical activity on a weekday	68
4.8	Average time spent per in physical activity on a weekend day	69
4.9	Raw and standardised scores for gross motor skills	71
5.1	Bivariate and partial correlations between EF, self-regulation and selective attention measures	90
5.2	Exploratory Factor Analysis 1: EF, self-regulation and attention	91
5.3	Exploratory factor analysis 2: EF and selective attention	91
6.1	Bivariate correlations between school readiness, self-regulation and executive function	98
7.1	Bivariate correlations between anthropometric measures, physical activity and GMS	109
7.2	Hierarchical regression models predicting BAZ score	110
8.1	Summary details of the multiple linear regression analyses predicting performance on EF tasks	118
8.2	Summary details of the multiple linear regression analyses predicting teacher-ratings of self-regulation	121
8.3	Summary details of the multiple linear regression analyses predicting teacher-ratings on selective attention tasks	124
8.4	Summary details of the multiple linear regression analyses predicting school readiness	125

LIST OF FIGURES

Figure number	Figure heading	Page number
2.1	Relationships between components of physical and cognitive development based on the current international evidence	27
2.2	Hypotheses with regards to how the relationships between outcomes of interest may differ in South African low-income settings.	28
3.1	Map showing the location of the two study sites and the University of Cape Town	33
3.2	Photos of the urban preschools and surroundings	34
3.3	Photos of the rural preschools and surroundings	35
3.4	Participant numbers	37
3.5	Inhibition assessment on the EYT: Go-No-Go	40
3.6	Shifting assessment on the EYT: Rabbits & Boats	41
3.7	Working memory (visual-spatial) assessment on the EYT: Mr Ant	42
3.8	Self-regulation assessment on the EYT: CSBQ	42
3.9	Baseline run with single target and no distractors	45
3.10	Run with single target and distractors	46
3.11	Baseline run with multiple targets and no distractors	46
3.12	Run with multiple targets and distractors	47
4.1	Proportion of urban and rural children classified as stunted or wasted	60
4.2	Proportion of female and male children classified as stunted or wasted	61
4.3	Proportion of urban and rural children per ECDC descriptive category	66
4.4	Proportion of female and male children per ECDC descriptive category	66
4.5	Graph showing the differences between time spent in physical activity on weekdays vs. weekend days for the total sample	69
4.6	Proportion of urban and rural children per gross motor skill ranking category	72
4.7	Proportion of female and male children per gross motor skill ranking category	72
6.1	Model 1 showing independent associations of executive function latent variable with cognitive self-regulation and school readiness. CSR = cognitive self-regulation	99
6.2	Model 2 showing associations of the executive function latent variable with cognitive self-regulation and school readiness. EF = executive function; CSR = cognitive self-regulation	100

6.3	Model 3 showing executive function and self-regulation latent variables with school readiness	101
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LIST OF APPENDICES

Appendix number	Appendix description	Applicable chapter
Appendix A	Information sheet and consent form for parents	Chapter 3
Appendix B	Information sheet for looking after accelerometers	Chapter 3
Appendix C	Child Self-regulation and Behavior Questionnaire (CSBQ)	Chapter 3

LIST OF ABBREVIATIONS

Abbreviation	Meaning
BAZ	BMI-for-age-z-score
BMI	Body mass index
BSR	Behavioural self-regulation
CSR	Cognitive self-regulation
EC	Effortful control
ECCE	Early Childhood Care and Education
ECD	Early childhood development
ECDC	Early Childhood Development Criteria
EF	Executive function
ESR	Emotional self-regulation
DCCS	Dimensional Change Card Sort
GMQ	Gross motor quotient
GMS	Gross motor skills
HAZ	Height-for-age-z-score
HICs	High-income countries
IOTF	International Obesity Task Force
IQR	Inter-quartile range
LMICs	Low- and middle-income countries
LMVPA	Light- to vigorous-intensity physical activity (total physical activity)
LPA	Light-intensity physical activity
MPA	Moderate-intensity physical activity
MVPA	Moderate- to vigorous-intensity physical activity
Q score	Quality of search score
SANHANES	South African National Health and Nutrition Examination Survey
SD	Standard deviation
SES	Socioeconomic status
TGMD-2	Test for Gross Motor Development Version 2
VPA	Vigorous-intensity physical activity
WAZ	Weight-for-age-z-score
WEIRD	Western, Educated, Industrialised, Rich and Democratic
WHO	World Health Organisation

CHAPTER 1: INTRODUCTION

Early childhood is a period of rapid development, particularly the development of executive function (EF; Blair, Zelazo, & Greenberg, 2005), a set of higher order cognitive skills that enable adaptive and goal-directed behaviours (Best & Miller, 2010). EF in the early years has been found to contribute to self-regulation (Hofmann, Schmeichel, & Baddeley, 2012), predict academic achievement (Ribner, Willoughby, & Blair, 2017), school readiness (Pellicano et al., 2017), lifelong achievement, health, wealth and quality of life (Moffitt et al., 2011). The preschool years are also critical for the development of basic gross motor skills (Clark, 2005), and for setting habits for health behaviours, including physical activity, that track across childhood and into adulthood (Telama et al., 2014). This is important considering the beneficial effects of physical activity on physical health (for e.g. cardiovascular health, bone health, body weight; Janssen & Leblanc, 2010), mental health (Biddle & Asare, 2011), social-emotional factors (Ludwig & Rauch, 2018) and, according to suggestions of more recent research, even cognitive aspects such as EF (Jackson, Davis, Sands, Whittington, & Sun, 2016). The potential reciprocal relationships between the physical and cognitive development raises the possibility that an appropriate intervention in one of these areas could have flow-on effects more broadly to other areas (such as recent proliferations of physical activity approaches to supporting EF development; Schmidt et al., 2015).

A recent Lancet series (Black et al., 2017; Britto et al., 2017; Daelmans et al., 2017) has emphasised not only the importance of the early years in setting children up for success, but also that this period presents a critical time for intervention. Intervening in the early years is of particular importance in low- and middle-income countries (LMICs) as children from LMICs are at risk for poor development, with 219 million (39%) children under the age of five years from LMICs being at risk for not reaching their developmental potential (Black et al., 2017). South Africa is one such LMIC, in which more than 7 million children live below the food poverty line (Hall, Richter, Mokomane, & Lake, 2018), and thus a large portion of children may be at risk for not reaching their developmental potential. While interventions targeting children living in poverty in this particular age group are therefore of the highest priority,

effective interventions necessitate a clear understanding of the specific context in which they are due to operate, in addition to underlying cognitive mechanisms and risk factors.

The effect of poverty on children's developmental potential (Lu, Black, & Richter, 2016) has been illustrated by research in school achievement, which has consistently shown that children from low-income settings have poorer academic achievement compared to children from high-income settings (Hair, Hanson, Wolfe, & Pollak, 2015). This is similarly evident in low-income settings of South Africa (Pretorius & Naudé, 2002; Spaul & Kotze, 2015), and shows that this achievement gap starts before school (Draper, Achmat, Forbes, & Lambert, 2012; Naudé, Pretorius, & Viljoen, 2003). Therefore, identifying methods to improve school readiness skills in children from low-income settings is necessary to reduce the achievement gap.

On the other hand, physical activity levels and gross motor proficiency is comparatively higher in South Africa (Tomaz, Hinkley, et al., 2019; Tomaz, Pioreschi, et al., 2019). Given the link between physical and cognitive development mentioned earlier, there is the possibility that this could be leveraged to promote aspects of cognitive development in South African settings. For example, one study showed that exposure to a motor development intervention not only improved GMS, but also improved school readiness skills in a sample of preschool children from low-income settings in South Africa (Draper et al., 2012). This finding suggested that GMS and physical activity could have a role to play in promoting school readiness skills. While research has begun to characterise the physical activity levels and gross motor proficiency of South African preschool children (Draper et al., 2019, 2017; Tomaz, Hinkley, et al., 2019; Tomaz, Pioreschi, et al., 2019), there has been no more research investigating the effects of GMS and physical activity interventions on school readiness, or even other aspects of cognitive development. What is more, the area of cognitive development is largely unexplored in the preschool age group in South Africa, including aspects of cognitive development that have been known to play a substantial role in school readiness and subsequent academic achievement, such as EF, self-regulation, and attention.

The intention of the study presented in this thesis was to more rigorously and comprehensively investigate these previously unexplored components of cognitive

development, and their associations with physical activity and GMS in preschool age children from low-income settings in South Africa. Chapter 2 aims to explore the existing evidence on cognitive and physical development, and their potential links, and highlights the areas of research that need to be covered. Chapter 3 aims to provide detailed descriptions of the methods that were followed to collect data on EF, self-regulation, selective attention, school readiness, physical activity, gross motor skills and anthropometric measures. Chapter 4 presents results on both physical and cognitive development in the studied settings, comparing urban and rural settings as well as boys and girls. Chapters 5 and 6 aim to analyse the associations between components of cognitive development and how these relate to school readiness. Associations between components of physical development are presented in Chapter 7, to determine whether results from previous research in similar settings are replicated in the current sample. Relationships between physical activity and GMS with each component of cognitive development are explored in Chapter 8, to determine whether these associations are similar to those found in international research. Finally, Chapter 9 provides a summary of the findings, highlighting novel findings and discussing implications of the results from Chapter 4 to 8. Chapter 9 also includes the strengths and limitations of this study as well as recommendations and avenues for future research.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Executive function (EF) is speculated to play a pivotal role in early development, and predict health and well-being outcomes later in life (Willoughby, Wirth, & Blair, 2012). For this reason, researchers and practitioners have been interested in understanding the development of EF, particularly the preschool years given that they show rapid development during these years. (Ackerman & Friedman-Krauss, 2017). This includes understanding the relationships between EF and other aspects of cognitive development such as self-regulation, attention, school readiness and academic outcomes. In addition, concerted efforts have also been directed to determining modifiable factors that might affect EF, both positively and negatively. Physical activity, for example, is a factor that has shown to have a positive effect on EF development – although the components, conditions and mechanisms of these relationships are less clear (Best, 2010; Carson et al., 2015; Diamond, 2012; Tandon et al., 2016). On the other hand, poverty has shown to have a profound negative effect on early childhood development, including EF development (Hackman, Gallop, Evans, & Farah, 2015).

Over the last decade, there has been increased interest in EF development in the early years; however, as with most trends in psychological research, the majority of it has been conducted in ‘western, educated, industrialised, rich and democratic’ (WEIRD) countries (Azar, 2010). Even the evidence for effects of disadvantage and deprivation has largely derived from low-income settings within high-income countries (HICs; Hackman, Gallop, Evans, & Farah, 2015). These findings often inform interventions and policies in low- and middle-income countries (LMICs), yet have unclear generalisability to those settings. Therefore, a better understanding of EF and its correlates in LMICs, such as South Africa, is necessary to inform interventions, policies and early education.

2.2 Executive Function

2.2.1 Definition of executive function

EF is a core component of cognitive development, central to success in school, social function and financial/career success (Diamond, 2013; Moffitt et al., 2011). The definition of EF and its subcomponents have evolved over the years and yet, even after the surge in interest in EF over the last decade, a concrete definition has not been established (Barkley, 2012; Karr et al., 2018). One of the first theories concerning the structure of EF posited a 'Central Executive' that controlled lower level cognitive contents in working memory (Baddeley & Hitch, 1974). Another theory proposed a 'Supervisory Attentional System', instead of the Central Executive, that controlled attention and attentional resources (Norman & Shallice, 1986). Both of these theories suggested a unitary view of EF and emphasised the role of the frontal lobes for EF processing. Since then, definitions of EF have become more nuanced. EF is now considered an umbrella term encompassing multiple cognitive skills, with neural correlates extending beyond the frontal lobes to include connecting structures (Alvarez & Emory, 2006; Shimamura, 2000).

EF skills enable adaptive and goal-directed behaviours that are employed when automatic responses would not be beneficial or sufficient (Best & Miller, 2010). Tripartite models of mature EF are characterized by the ability to: (a) hold information in mind, mentally work with that information and behave based on it; (b) exercise self-control by suppressing impulses and strategically selecting alternative behaviours; and (c) flexibly adjust to changing task demands and situations (Diamond, 2013; Garon, Bryson, & Smith, 2008). These abilities make up the broad framework of EF and are referred to respectively as working memory, inhibition, and shifting (Best & Miller, 2010; Diamond, 2013; Miyake et al., 2000; Obradovic et al., 2012).

The increased interest in EF in early childhood has been motivated by its predictive associations with broad outcomes from childhood to adulthood. For example, longitudinal studies have found that early childhood EF predicted academic and occupational functioning (Bull, Espy, & Wiebe, 2008; Miller, Nevado-Montenegro, & Hinshaw, 2012). Another study found that adolescent EF predicted risky behaviour (e.g. smoking, alcohol, drugs, sex, driving

and antisocial behaviour) during adolescence and emerging adulthood (Pharo, Sim, Graham, Gross, & Hayne, 2011). This was also found in early childhood as self-control (component of inhibition) from as young as three years old predicted physical health, substance use, personal finances and criminal activities in adulthood (Moffitt et al., 2011). EF has even been identified as a predictor of food intake and physical activity (Riggs, Chou, Spruijt-Metz, & Pentz, 2010), as well as body mass (Schlam, Wilson, Shoda, Mischel, & Ayduk, 2013).

2.2.2 Executive function in the preschool years

Research in EF in the early years (particularly infants and preschool-age children) was later to emerge, as it was initially believed that EF skills did not emerge until later in childhood or even adolescence (as highlighted by Hughes, 2007). Among other reasons, this delay was largely driven by the fact that most EF measures were designed for adults, which were not appropriate for accurate and sensitive capture of young children's EF abilities (Hughes & Graham, 2002). However, in recent decades this research has expanded exponentially, and these findings have highlighted the preschool years as a period of rapid development in cognitive outcomes (particularly EF; Zelazo et al., 2003). Despite this rise in interest, EF in the early years is still insufficiently understood (e.g., its nature, development, antecedents and casual outcomes), especially in non-WEIRD settings.

In the adult literature, there is general agreement that EF is an umbrella term encompassing dissociable yet related factors (inhibition, shifting and working memory), also referred to as the tripartite or three-factor organisation (Miyake et al., 2000). In contrast, the organisation of EF in the early years is still very much under debate with some researchers suggesting that EF is a unitary construct (Hughes, Ensor, Wilson, & Graham, 2010; Wiebe, Espy, & Charak, 2008), while others suggest a diversity of factors (Lee, Bull, & Ho, 2013). Even those who agree on a diversity of factors disagree on the number of factors encompassed by EF. These heterogeneous results point towards age-related changes in EF that occur over the preschool years that can generally be reconciled into a developmental model of EF (Lee et al., 2013). Each of these components will be described in turn.

Inhibition is the ability to control one's thoughts, attention and behaviours through actively inhibiting a dominant response (response inhibition), and resisting distractions (interference control), where necessary to achieve a goal (Friedman & Miyake, 2004). In early childhood, inhibition allows a child to stop doing something they might not want to stop – such as playing on the swings – and start doing something they might not want to do – such as washing their hands for lunch. Inhibition is found to appear towards the end of the first year of life, with the most rapid development seen in the toddler and preschool years. However, full maturity is not reached until late adolescence or early adulthood (Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002; Diamond, 1990; Dowsett & Livesey, 2000; Durston et al., 2002).

Working memory is the capacity to keep verbal and non-verbal (visual-spatial) information in mind for a short period of time, as well as update, combine and manipulate that information when it is needed to complete a task or carry out an action (Alloway, Pickering, & Gathercole, 2006; Baddeley & Hitch, 1974; Diamond, 2013). This skill is needed to perform everyday tasks such as interpreting and maintaining instructions in mind, in order to act accordingly, such as remembering and abiding by the rules in a classroom or on the sports field (Diamond, 2013). The prefrontal cortex—and more specifically the dorsolateral prefrontal cortex—are believed to be critical in working memory by keeping information in a dynamic state, making it easily accessible and therefore more easily processed (Goldman-Rakic, 1987; Kane & Engle, 2002). The development of working memory starts at infancy with the ability to keep small pieces of information in mind, followed soon by the ability to update that information, which is seen between the ages of nine and twelve months (Diamond, 1985). However, the ability to concurrently process and manipulate more substantial amounts of information, at greater accuracy, has a much slower developmental trajectory. Working memory skills emerge progressively over the first five years of life, with linear changes successfully measured from age three (Hughes et al., 2010; Lee et al., 2013), reaching the differentiation from other EFs that are measured later in childhood and adulthood (Miyake et al., 2000) at around six years of age.

Shifting is the ability to adjust or adapt responses and resources according to the situational demands (Chevalier & Blaye, 2008; Zelazo, 2006), and allows one to think creatively, multitask and problem solve. This ability to shift between very simple behavioural responses can be

seen as early as infancy (e.g. between possible locations for a hidden object as in the A-not-B task); however flexibly shifting between complex sets of rules and changing contexts is dependent on the other two components, (working memory & inhibitory control) and as a result only matures later in the preschool years (Davidson et al., 2006; Diamond, 2013; Obradovic et al., 2012). This is illustrated in performance on the Dimensional Change Card Sort task (Zelazo, 2006), in which children have to sort cards based on alternating rules (colour and shape). In this task, 3-year-olds often perseverate on an initial sorting rule, which is typically mastered by 4-5 years of age. Flexible switching on this task (between sorting rules) is not consistently found until around age 7.

2.2.3 Factors influencing the development of executive function

Given findings of the importance of EFs for immediate adaptive function (e.g. Becker, Miao, Duncan, & McClelland, 2014; Ribner et al., 2017) and longitudinal outcomes (e.g. Clark, Sheffield, Weibe, & Espy, 2013; Pharo et al., 2011), understanding factors that underlie and influence EF development is vital. It has long been known that brain development is shaped by early life experiences (Greenough, Black, & Wallace, 1987; Gunnar & Fisher, 2006). To date, research has identified individual (e.g., genetics; Barnes, Dean, Nandam, O'Connell, & Bellgrove, 2011; Friedman et al., 2008) and environmental characteristics (e.g., parenting: Hughes & Devine, 2019, early education: Bierman & Torres, 2010, socioeconomic status; Blair & Raver, 2016) associated with the development of EF in early childhood, with the latter often targeted as more-malleable antecedents of EF.

Environmental factors affecting the development of EF in the preschool years mainly involve a child's family and early education experiences. In terms of the family, parenting practices (Bernier, Carlson, & Whipple, 2016; Fay-Stammach, Hawes, & Meredith, 2014; Hughes & Devine, 2019; Lucassen et al., 2015; Vernon-Feagans, Willoughby, & Garret-Peters, 2016), parental education (Bradley & Corwyn, 2002; Noble et al., 2015), parental EF (Warner, Sanchez, Dawoodian, Li, & Momand, 2014), household chaos (Vernon-Feagans et al., 2016), household crowding (Evans & English, 2002) and stressful events (Blair & Raver, 2016) have all been associated with EF. Good quality education in the preschool years has also been positively associated with EF development (Bierman & Torres, 2016). Environmental factors

also include risk factors during pregnancy (e.g. maternal alcohol consumption, maternal anxiety, gestational exposure to Bisphenol A; Kesmodel et al., 2012; Buss, Davis, Hobel, & Sandman, 2011; Braun et al., 2011).

Many of the factors above that negatively influence EF, in its influence on characteristics of a child's environment, are prevalent in settings of poverty. Numerous studies have reported that children growing up in low-income settings perform worse on measures of cognitive development, including EF, than children from higher income settings (Mezzacappa, 2004; Noble, McCandliss, & Farah, 2007). Further, children from low-income households tend to experience more stressful events than children in higher-income households (Evans & English, 2002; Evans & Kim, 2007, 2013), leading to neurochemical changes in the stress response system that negatively impact the prefrontal cortex and its connecting structures, with likely negative flow-on effects for EF development (Arnsten, 2009, 2011; Blair, Granger, & Razza, 2005).

Many of these factors are not easy to change. For example, changing the socio-economic status of a family, parental education levels or early life experiences would require extensive and intensive interventions that, although important, may not always be possible. For this reason, researchers have looked to factors associated with EF that may be more accessible, economical or tolerable to change. Physical activity (Best, 2010) and gross motor skills (GMS; Oberer, Gashaj, & Roebbers, 2017) have been speculated as two of these factors that might have not only implications for health and physical well-being, but also cognitive development. However, the exact nature, components, conditions and mechanisms with which physical activity and GMS might related to EF remains unclear, with mixed results (Best, 2010). In addition, it is unclear to what extent physical activity and GMS might interact with other components related to EF, such as self-regulation (Hofmann et al., 2012), attention and school readiness (Pellicano et al., 2017). A better understanding of these physical components and how they interact with EF (and related abilities) is crucial to determining how these might leveraged (if at all) to improve EF, particularly in children who may be at risk for poor cognitive development.

2.2.4 Executive function in low- and middle-income countries

Much of what is known about EF, including its early precursors and correlates, is drawn from HICs with only limited evidence from LMICs. Nevertheless, the small pool of evidence from LMICs has indicated both similarities and dissimilarities with HICs. For example, this evidence replicates the finding in HICs that EFs are susceptible to change, with certain interventions having shown to successfully improve EF performance (e.g., music training, rituals, physical activity programs; Alemán et al., 2017; Rybanska, McKay, Jong, & Whitehouse, 2017; Wen et al., 2018; Xiong, Li, & Tao, 2017). The well-established socio-economic gradient of EF in HICs (Hackman, Gallop, Evans, & Farah, 2015; Obradović, Portilla, & Ballard, 2016; Ursache & Noble, 2016) has also been found in some LMICs (Fernald, Weber, Galasso, & Ratsifandrihamanana, 2011; Howard et al., 2019; Piccolo, Arteche, Fonseca, Grassi-Oliveira, & Salles, 2016).

The existence of this socio-economic gradient of EF in both HICs and LMICs would imply that children from HICs should have better EF skills compared to children from LMICs. However, cross-cultural studies have suggested that this may not universally be the case. To date, there have been a various studies that attempted to compare EF performance cross-culturally (Ellefson, Ng, Wang, & Hughes, 2017; Gonen et al., 2018; Holding et al., 2018; Legare, Dale, Kim, & Deák, 2018; Sabbagh, Xu, Carlson, Moses, & Lee, 2006; Song & Jinyu, 2017; Wang, Devine, Wong, & Hughes, 2016), of these however, very few have directly compared samples from a LMIC with a sample from a HIC. One study identified that has done this (Gonen et al., 2018), compared two low-income samples: one from the United States (HIC) and the other from Turkey (LMIC). Results revealed that the sample from Turkey performed better on measures of EF compared to the U.S. sample. In a similar study, Chinese preschoolers (LMIC) outperformed their United States counterparts (HIC) on all measures of EF (Sabbagh et al., 2006). Even a sample from South Africa (including data from the current study) has shown greater performance on EF measures compared to children from Australia (Howard et al., 2019). The reason for this superior performance of children in at least some LMIC contexts remains unknown, but suggestions include: that the saliency and impact of risk-factors may differ based on social-cultural backgrounds (Bradley et al., 2001; Gonen et al., 2018); or certain contextual factors in LMICs (e.g., rituals, collectivist culture, children's roles and responsibilities, high levels of physical activity) may promote the development of EF. Although

these studies present some evidence of cross cultural comparisons, they do not ascribe casual pathways and are therefore unable to rule out potential confounds. For example, in the cross cultural comparison between South Africa and Australia, the authors suggest that differing levels of compliance may have affected performance on the EF tasks (Howard et al., 2019). Similarly, Gonen et al. (2018) noted that the quality and nature of preschool education and relationships with caregivers and teachers may have affected development and thus, performance on EF tasks. Therefore, more experimental research from LMICs is needed to understand whether and how different factors influence EF.

South Africa is a LMIC that in many ways is representative of many other LMICs. For example, there is widespread inequality in which the low-income settings do not have access to the same resources and infrastructure that is available to the higher-income groups in the country. Issues such as poverty, poor early childhood education, lack of basic amenities and food insecurities are all prevalent in South Africa's low-income settings, many of which are prevalent in other LMIC's in Africa, Asia and South America. South Africa also has unique characteristics and social-cultural contexts. For example, Ubuntu is a value that is entrenched in the African culture and is defined as the capacity to: "express compassion, reciprocity, dignity, harmony and humanity in the interests of building and maintaining community with justice and mutual caring" (Nussbaum, 2003, p. 2). As a result, there is a strong sense of community and family within the African culture including a great respect for elders, participation in community and family gatherings (church, funerals, weddings), and a sense of responsibility within the family structure. South Africa is also rich with diversity, with 11 official languages and numerous ethnicities. Yet, very little is known about EF in typically developing preschool children in these unique contexts. Indeed, factors that are known to negatively influence EF are prominent in South Africa. For example, figures have shown that more than half of the South African population lives in poverty (Statistics South Africa, 2014), which current international literature (Hackman et al., 2015) would suggest places more than half the population at risk for poor EF. However, as with the other LMICs, EF risk-factors and or EF promoting factors may operate differently in South African settings, warranting research in this setting.

2.2.5 Assessing executive function in preschool children

There are many challenges associated with measuring EF in infants and preschool children, and these have limited our understanding of EF in this age group. As highlighted above, one of the biggest limiting factors is the lack of consensus regarding the structure and organisation of EF in the early years (Morra, Panesi, Traverso, & Usai, 2018). Because researchers choose measures based on their understanding of EF, there is inconsistency in the current literature as studies differ in both the types of measures and the number of factors that are measured. While there are more commonly used and trusted measures, there is still no 'gold-standard'.

Some commonly used performance-based measures of inhibition include Stroop-like tasks (e.g., do the opposite to what a pre-established impulse dictates), such as the shape Stroop, day-night Stroop and grass/snow Stroop. Other tasks include the hand game (Luria, Pribram, & Homskaya, 1964), Bear and dragon (Kochanska, Murray, Jacques, Koenig, & Vandegest, 1996) and day and night test (Gerstadt, Hong, & Diamond, 1994). Also measuring inhibition are go/no-go tasks and stop-signal tasks (e.g., respond to the frequent stimuli that generate a pre-potent response, and withhold responding for other less frequent stimuli). Delay tasks such as the snack delay and gift delay (e.g., withhold indulging in a desired food or activity for a period of time) are used to assess delay of gratification aspects of inhibition. For shifting, card-sorting tasks such as the Dimensional Change Card Sort Test (Philip David Zelazo, 2006), the Wisconsin Card Sort Test (Chase-Carmichael, Ris, Weber, & Schefft, 1999), Hearts and Flowers (Diamond, Barnett, Thomas, & Munro, 2007) and Shape School (Epsy, Bull, Martin, & Stroup, 2006) are commonly used. For working memory, commonly used are span tasks (e.g., repeat a verbally presented sequence of digits/letters/stimuli either in forward or reverse order; Carlson, Moses, & Breton, 2002), Corsi Blocks (tap a sequence of blocks in the same or backwards order from what was presented; Vandierendonck, Kemps, Fastame, & Arnaud, 2004), and Spin the pots (Hughes & Ensor, 2010).

Selecting consistent, age- and context-appropriate EF measures is thus challenging; however, selecting them for low-income samples, particularly in LMICs, presents even more challenges. This is because the majority of measures have been created and validated in WEIRD contexts (Azar, 2010). Non-WEIRD settings differ in language, contextual background, prior knowledge and even technological expertise. Recent studies have attempted to adapt WEIRD measures

in LMICs with success (Holding et al., 2018; Willoughby, Piper, Kwayumba, & McCune, 2019). Both studies revealed that although these LMIC contexts differ vastly from the contexts for which these tasks were created, it seems that with linguistic and cultural adaptations, they are still accurately able to measure EF with little confounding effects. However, cultural and linguistic factors are not the only factors to consider when conducting field testing in a LMIC setting. Additional considerations include transportability of testing equipment, safety and security when traveling with equipment, access to electricity and even access to internet.

An opportunity for the measurement of EF in LMICs (and of cognitive development more broadly) is provided with the move toward touch-screen-enabled computerised equipment. These technologies can limit the opportunities for errors in administration, lessen the amount of equipment needed (one tablet in place of cards, blocks, etc.), lessen the burden of staff training and assist data entry. At the same time, the move towards computerised tasks brings about the possibility that participants who have had less exposure to or are less familiar with technology (e.g. tablets) might be at a disadvantage compared to participants who are more familiar with technology. However, a recent study assessed EF using a touch screen enabled tablet in 3-5 year-old children from Kenya and reported high completion rates of the tasks despite likely more-limited exposure to tablets (Willoughby et al., 2019). As such, measures that are well designed for the technology and context provide an opportunity for comparable measures of EF to be generated across diverse contexts.

2.3 Components of cognitive development related to executive function

EF, in its role as a core cognitive capacity for the capacity and control of attention, is related to (underpins, is underpinned by, or enables) other aspects of cognitive development such as self-regulation and attention. These cognitive capacities form the basis on which higher level cognitive functions are built, such as problem solving, planning and reasoning. Furthermore, these cognitive capacities are fundamental for academic success, including school readiness and academic performance throughout school (Diamond, 2013). However, the exact nature of these associations (e.g., causality, directionality, interactions) remain unclear.

2.3.1 Self-regulation

As with EF, there is no single definition of self-regulation. However, researchers agree that it permits control over automatic urges and impulses to instead regulate attention (e.g., sustain attention and resist distraction), thinking (e.g., remain cognitively engaged in a task), behaviour (e.g., delay gratification, take turns), emotions (e.g., resist tantrums) and social interactions (e.g., considering others' perspectives) in the pursuit of a goal (Blair & Ursache, 2011). Therefore, self-regulation consists of, and is often assessed in terms of its cognitive, behavioural and social-emotional dimensions/applications (Blair & Ursache, 2011).

Although the dimensions of self-regulation are considered inconsistently in the literature, their typical operationalisation provides clear distinctions between its applications (Howard & Melhuish, 2017). For instance, cognitive self-regulation pertains to the ability to focus and sustain attention, cognitively engage in tasks and learning, and be thoughtful and 'planful'. A child with good cognitive self-regulation will be able to pay attention and avoid distractions, persist with difficult tasks, attempt to solve problems independently, and ask questions and suggest answers. Behavioural self-regulation permits control of one's behaviour according to the goal or demands of a situation. A child with good behavioural self-regulation can pay attention and follow instructions, cooperate with others and resist impulsive behaviours. Emotional self-regulation refers to the ability to maintain control over one's emotions when necessary. A child with good emotional self-regulation is generally calm and well-adjusted and gets over being upset quickly. There is emerging empirical evidence of the separability of these self-regulation dimensions (Howard, Vasseleu, Neilsen-Hewett, de Rosnay, & Williams, 2019), as well as evidence that these dimensions differ in their patterns of association with child outcomes (Howard et al., 2019).

Successful self-regulation—whether behavioural, cognitive or social-emotional—is the result of a combination of factors, decisions and abilities (Baumeister & Heatherton, 1996; Hofmann et al., 2012). Firstly, one needs to select a standard, ideal or goal that must be met. This aspect of self-regulation will differ between individuals and contexts, as ideals and standards depend on individual, familial, cultural, religious or even societal factors (Chasiotis, Kiessling, Campos, & Hofer, 2006). Secondly, one needs to have sustained motivation to achieve or reach these standards or goals (Howse, Lange, Farran, & Boyles, 2003). Finally, one needs to have the

capacity to sustain this control over one's self, until completion; EFs have been proposed as this capacity component of self-regulation (Hofmann et al., 2012). As such, EFs have been proposed as a necessary but not sufficient condition for successful self-regulation.

Physiological underpinnings of self-regulation are similar to those of EF, as the frontal areas of the brain have been implicated in the regulation of behaviour (Calkins, 2014). Therefore, developmental trajectories of self-regulation mimic that of EF, with the preschool years being a crucial time for the development of self-regulation. Like EFs, aspects of preschool self-regulation are also associated with school readiness (Blair & Raver, 2015) and later academic achievement (Becker, McClelland, Loprinzi, & Trost, 2014), in addition to health behaviours (Miller et al., 2017) such as the regulation of eating (Dohle, Diel, & Hofmann, 2017) and sports participation (Howard, Vella, & Cliff, 2018; Piché, Fitzpatrick, & Pagani, 2015). Moreover, self-regulation has also shown predictive associations with health, wealth and pro-/anti-social behaviours (e.g. substance abuse and criminal activity; Moffitt et al., 2011).

2.3.2 Selective attention

Attention is another fundamental cognitive capacity central to early childhood development (Mezzacappa, 2004). Similarly to both self-regulation and EF, the frontal regions of the brain have been implicated in attention processing from infancy (Morasch & Bell, 2011) into childhood (Rueda et al., 2004) and adulthood (Fan, McCandliss, Fossella, Flombaum, & Posner, 2005). Attention is also a multifaceted component of cognition and has been described in many different ways and in different models across the literature (Scerif, 2010). However, all definitions in one way or another explain that attention processes allow us to prioritise relevant information over irrelevant information to suit situational demands or goals (Scerif, 2010). The different models and components that have been implicated in attention research include a variety of attentional mechanisms: alerting and orienting, sustained attention, selective attention and executive attention (Petersen & Posner, 2012; Posner & Peterson, 1990). Early in development, however, these are closely related and more so than later in adulthood (e.g. Breckenridge, Braddick, & Atkinson, 2013; Pozuelos, Paz-Alonso, Castillo, Fuentes, & Rueda, 2014). A single complex attention task, a multi-target cancellation, taps selective attention skills that are complementary to EF constructs. This

single task provides a good framework to gain an understanding the basic function of selective attention, that being to focus on relevant stimuli while ignoring distracting or irrelevant stimuli (Mahone & Schneider, 2012), while also providing more strategic indices that are hypothesised to align with EF in young children. Indeed, selective attention in the preschool years has been intrinsically linked to other aspects of cognitive development (self-regulation and EF; Kaplan & Berman, 2010), as well as school readiness and academic achievement (Steele, Karmiloff-Smith, Cornish, & Scerif, 2012).

2.3.3 School readiness

School readiness has been described as the minimum developmental progress a child should have acquired—in domain-general and domain-specific knowledge, skills and abilities—in order to derive available benefits from and perform well in school (Carlton Latorre & Winsler, 1999; Lemelin et al., 2007). The exact skills that make up school readiness are debated, with some placing emphasis on cognitive skills (pre-academic skills, such as knowledge of numbers and letters, vocabulary; Duncan et al., 2007), while others emphasise a collection of behaviours and skills that enable children to learn (e.g., self-regulation skills, EF, social and emotional skills, enthusiasm to learn, ability to sustain attention; Blair & Raver, 2015; Duncan, Schmitt, Burke, & McClelland, 2018; Heaviside & Farris, 1993; Lin, Lawrence, & Gorrell, 2003). Despite this, cognitive (content-based) skills are often used as an indicator of school readiness as they are more easily and objectively measured, and are less susceptible to cultural interpretations (Grantham-McGregor et al., 2007; Sherry & Draper, 2013).

This content-based school readiness knowledge and skill develops rapidly in the preschool years, and forms the foundation on which more complex skills are built, such as mathematics, reading and writing. In the international literature, these often include (among others) letter and word recognition, vocabulary, phonological awareness (Snowling & Hulme, 1994) and spatial skills (Verdine, Golinkoff, Hirsh-Pasek, & Newcombe, 2014). For instance, spatial skills in preschool are strongly correlated with achievement in the science, technology, engineering and mathematics subjects (Verdine et al., 2014). Additionally considering the EF and self-regulation evidence, it is likely that both contribute to school readiness (Blair, 2002). What is more, EF and self-regulation (specifically cognitive self-regulation) have been related to pre-

academic skills and academic readiness, as they contribute to a more general ability to learn and remember (Blair, 2002; Ursache, Blair, & Raver, 2012). Based on the literature presented above, it is clear school readiness is a multi-faceted construct and that both pre-academic and cognitive skills play a vital role in a child's readiness to learn. In the current study however, school readiness, as it is measured, is understood to consist of the pre-academic skills, while the cognitive skills such as EF, attention and self-regulation are measured separately.

Education in low-income settings in South Africa has been characterised, on average, by poor academic performance and high dropout rates (Fleisch, 2008; Pretorius & Naudé, 2002; Spaul, 2015; Spaul & Kotze, 2015). This is in contrast to high levels of academic achievement in children from high-income settings in South Africa. This achievement gap is largely due to the high levels of inequality that persist to this day, and the impact this has on access to quality education (Spaul, 2015). There is evidence to suggest this poor performance starts before school, and is entrenched by Grade 3, with children in the poorest 60% of schools already being 3 years' worth of learning behind their wealthier peers (Spaul, 2015).

Studies highlight the poor school readiness skills in South African children from low-income settings (Draper et al., 2012; "IDELA Early Childhood Pilot Study in South Africa," 2016; Katz, 2005; Lessing & De Witte, 2005; Naudé et al., 2003), with the majority of children in each study scoring below average for measures of cognitive skills and early language, literacy and numeracy skills. It is clear that children from these settings experience barriers to the acquisition of pre-academic skills (Draper et al., 2012; Pretorius & Naudé, 2002). While the reasons for this achievement gap and poor school readiness require further and more conclusive evidence, some barriers experienced by children in low-income settings include a lack of stimulating play materials in the household (Herbst & Huysamen, 2000) and low quality preschools (Richter & Samuels, 2018). Although there has been increased effort to improve access to preschool in South Africa in recent years, the quality of education remains poor due to inadequate teacher training, low levels of funding, insufficient educational materials, and inadequate monitoring and quality insurance (Richter & Samuels, 2018). Additionally, early childhood education for children under the age of 5 remains largely unsupported and unregulated, with most early education centres being run by community-based organisations or low-trained volunteers from the community (Albino & Berry, 2013;

Biersteker & Motala, 2008; Sherry & Draper, 2013). As a result, the majority of early childhood education practitioners have received little or no training in early childhood development (Biersteker & Motala, 2008). This is just one of the potential antecedents of low school readiness in these communities, but there is a need to better understand the range of factors that may contribute to this phenomenon.

2.3.4 Relationships between components of cognitive development

Taken together, the available evidence suggests that EF, self-regulation and attention are core aspects of cognition that are highly related (in functional processes and underpinning brain regions; Bunge et al., 2002; Davidson et al., 2006; Miller & Cohen, 2001). However, research on these components has generally been conducted independently from each other, or at best in parallel. As such, our understanding of how they might relate and interact is limited. Nevertheless, research has begun to identify areas of overlap that suggest these components may be complementary, with some skills supporting others (e.g., EF as a capacity component of self-regulation). While these relationships are described in more detail in Chapter 5, some of the current evidence suggests that self-regulation is achieved when EF skills are employed to regulate and control attentional resources (Kaplan & Berman, 2010) in a goal directed manner. In other words, EF and attention skills might subserve the ability to self-regulate (Blair & Ursache, 2011; Hofmann et al., 2012).

The finding that EF, self-regulation and attention contribute to school readiness and academic achievement further suggests that these cognitive skills interact to form a foundation upon which more complex cognitive (e.g. problem solving, decision making; Zelazo et al., 2003) and academic skills (for e.g. numeracy, literacy, comprehension; Welsh, Nix, Blair, Bierman, & Nelson, 2011) are built. Which components and in which way this might occur is less clear.

2.4 Components of physical development related to executive function

2.4.1 Physical activity

Physical activity is defined as any movement of the body that requires the use of skeletal muscles and the release of energy (Caspersen, Powell, & Christenson, 1985) and has been

associated with multiple physical and mental health benefits in children (Janssen & Leblanc, 2010; Lubans et al., 2016). For example, in preschool children, regular participation in physical activity has been positively associated with bone and skeletal health, cardio-metabolic health, adiposity, psychosocial health, and motor and cognitive development (Carson et al., 2017). To derive these benefits, physical activity has to be carried out for a specific duration and intensity. For this reason, guidelines pertaining to optimal duration and intensity have been specified. The intensity of physical activity refers to the amount of physical power that is required for a specific activity. Based on this, activities are classified as either light intensity, moderate intensity or vigorous intensity. During the preschool years, physical activity is often classified as either structured or non-structured depending on the context of the activity. Structured physical activity refers to planned, organised and led by an adult (teacher, coach, parent, etc.; Burdette & Whitaker, 2005). Unstructured physical activity is also referred to as 'free play' and is the spontaneous movement of children, often in the form of short bursts of physical activity (Burdette & Whitaker, 2005).

Guidelines stipulating the minimum intensity and duration of physical activity necessary to optimise preschool children's development state that children aged 3 to 5 years should be doing at least 180 minutes of physical activity per day, which should include 60 minutes of moderate and vigorous physical activity (Laureus, 2019; Okely et al., 2017; Tremblay et al., 2017; World Health Organization, 2019). The inclusion of 60 minutes of moderate and vigorous physical activity in recent guidelines was driven by the finding that physical activity performed at a light intensity was not associated with positive health indicators. Yet, moderate and vigorous physical activity, vigorous physical activity and total physical activity consistently did show these associations (Carson et al., 2017). For example, one study showed that children who replaced sedentary time with MVPA scored better on tests of self-regulation (Fanning et al., 2018). Another study in preschool children suggested that decreasing light physical activity and increasing vigorous physical activity was longitudinally beneficial for cognitive and psychosocial development (McNeill, Howard, Vella, Santos, & Cliff, 2018).

Despite the known benefits of regular physical activity, insufficient physical activity has become a global issue, particularly in HICs. The prevalence of insufficient physical activity is

far greater in HICs than in low-income countries, such as those in Sub-Saharan Africa (Guthold, Stevens, Riley, & Bull, 2018). As such, this different pattern of strengths and difficulties in HIC and LMIC contexts indicates differing needs, and potentially differing patterns of association between aspects of development, which warrant separate investigation (and potentially also different approaches). Much of the available evidence stems from older children and adults, as it was believed that preschool age children are naturally active. However, this is not always the case as international research (mostly from HICs) on preschool children has found that not all children are meeting daily recommendations for physical activity (Beets, Bornstein, Dowda, & Pate, 2011; Chaput et al., 2017).

On the contrary, there is some evidence that suggests that preschool children in South Africa are very active (Draper et al., 2017; Tomaz, Pioreschi, et al., 2019). These studies (mostly from low-income settings) have reported that South African preschool children are not only meeting the guidelines for physical activity (Laureus, 2019; Okely et al., 2017; Tremblay et al., 2017; World Health Organization, 2019), but far exceeding them, with some children accumulating more than 400 minutes of total physical activity, including over 100 minutes of moderate and vigorous intensity physical activity (also referred to as energetic play, or play that has children using energy such as playing a game of tag or riding a bicycle) per day (Draper et al., 2019).

Studies in both urban (Jones, Hendricks, & Draper, 2014) and rural (Tomaz, 2018) low-income settings in South Africa investigating physical activity in preschoolers, using the Observational System for Recording Physical Activity in Children – Preschool (OSRAC-P; Brown et al., 2006), further revealed that there is very little structured and teacher-led physical activity during preschool time. As such, there are likely also differences not only in quantity, but also in the nature of physical activity being undertaken across HIC and LMIC contexts. Teacher-arranged and -led gross motor activities in these South African studies made up as little as 6% of total physical activity in the urban preschools, and 13% in rural preschools. Furthermore, children received minimal prompts from the teachers regarding their physical activity, with 86% and 96.5% of activity being unsupported (not teacher-led) in the urban and rural settings, respectively. Moreover, children in low-income settings in South Africa have limited access to after-school activities that children from high-income settings have increased access to, such

as sports coaching, dance and music lessons. The implications of this differing quantity and nature of physical activity, compared to HIC contexts (or even high-SES LMIC contexts) from which much of this evidence is derived, is unclear.

2.4.2 Gross-motor skills

GMS are movements involving the large muscles of the body, while fine motor skills (FMS) involve the smaller muscles (Eliason & Jenkins, 1986). Both of these skills are essential for carrying out daily activities such as playing and learning. GMS typically include general body coordination and balance, comprising locomotor and object control skills. Locomotor skills are movements that take you from one place to another (running, jumping, hopping, etc.). Object control skills are movements that require hand- or foot-eye coordination (catching, throwing, kicking, etc.). The development of GMS in particular is significant, especially in the preschool years, as it forms a foundation for more complex skill development and movement patterns that are required when participating in physical activities later on (Gallhue & Ozmun, 2006). Furthermore, GMS competency in the early years has shown to predict physical fitness, participation in physical activities later on in life and overall health behaviours (Robinson et al., 2015; Vlahov, Baghurst, & Mwavita, 2014).

The preschool years present a key period for developing foundational GMS, often referred to as fundamental movement skills. However, GMS do not linearly improve with increasing age for all children, but rather development of GMS are dependent on environmental influences such as exposure to training of these skills and opportunities for practice (Clark, 2005). Studies (mostly from HICs) have shown that children from low-income settings are at risk for gross motor delays (Liu, Hoffmann, & Hamilton, 2017; Morley, Till, Ogilvie, & Turner, 2015). In contrast, a recent study in South Africa showed preschool children generally have average or above average gross motor proficiency for their age, and children from low-income settings were equivalent in their skills compared to children from high-income settings (Tomaz, Hinkley, et al., 2019). Less clear are the implications of this heightened GMS proficiency relative to components of cognitive development.

2.4.3 Anthropometric measurements

Anthropometric measurements provide an indication of the size, shape and composition of the body. Typical measurements include height, weight, waist circumference and skinfolds, while more complex measurements include bioelectrical impedance and dual-energy X-ray absorptiometry. The rise in paediatric obesity levels worldwide has not been limited to HICs; in fact, children in LMICs make up 76% of overweight children under the age of 5 years (de Onis, Blossner, & Borghi, 2010). In South Africa specifically, 22.2% of children between the ages of two and five years are overweight or obese (Shisana et al., 2013). This global rise has led to increased efforts to understand the correlates of adiposity and how they can be used to prevent overweight and obesity. However, in many LMICs, the rise in obesity levels is not the only concern. In these countries undernutrition remains persistent (Tzioumis & Adair, 2014), which, along with the rising obesity levels, results in a double burden of over- and undernutrition.

The World Health Organisation (WHO) and the International Obesity Task Force (IOTF) have provided indicators for over- and undernutrition. The WHO child growth standards use anthropometric measurements (weight and height) as well as demographic variables (age and sex) to determine body mass index-for-age (BAZ), weight-for-age (WAZ) and height-for-age (HAZ) z-scores. These scores are used to classify children as either underweight (BAZ), stunted (HAZ) or wasted (WAZ), all of which are indications of impaired growth and development. For example, if a child is stunted, it means that they have a lower than average height for their age, if a child is classified as wasted, it means that they have a lower than average weight for age. More specifically, children are classified as either underweight, stunted or wasted if their z-score is more than two standard deviations below the WHO child growth standards median. Similarly, a BAZ score that is more than two standard deviations above the WHO child growth standards median is classified as obese, and more than one standard deviation above is classified as overweight. The IOTF classifies under- and over-nutrition using cut offs for BMI that are age- and sex-specific. IOTF classifications include thinness (low BMI-for-age), overweight, normal weight, obese, and morbidly obese. BMI and BAZ are commonly used as an indicator of adiposity in adults and children respectively (Zemel, Riley, & Stallings, 2002), while HAZ and WAZ are more commonly used as indicators of nutritional status (Mamabolo, Alberts, Steyn, Delemarre-van de Waal, & Levitt, 2005).

The most recent nationally representative sample (N=2511 children ages 2-9 years) that includes 4-6-year-old children in South Africa reported the prevalence of underweight at 8.6%, stunting at 11.5% and wasting is 1.8%. For children aged 2-5 years in the same sample, the prevalence of overweight and obesity was found to be 18.2% and 4.7%, respectively (Shisana et al., 2013). This data highlights South Africa as a LMIC experiencing the double burden of over- and undernutrition. Both under- and overnutrition have both been unfavourably associated with outcomes including physical health, psychological health, and even cognitive abilities. For example, obesity is associated with increased risk for cardiovascular disease and metabolic syndrome (van Zyl, van der Merwe, Walsh, Groenewald, & van Rooyen, 2012), depression (Reeves, Postolache, & Snitker, 2008), sleep problems (Hakim, Kheirandish-Gozal, & Gozal, 2015) and poor academic achievement (Kamijo et al., 2012). Undernutrition, specifically stunting, has been associated with higher risk for obesity (Sawaya, Martins, Grillo, & Florencio, 2004), poor behavioural regulation (Chang, Walker, Grantham-McGregor, & Powell, 2002; Walker, Chang, Powell, Simonoff, & Grantham-McGregor, 2007) and poor academic achievement (Dewey & Begum, 2011). These findings demonstrate the importance of considering anthropometric measures in studies looking at factors contributing to cognitive and physical development in LMICs.

2.4.4 Relationships between components of physical development

Previous research has identified beneficial associations between levels physical activity, gross motor proficiency and various anthropometric measures. Moreover, these associations are not only beneficial, but are also reciprocal and predictive of later health outcomes. For example, a review revealed that motor competence was positively associated with aspects of physical health, such levels of physical activity, cardiovascular fitness, muscular strength and endurance, and a healthy body weight (Robinson et al., 2015). A number of other studies have also shown that good gross motor proficiency is associated with higher levels of physical activity (e.g. Silva-Santos, Santos, Duncan, Vale, & Mota, 2019; Williams et al., 2008). In these studies, it is hypothesised that children who have better GMS are more likely to choose to participate in more physical activity and sports activities, and in this way, leads to increased physical fitness and a healthier body weight (Stodden et al., 2008). On the other hand, studies

have also shown that increased time spent in physical activity is associated with better gross motor proficiency (e.g. Barnett, Salmon, & Hesketh, 2016). In these studies, it is proposed that spending more time in physical activity allows for more opportunity to develop and practice GMS (Barnett, Salmon, et al., 2016). These studies highlight the reciprocal nature of the relationship between physical activity and GMS, and that these are important in both directions and that both are important for a healthy body weight (Stodden et al., 2008).

2.5 Relationships between components of cognitive and physical development

2.5.1 Physical activity and components of cognitive development

Research suggests that physical activity may be beneficial for cognition (Jackson et al., 2016). The first discovery of the association between physical activity and cognition occurred in the 1960s, when a positive association was observed between grip strength and depression in adult male participants (Morgan, Roberts, Brand, & Feinerman, 1970). Over the last five decades, this field of research has gained further traction, with the most prevalent evidence pointing to a relationship between physical activity and EF (Colcombe & Kramer, 2003). A recent review examining the relationship between physical activity and cognitive development in early childhood (0 to 5 years) included only seven studies, most of which were HICs (Canada, Switzerland, Germany and the United States) and only one LMIC (Philippines; Carson et al., 2015). While this review provided preliminary evidence that physical activity may indeed have a beneficial effect on cognitive development, it also highlighted the lack of evidence for this relationship outside the most commonly studied WEIRD samples.

The components and mechanisms underpinning the relationship between physical activity and cognitive development have not been clearly defined, though both physiological and psychosocial mechanisms have been proposed. In terms of the physiological mechanisms, engaging in physical activity has been shown to influence the structure and function of the frontal regions of the brain through the upregulation of neurotrophic growth factors and neurotransmitters, as well as increased cerebral blood volume (Colcombe et al., 2006). That physical activity might be a vehicle through which to gain real-world expertise in mobilising higher-order cognitive processes is also suggested. Engaging in physical activity or exercise

involves more than just physical input; it involves social, emotional and cognitive factors as well. For example, playing a sport requires complex coordination and motor skills, as well as the ability to strategise and work with a team. Therefore, just as deriving physical health benefits from physical activity require that certain criteria are met, cognitive benefits may also be realised when physical activity is cognitively challenging and engaging. Although there are not yet concrete guidelines for this, researchers have suggested that the context/type of physical activity plays a role in the degree to which physical activity exerts positive effects on cognitive development (Diamond, 2015).

Research has begun to identify types of physical activities that exert these beneficial effects on cognitive development. This includes physical activity that involves cognitive engagement and physical activity that facilitates positive social interactions with teacher/coach and peers (Diamond, 2015). Examples of physical activities that have shown to have a positive effect on cognition include martial arts (Lakes & Hoyt, 2004), yoga (Gothe, Pontifex, Hillman, & McAuley, 2013), sports coaching (Alesi, Bianco, Luppina, Palma, & Pepi, 2016; Ishihara, Sugawara, Matsuda, & Mizuno, 2016) and targeted exercise interventions (Chang, Tsai, Chen, & Hung, 2013; Crova et al., 2014; Schmidt, Benzing, & Kamer, 2016) However, these trials are typically small, short-term and they focus on activities are not always available to children, particularly children in low-income settings.

Less still is known about the effect of naturally occurring, habitual physical activity on cognitive development. This is a particularly important to understand in settings where children do not have access to organised physical activity (sports/extra-curricular activities). There has only been one study, in one HIC, to investigate naturally occurring physical activity and its relationship with cognitive development (EF) in preschool children (Willoughby, Wylie, & Catellier, 2018). This study found that daily physical activity was negatively (detrimentally) associated with EF. It is clear from above that current evidence shows inconsistent associations between physical activity and cognition, and that the associations are dependent on the context/type of physical activity (e.g. structured vs. unstructured) and how it is measured (e.g. intervention vs. free living physical activity). Therefore, more research is needed to determine exactly how physical activity exerts its effects (or not) on cognition. Additional research is needed to investigate this in low-income settings in a LMIC context.

2.5.2 Gross motor skills and components of cognitive development

Despite mixed findings in associations between physical activity and cognitive development, GMS and cognitive development show consistently positive associations. Explanations for this relationship has its origins in Piaget's theory of development, which positions the emergence of motor and sensorimotor abilities as precursors for cognitive development (Piaget & Cook, 1953). Neuroimaging studies have provided further evidence for the link between motor and cognitive outcomes (Diamond, 2000; Piek et al., 2004; Wassenberg et al., 2016), showing that the cerebellum (critical for motor skills) and prefrontal cortex (critical for higher-order cognition) are co-activated during cognitive and motor tasks (Berman et al., 1995). Although this deviates from the inconsistent pattern of relations for PA, this is consistent with suggestions that EF benefit is more likely conferred from movement with thought (e.g., GMS) than movement without thought (e.g., PA, which may conflate more and less cognitively engaging activity).

Studies investigating the relationship between GMS and cognitive development have included a wide variety of GMSs, including locomotor skills, object control skills, stability skills and even measures of motor coordination and visual-motor skills. For example, a study in 5- and 6-year-old children found that ball skills, but not stability skills, were associated with EF and externalising behaviour (an aspect of behavioural self-regulation; Livesey, Keen, Rouse, & White, 2006). Similarly, a study in preschoolers found a positive association between visual-motor integration and object manipulation skills with EF and social behaviour (also related to behavioural regulation; MacDonald et al., 2016). Another study measured whole-body coordination tasks (involving locomotor skills) and stability skills and found that they were positively associated with EF (Oberer et al., 2017). Each of these studies derived from HICs.

Further links between GMS and self-regulation are highlighted by teacher-ratings of GMS and behaviour (Kim et al., 2015). Kim and colleagues (2015) showed that children who had higher ratings of GMS also had better social skills and fewer behavioural problems. The researchers' explanation for these results were that children who had more developed GMS experienced less frustration and difficulties during activities that required basic GMS, and thus were able

to focus their attention on other aspects of the task (Kim et al., 2015). Evidence for this GMS-self-regulation association is also found in literature on neurodevelopmental disorders such that disorders of coordination and disorders of attention often coexist (Piek et al., 2004). For example, attention deficit hyperactivity disorder (ADHD) and developmental coordination disorder (DCD) have high levels of comorbidity, suggesting a common underlying neurocognitive mechanism. Some researchers have referred to this mechanism as Atypical Brain Development (Kaplan, Wilson, Dewey, & Crawford, 1998), and others as Deficits in Attention, Motor control and Perception (Gillberg, 2003).

GMS have also been associated with early academic skills (school readiness). For example, a study in low-income settings in South Africa found that performance on a school readiness task improved following an intervention that included a weekly programme of structured gross motor (locomotor and object control) play activities (Draper et al., 2012). Potential explanations for the link between GMS and early academic skills have been illustrated through the role that motor coordination and visual-motor integration play in both early academic skills (early reading, writing and mathematics skills) and GMS (Cameron, Cottone, Murrah, & Grissmer, 2016). For example, to be able to sit at a desk and carry out reading and writing activities requires the large muscles of the body (involved in GMS) to keep sitting upright, and motor coordination (specifically bimanual coordination) is needed to be able to hold the book or paper in one hand and use the other hand to read or write (Cameron, 2018). Early mathematics skills are also related to perceptual motor skills and spatial awareness (Verdine et al., 2014).

2.5.3 Hypothesised relationships based on current international evidence

The relationships between foundational aspects of cognitive (i.e., EF, self-regulation, selective attention, school readiness) and physical development (i.e., physical activity, GMS, adiposity), which are included in this study, have been investigated, but in isolation. This includes studies on associations of: EF and physical activity (Willoughby et al., 2018); self-regulation and school readiness (Blair & Ursache, 2011); EF and school readiness (Pellicano et al., 2017); GMS and EF (McClelland & Cameron, 2018); and, attention and physical activity (Janssen, Toussaint, van Mechelen, & Verhagen, 2014). Despite potential for complex associations and

interactions between these factors, no studies have investigated all of these components in the same sample. Nevertheless, hypotheses can be drawn from the available evidence with regards to how these outcomes may interact. Figure 2.1 illustrates these hypothesised relationships showing that components of cognitive development are positively associated with components of physical development and, also, that these associations are likely to be bidirectional in nature. Additionally, the effects of overweight and obesity, as well as stunting, has the potential to negatively impact both physical and cognitive development.

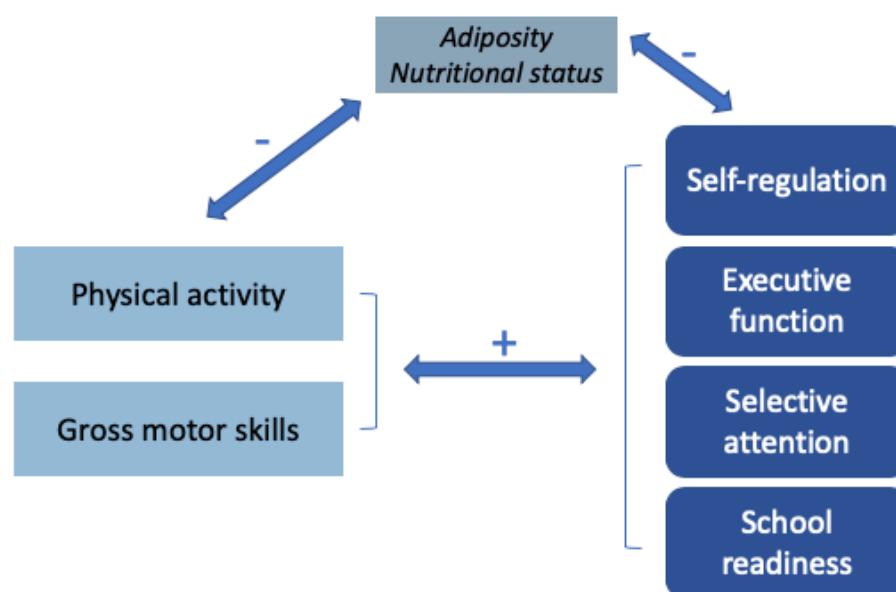


Figure 2.1 Relationships between components of physical and cognitive development based on the current international evidence. Symbols indicate the direction of the associations (+ represents a positive association, - represents an inverse association).

2.5.3 Hypothesised relationships based on South African and LMIC evidence

The general model and hypothesis presented above, however, is based on evidence predominantly drawn from HIC contexts. It is currently unable to account for the potential effect of confounding factors or differences in the characteristics of the sample that might be present in a LMIC context, such as high levels of poverty and physical activity. Based on the available evidence, children growing up in low-income settings in South Africa are likely to be at risk for poor cognitive development and school readiness (Bruwer, Hartell, & Steyn, 2014; Lawson & Hook, 2014; Sherry & Draper, 2013), particularly EF (Haft & Hoef, 2017). However, evidence of the effect of poverty on underlying cognitive capacities in LMICs (EF, attention

and self-regulation) is inconsistent. Additionally, undernutrition is prevalent in South African low-income settings (Said-Mohamed, Micklesfield, Pettifor, & Norris, 2015), particularly in rural settings (Kimani-Murage et al., 2010), with unclear implications. Further, while there is evidence of poorer cognitive development in these contexts, there is also emerging evidence that EFs might be unaffected (or indeed superior) in some settings (Gonen et al., 2018; Sabbagh et al., 2006).

Regarding physical activity and GMS, the evidence presented earlier showed that South African preschool children from low-income settings are engaging in high levels of physical activity (Draper et al., 2017; Tomaz, Pioreschi, et al., 2019) and have generally display good gross motor proficiency (Tomaz, Hinkley, et al., 2019). This suggests that the South African context presents a novel setting in which the relationships described earlier might not play out as uniformly as in HICs. Figure 2.4 presents some initial hypotheses for how these components may differ in South African low-income settings.

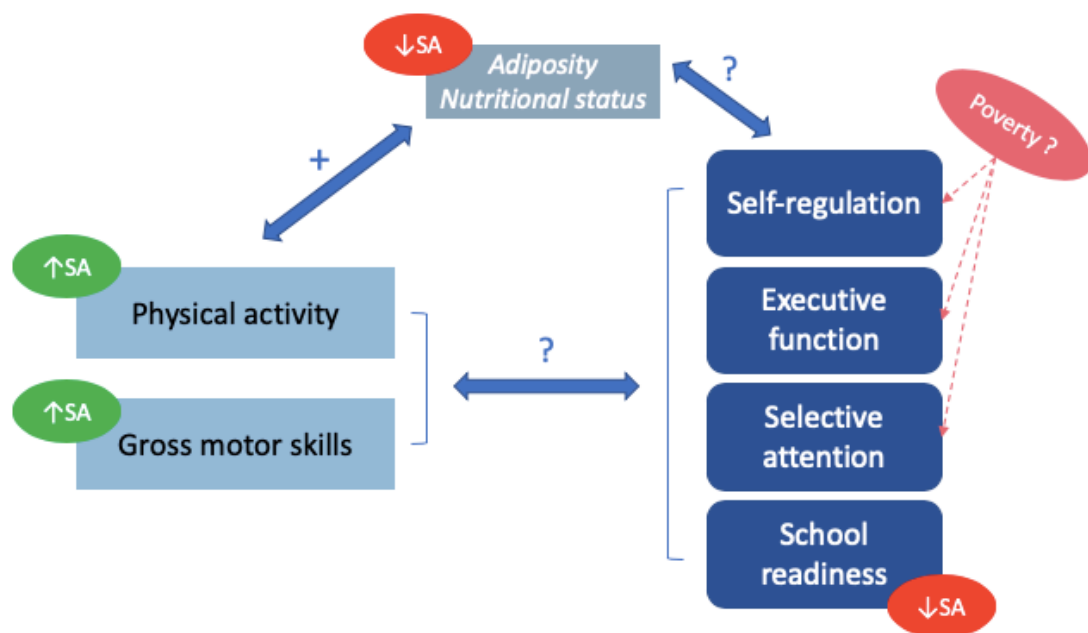


Figure 2.2 Hypotheses with regards to how the relationships between outcomes of interest may differ in South African low-income settings. Symbols indicate the direction of the associations (+ represents a positive association, - represents an inverse association, ? represents an unknown association). SA = South Africa.

Therefore, additional research is needed in South Africa to explore components of cognitive development, particularly EF, self-regulation and attention, as they have not been previously studied in this setting and age group. Following initial explorations, research is also needed to determine how these components interact with each other and their influence on school readiness. Furthermore, research is needed to investigate relationships between components of cognitive development with physical activity and GMS in this setting.

2.6 Aims and objectives

Based on these gaps and speculative hypotheses, this thesis aimed to investigate cognitive and physical outcomes in a sample of children attending preschools in low-income settings in South Africa. Specifically, this thesis aimed to answer exploratory questions in a sample of preschool-aged children from urban and rural low-income settings in South Africa. Specifically, this thesis aims to:

1. Describe components of cognitive development (EF, self-regulation, attention, school readiness) and components of physical development (objectively measured physical activity levels, gross motor skill proficiency, body composition) and investigate the differences between urban and rural settings as well as the differences between boys and girls for each component mentioned.
2. Explore all the associations between components of cognitive development (EF, self-regulation and attention).
3. Explore all the associations between EF, self-regulation and school readiness to determine the direction and strength of the association and in addition, determine the latent structure of EF and self-regulation.
4. Explore all the associations between physical activity, GMS and adiposity.
5. Explore the associations between physical activity, gross motor skills and components of cognitive development. Specifically, associations between physical activity and gross motor skills with (a) EF; (b) self-regulation; (c) selective attention; (d) school readiness.

On the basis of available evidence from HICs and limited insight from LMICs, it was expected that components of cognitive development (EF, self-regulation and attention) would be positively associated and that EF and self-regulation would be associated with school readiness. Positive associations between physical activity, particularly at higher intensities, and gross motor proficiency were also expected. In addition, higher amounts and intensities of physical activity as well as better gross motor proficiency were expected to be beneficially associated with adiposity. Relationships were expected to be found between components of cognitive development with physical activity and GMS. More specifically, that physical activity at higher intensities and greater gross motor proficiency would be associated with greater cognitive abilities.

CHAPTER 3: METHODS

3.1 Study settings

Data were collected from children in an urban and a rural setting, to capture diverse low-income South African contexts. The urban setting was situated in a sub-district of greater Johannesburg-Soweto, and the rural setting in the Bushbuckridge district of Mpumalanga Province. The specific settings were chosen based on existing institutional links between CD (Principal Investigator of the broader research study) and research centres in these settings (the Developmental Pathways for Health Research Unit/DPHRU in the urban setting and the MRC/Wits Agincourt Unit in the rural setting). These links are vital as they help in gaining access to and engaging with the communities, while ensuring cultural sensitivity. Furthermore, these settings both have a number of challenges that are inherent to many low-income areas in South Africa such as unemployment, poor educational outcomes, food insecurity, and exposure to stressors such as violence. For example, a recent study conducted in the rural setting (Pettifor et al., 2017) reported that 61.7% of men and 81.7% of women were unemployed, and only 56.2% of the population completed high school. A study from the urban setting revealed that out of the 830 adolescents interviewed, 52% reported high levels of food insecurity (Cui et al., 2017). Another study estimated that 42% of young women in Soweto between the ages of 13 and 23 years have experienced intimate partner violence (Makongoza & Nduna, 2017).

Given the lack of granular socio-demographic data at the individual level in South Africa, community-level socioeconomic status was used in the current study. Community-level socioeconomic status was also chosen due to the difficulties often associated with acquiring individual-level socioeconomic status. Difficulties include participants' unwillingness to disclose income and the burden of accuracy of participant's reports of income.

Although both study settings are considered low-income, they have distinguishable features. The urban study setting is classified as an urban informal area, or 'township' (Statistics South Africa, 2003). These townships, historically, were situated outside of the city limits for housing

the black migrant labour force (enforced by the Group Areas Act during apartheid; Maharaj, 1997). In Soweto, where the predominant ethnicity is black African, the population density is 6357.29 per km² (Statistics South Africa, 2011) and the household density is 1,776.42 people per km². At least 10 of the 11 South African languages are spoken in this area due to the large proportion of migration from rural areas around South Africa (Collinson, Tollman, & Kahn, 2007). Of these, isiZulu and Sesotho are the two most widely spoken languages, followed by Setswana and Xitsonga. Most of Soweto is comprised of both formal and informal housing. Service delivery remains poor in townships, and common issues include overcrowding, high levels of crime and violence (Biersteker, 2010; Winton, 2004). Preschools and early childhood development (ECD) centres in Soweto are typically small, with limited classroom space and almost no outdoor space or outdoor play equipment.

The rural study setting is classified as a rural tribal setting, meaning it is an area that falls within the domain of a tribal authority (Statistics South Africa, 2003). The predominant ethnicity in this district is Black African 99.7%, with Xitsonga being spoken by 94.7% of the population (Statistics South Africa, 2011). Population density is much lower than the urban setting, at 610 people per km², although extreme poverty is similarly pervasive. The district has a slow rate of infrastructure development and very few tarred roads. Typical living conditions include household plots with a small area to support home-grown crops. Electricity is available in the village; however, most households have no electricity in the home due to its high cost, and therefore rely on open fires for cooking. Additionally, many households have only limited access to running water and rudimentary sanitation with 85% of households having pit toilets (Kahn et al., 2012). Typically, preschools in the area have ample space inside the classrooms and outdoors, including outdoor play equipment. However, the infrastructure of these buildings is generally poor, with limited access to electricity, running water and sanitation. Many preschools (as well as primary and secondary schools) cook food for the children over open fire on the school property.

Although these two regions do not cover the whole range of low-income settings in South Africa, they capture two distinct types of settings that reflect some of the key differences and diversity across low-income areas of South Africa.



Figure 3.1 Map showing the location of the two study sites. Retrieved from <http://maps-africa.blogspot.com/2012/05/south-africa-map-pictures.html> in December 2018



Figure 3.2 Photos of the urban preschools and surroundings



Figure 3.3 Photos of the rural preschools and surroundings

3.2. Sample details

3.2.1 Recruitment of preschools

Urban setting

As mentioned previously, the two urban preschools were chosen based on an existing connection with the research unit. To approach the centres for this study, a local field worker from the DPHRU (collaborators on the study) put CD in touch with the preschools to provide information about the study and invite them to participate. Both preschools agreed to participate. The field worker then helped to arrange parent meetings at each school.

Rural setting

Similarly, the three rural preschools that were approached had been involved in a previous study with CD. Community engagement officers made contact with the preschools to inform them about the study and ask if they would be willing to participate. All three preschools agreed to participate. Thereafter, local fieldworkers assisted in organising a meeting with the parents and caregivers of eligible children.

3.2.2 Recruitment of parents and caregivers

All parents and caregivers of eligible children in the recruited preschools were invited to an information meeting at the school, during which they were given both written and verbal information about the study. Written information sheets and consent forms were available in English, Xitsonga (for the rural group), Sesotho and isiZulu (for the urban group). Verbal information and the consent forms were explained in the preferred language of the group, with the assistance of a local fieldworker. Thereafter, parents and caregivers were given the opportunity to ask any questions and voice any concerns. Those who were unable to attend the meeting were given the written information, and contact details of the PI and field worker, in case they had any questions. Parents and caregivers were given up to five days to sign and return the consent forms to the preschool, the forms were then collected by the ECD practitioners who then handed them over to the researchers. Contact details of the parents and caregivers were also collected so that the research team could stay in contact throughout period of data collection. This was done so that the fieldworker could reiterate the

instructions pertaining the accelerometers and to answer any questions or concerns that may have arisen.

3.2.3 Participants

To be eligible for participation, children had to: be enrolled at a participating preschool; be aged 3- to 6-years; provide signed consent from a parent or caregiver; and attend preschool on the day of testing. This yielded an eligible sample of 187 children. Eligible children for whom consent was not given by their parents/caregivers ($n=51$) did not significantly differ in age ($p=0.32$) or sex ($p=0.13$) from the consented sample. Children who expressed unwillingness to participate were excluded before testing. Additional missing data was due to participants being absent on testing days or not meeting wear time criteria for physical activity measure (as explained in the measures section below). Diagram 3.2 depicts these participant numbers.

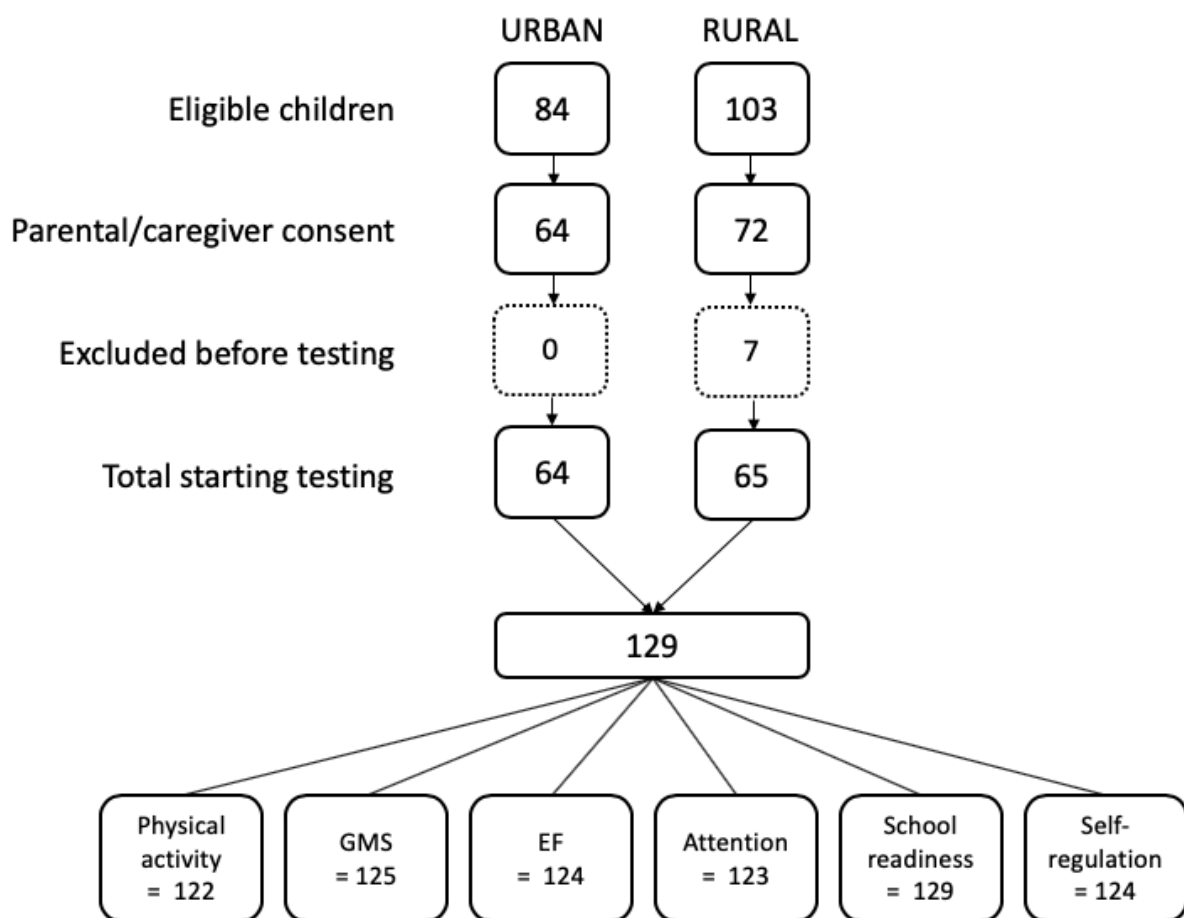


Figure 3.4 Participant numbers

3.3 Data collection: measures

3.3.1 Executive function

As discussed in chapter 2, one of the biggest challenges mentioned in the EF literature is the inconsistency and variability of EF measures used for research. With a vast array of assessment tools available, selecting appropriate tools requires careful consideration. This choice is often based on researchers' perceptions of EF (e.g., its nature, structure, development and organisation), and suitability or appropriateness of a tool for the sample and setting. For example, size and portability of equipment, requirement for a continuous connection to power or internet and availability of space are barriers to use in low-income settings such as those in the current study.

Recent studies have shown successful adaptation of "Western" measures in low-income LMICs settings, including the use of tablets in these settings, such as Uganda (Nampijja et al., 2010), Zambia (McCoy, Zuilkowski, & Fink, 2015) Pakistan (Tarullo et al., 2017), and Kenya (Willoughby et al., 2019). The study in Kenya was the only study to have used computerised data collection and while it might be assumed that a lack of exposure to technology would confound the results, this was not the case as shown by the high completion rates in this study (Willoughby et al., 2019). Given that not all low-income settings are the same, some factors unique to the South African context had to be considered. These considerations included the participants' language; relative (lack of) technological experience; the lack of access to electricity and internet at the testing sites; portability of testing equipment; and even weather conditions (considering the possibility of devices overheating in hot weather). Given these factors, the Early Years Toolbox (EYT) – a collection of iPad-based direct assessments of EF, language, self-regulation and social-emotional development (Howard & Melhuish, 2017) – was selected and translated (in collaboration with the Toolbox developers) to assess EF.

The EYT was chosen as it addressed many of the concerns and challenges that come with measuring EF in low-income South African settings. For example, the iPad-based nature of EYT means that it is portable and can run without active power or an internet connection. Additionally, the design of the EYT leverages the affordances of technology but does not advantage children with technological expertise (i.e., children interact with the iPad as they

would a piece of paper; Howard & Melhuish, 2017). This is possible as responses required are intuitive and were designed to mirror those of non-computerised versions of these tasks (Howard & Okely, 2015; Howard & Melhuish, 2017). For example, whereas the physical version of the Dimensional Change Card Sort task requires children to sort cards into boxes, the tablet version asks children to do the same by pointing at (tapping) the selected sort location. Stimuli embedded in the tasks are engaging, developmentally appropriate and familiar to the children in these settings. Furthermore, effort was made to minimise the literacy and numeracy demands of the EYT tasks, something that was particularly salient in these settings given the evidence for poor literacy and numeracy skills in South African children (Mohangi, Krog, Stephens, & Nel, 2016; Naudé et al., 2003; Pretorius & Naudé, 2002).

Measures that assessed key EF components were selected, namely: Go/No-Go (inhibition), Card Sorting (shifting) and Mr Ant (working memory). These tasks showed good convergent validity with existing measures of EF from the NIH Toolbox cognition battery (List Sorting for working memory; Flanker for inhibition; and Dimensional Change Card Sorting [DCCS] for shifting; Zelazo et al., 2013), as indicated by the correlations with the comparison measures: working memory, $r(79) = .46$, $p < .001$ (with visual-spatial) and $r(79) = .42$, $p < .001$ (with phonological); inhibition, $r(80) = .40$, $p < .001$; and shifting, $r(80) = .45$, $p < .001$ (Howard & Melhuish, 2017). Additionally, the tasks have shown predictive validity of later school readiness in studies of preschool children from HICs (Howard & Melhuish, 2017).

Each task included instructions and practice embedded in the iPad app, presented in the home language of the participant.

Inhibition

The EYT Go/No-Go task (Figure 3.3) consists of 'go' (catch a fish by tapping the screen) and 'no-go' trials (avoid the sharks by resisting tapping the screen), presented 80% and 20% of the time respectively. The ratio of go to no-go trials and speeded nature of the task creates a pre-potent tendency to tap the screen on every trial, requiring a child to inhibit their pre-potent response to tap whenever a no-go trial is presented. Initial practice consists of instructions and 20 practice trials to allow familiarization with the task. The task then follows with 75 stimuli, divided evenly into three 1-minute test blocks that are separated by a short rest and

repetition of instructions. Each stimulus is presented on the screen for 1.5 s followed by a 1.0 s interval before the next stimulus. Inhibition was indexed by an impulse control score that represents the product of the Go and No-Go proportional accuracy (e.g., 0.80 on 'go' trials x 0.90 on no-go trials = 0.72), therefore representing the strength of the pre-potent response in relation to their ability to overcome this response.

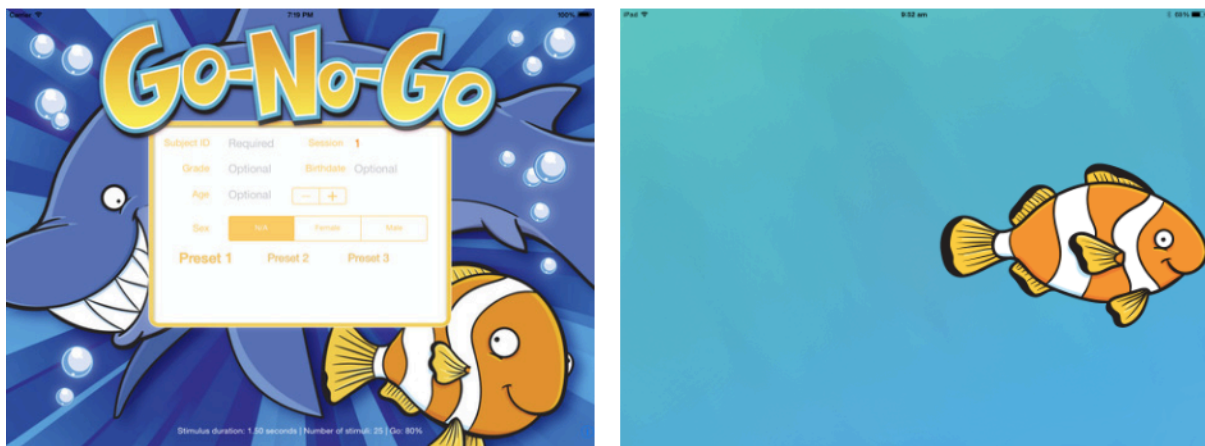


Figure 3.5 Inhibition assessment on the EYT: Go-No-Go. Retrieved from <http://www.eytoolbox.com.au/about> in December 2018.

Shifting

The EYT Card Sorting task (Figure 3.4) requires participants to sort stimuli (i.e., red rabbits, blue boats) according to a changing sorting rule. The first phase (pre-switch phase) requires participants to sort stimuli by colour (e.g., red rabbits with red boats). After six trials, the sorting rule changes (post-switch phase) and participants must sort the stimuli according to shape (e.g., red rabbits with blue rabbits). The third phase (border phase) is reached if the participant sorts at least five stimuli correctly during both the pre- and post-switch phases. There are 6 trials per phase (pre-switch phase, post-switch phase and border phase) and therefore a total of 18 trails. In this last phase, stimuli are either presented with or without a black border. If there is a black border, cards must be sorted according to colour, or if there is no black border by shape. The first and last phases begin with a demonstration and two practice trials, during which incorrect sorting is corrected and sorting rules are repeated. Reiteration of the sorting rule occurs on every test trial, before the stimulus to be sorted is presented. Shifting was indexed by the number of correct sorts that occurred after the pre-switch phase. There are no criteria to progress from the pre-switch phase to the post-switch phase. However, where pre-switch scores were lower than post-switch scores (e.g., a child

incorrectly started sorting by shape, and then continued to sort by shape in the next level), these scores are reversed to better reflect an index of the child's switching ability.



Figure 3.6 Shifting assessment on the EYT: Rabbits & Boats. Retrieved from <http://www.eytoolbox.com.au/about> in December 2018.

Working memory

In the EYT Mr Ant task (Figure 3.5), participants are asked to remember the spatial location of stickers on a cartoon ant. The cartoon ant, called Mr Ant, is presented with one or more stickers on the screen for 5 s. This is followed by a blank screen presented for 4 s, and then an image of Mr Ant without stickers on which participants indicate where the stickers were by tapping the relevant spatial locations on Mr Ant. Test trials increase in difficulty, from level one (1 sticker) to level eight (8 stickers). Each level consists of three trials, with the task continuing until the completion of level eight or failure on all three trials of the same level. Working memory was indexed by a point score that awards: 1 point for each consecutive level in which a child successfully performs at least two of the three trials (beginning from Level one); and then, from the first level in which the child completes only one trial correctly, 1/3 of a point for each correct trial thereafter.

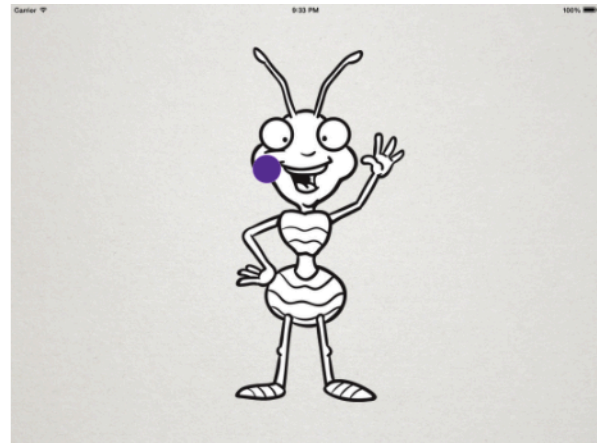
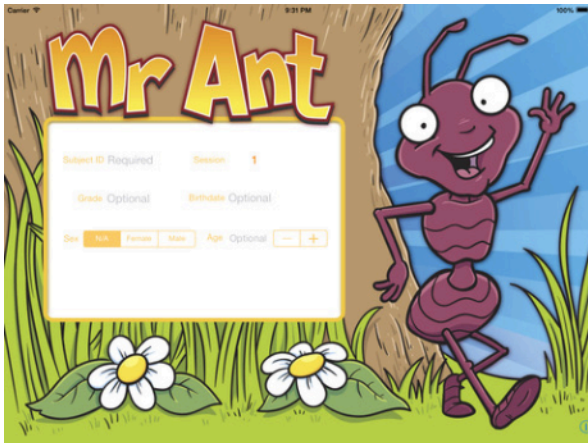


Figure 3.7 Working memory (visual-spatial) assessment on the EYT: Mr Ant. Retrieved from <http://www.eytoolbox.com.au/about> in December 2018.

3.3.2 Self-regulation and social development

The EYT Child Self-Regulation & Behaviour Questionnaire (CSBQ; Howard & Melhuish, 2017), was selected to index self-regulation. The CSBQ, which was reported by each child’s preschool educator, comprises 33 questions about the typicality of everyday self-regulatory behaviours. It includes subscales of cognitive self-regulation (e.g., ‘persists with difficult tasks’), behavioural self-regulation (e.g., ‘waits their turn in activities’) and emotional self-regulation (e.g., ‘gets over being upset quickly’). It also yields subscales of prosocial behaviour and sociability, and externalising and internalising behaviour problems. The typicality of these behaviours is rated on a scale from 1 (not true) to 5 (certainly true). CSBQ has shown good convergent validity with Strengths and Difficulties Questionnaire (SDQ) subscales (*rs* ranging from .66 to .91).



Not True	Somewhat True	Certainly True	1. Considerate of other people's feelings
Not True	Somewhat True	Certainly True	2. Restless, overactive, cannot stay still for long
Not True	Somewhat True	Certainly True	3. Often complains of headaches, stomach-aches or sickness
Not True	Somewhat True	Certainly True	4. Shares readily with other children (treats, toys, pencils etc.)
Not True	Somewhat True	Certainly True	5. Often has temper tantrums or hot tempers
Not True	Somewhat True	Certainly True	6. Rather solitary, tends to play alone
Not True	Somewhat True	Certainly True	7. Generally obedient, usually does what adults request
Not True	Somewhat True	Certainly True	8. Many worries, often seems worried
Not True	Somewhat True	Certainly True	9. Helpful if someone is hurt, upset or feeling ill
Not True	Somewhat True	Certainly True	10. Constantly fidgeting or squirming
Not True	Somewhat True	Certainly True	11. Has at least one good friend
Not True	Somewhat True	Certainly True	12. Often fights with other children or bullies them
Not True	Somewhat True	Certainly True	13. Often unhappy, down-hearted or tearful
Not True	Somewhat True	Certainly True	14. Generally liked by other children

Figure 3.8 Self-regulation assessment on the EYT: CSBQ. Retrieved from <http://www.eytoolbox.com.au/about> in December 2018.

EYT scoring and data collation

All data were collected and collated by the iPad applications, and sent to a secure online database whenever the iPad connected to internet. This database collated, processed and scored the data according to protocols described by Howard and Melhuish (2017). These processed data from each task were downloaded as a CSV file to integration in the analytic dataset. For each task, this consisted of trial-by-trial accuracy and response time, as well as an overall performance index (as described above for each task).

3.3.3 Selective attention

Like EF, attention is a broad term, covering a range of cognitive capacities that are conceptualised differently depending on the school of thought and understanding of the concept. As discussed in chapter 2, the current study focuses on selective attention (visual). A common performance-based assessment to measure selective attention is a visual search task, sometimes referred to as a cancellation task. This task has typically been used to evaluate visuospatial function and diagnose visuospatial neglect (Ferber & Karnath, 2001; Laurent-Vannier, Chevignard, Pradat-Diehl, Abada, & De Agostini, 2006). More recently, it has also been used to assess selective attention skills in neurotypical adults, children and preschoolers (Mark, Woods, Ball, Roth, & Mennemeier, 2004; Steele et al., 2012; Woods et al., 2013) thus proving usefulness in both clinical and research settings.

There are two types of visual search tasks: feature search and conjunction search (J. Duncan & Humphreys, 1989; Treisman & Gelade, 1980). In a feature search, the targets have distinguishable features, whereas in a conjunction search the targets and distractors share common features. Both require several cognitive domains including selective and sustained attention, motor coordination, visuospatial searching and psychomotor speed (Brucki & Nitrini, 2008). However, a conjunction search might require additional skills such as motor planning, working memory and inhibitory control, skills that fall under the term EF (Luria & Vogel, 2011; Treisman & Gelade, 1980). A multi-target visual search task (or cancellation task) is similar to visual search tasks in that targets need to be identified in amongst distractors. A single-target search task has only one target, whereas a multiple target search has many

targets (Woiciulik, Husian, Clarke, Driver, 2001; Dalmaijer, Van der Stigchel, Nijboer, Cornelissen, Husain, 2015). Visual search tasks have recently transitioned from simple pencil and paper tasks to sophisticated computerised, tablet based tasks (e.g. Dalmaijer, Van der Stigchel, Nijboer, Cornelissen, & Husain, 2015). Computerised tasks provide a far more efficient method to collect and record cancellation data, including speed, task accuracy and search organisation. Considering the ease of administration combined with the rich information one can gain from administering a computerised cancellation task, it is a valuable tool to explore neurocognitive abilities in children and adults from a range of settings and backgrounds.

A multiple target visual search task that was adapted from previously validated cancellation tasks (Steele et al., 2012) was used to assess selective attention in the current study. The new task was created by a team that included members of the current research team, a software engineer and a graphic designer. It was necessary to adapt the existing tasks for multiple reasons. The first consideration was that cancellation tasks previously used with preschoolers (e.g., Steele et al., 2012) and toddlers (e.g. Doherty et al., 2018) required software (E-prime software, Psychology Software Tools Inc.) and equipment (a 17" EloTouch touchscreen, connected to a separate control computer) that were not practical for the testing in these study settings. To address this issue, the new task was optimised for administration on a tablet, making it easily portable and only required the tablet, rather than an additional touchscreen. Secondly, although the existing tasks (Scerif, Cornish, Wilding, Driver, & Karmiloff-Smith, 2004) were engaging, they may not have been as engaging or familiar for young children in our settings. Therefore, the new task saw the addition of an appropriate narrative, animations and enhanced stimuli to ensure the task was equally as engaging as the EYT and adapted to the local context.

The new visual-search task used in the current study is called Home Before Dark with the narrative encouraging the participant to select (collect) all the dogs and animals in each round so that they can be home before the sun sets. In the current study, the task was administered on a Microsoft Surface Pro 4 with a stylus. Task instructions that appeared on the screen were read out by the fieldworker in the participants' home language. The task includes practice rounds (that could be repeated) to allow familiarisation with the task instructions and the use

of the stylus. These practice rounds consisted of three types of stimulus on a horizontal line, two of which were a target, the other being a distractor. A participant only began the trials once it was clear they understood the task during the practice rounds.

After the practice rounds, there were six trials in total: three conjunction (multiple target) search trials and three feature (single target) search trials. For each search type, there was a baseline run first with only the target items presented (30 in total for each search type, either 10 pigs, 10 cows, and 10 goats or 30 dogs; see figures 3.7 and 3.9). This was followed by two trials consisting of 60 items in total each (30 targets and 30 distractors; see figures 3.8 and 3.10). The conjunction search was always performed first and the presentation of the items on the screen was randomized in each trial. In the conjunction search, the distractors and targets share common features: the chair was selected to match the cow in terms of basic perceptual features, the goat with the table and the pig with the shoe. In the feature search, the target (dog) did not share any common features with the distractors (objects). The total experiment lasted about 5 minutes. There were additional practice rounds between each trial to remind the participant of the rules.

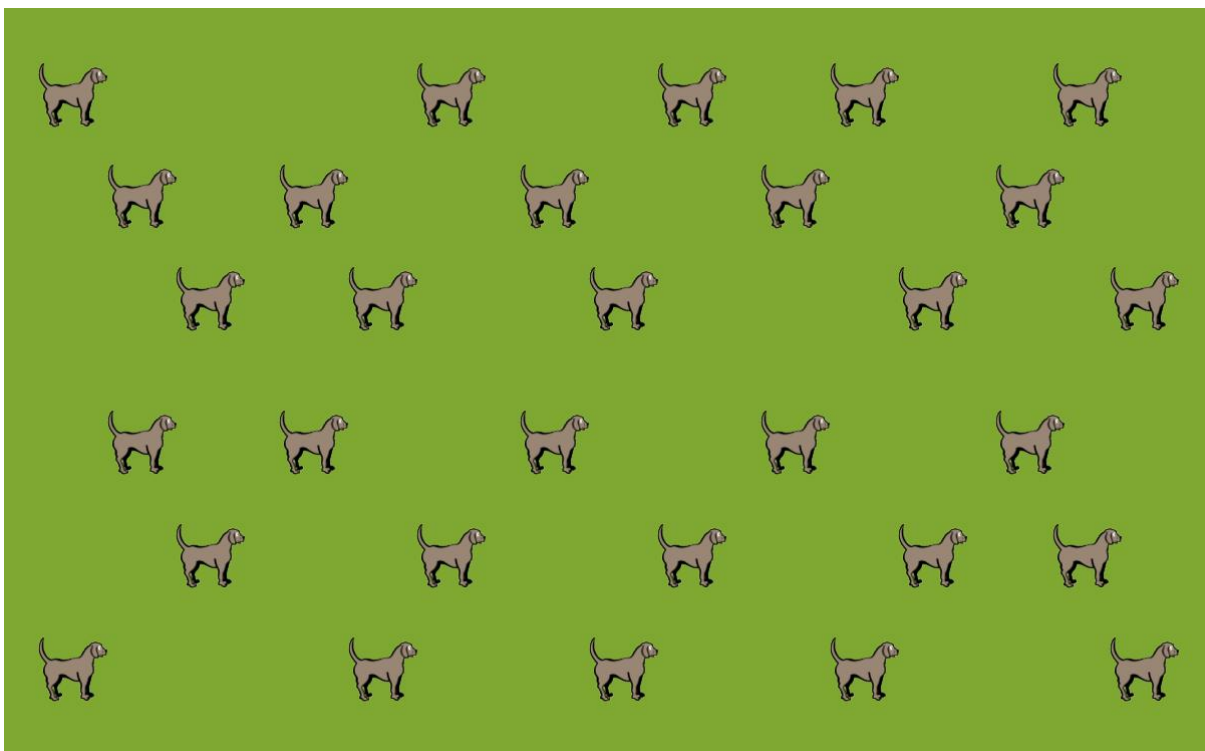


Figure 3.9 Baseline run with single target and no distractors.

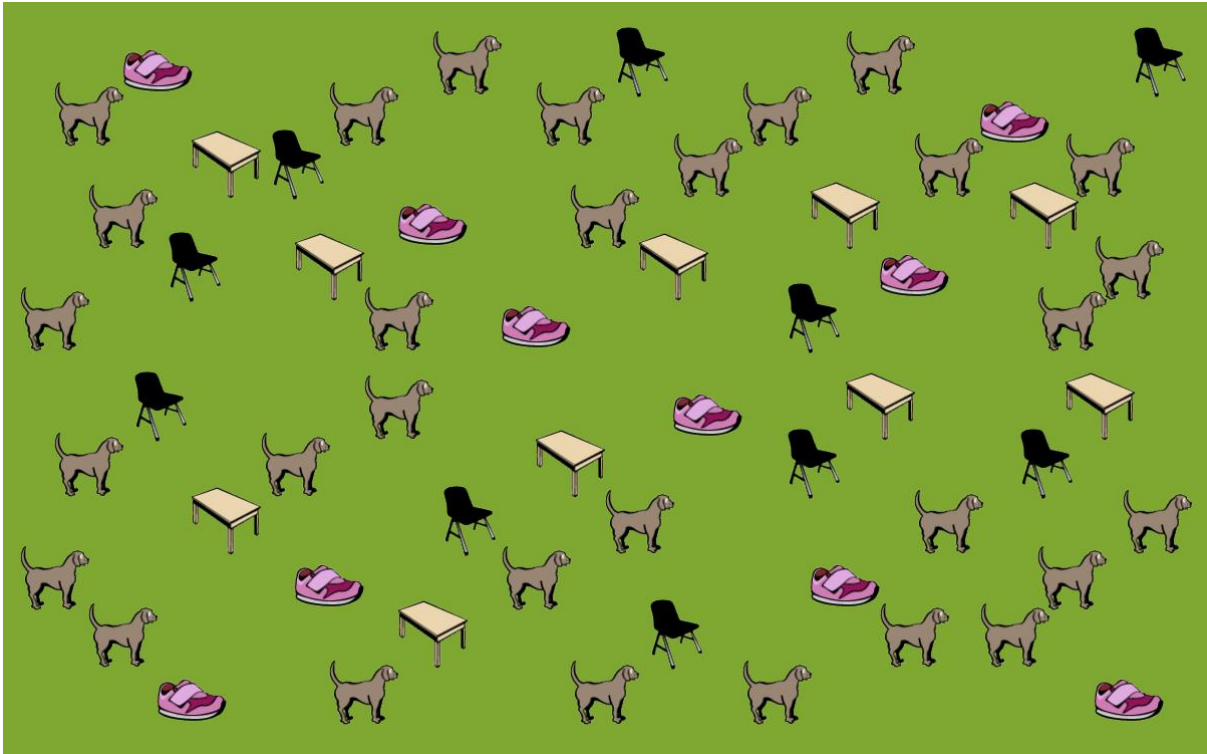


Figure 3.10 Run with single target and distractors.

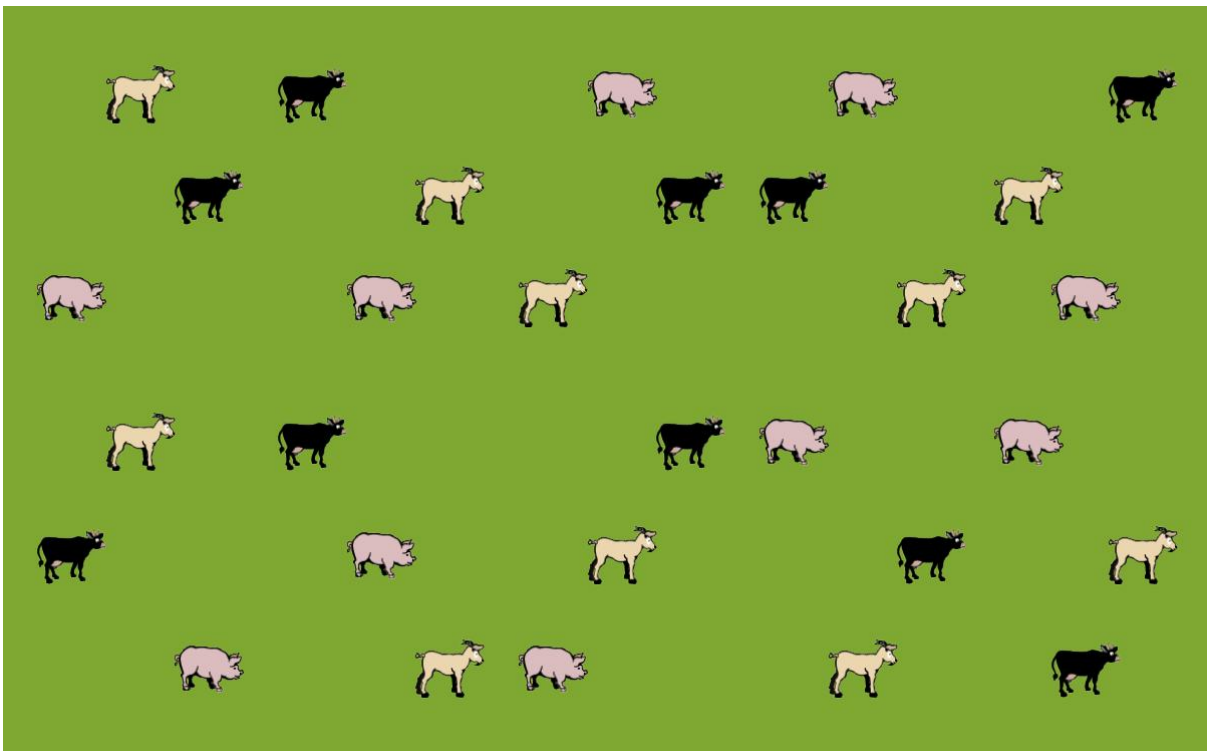


Figure 3.11 Baseline run with multiple targets and no distractors.

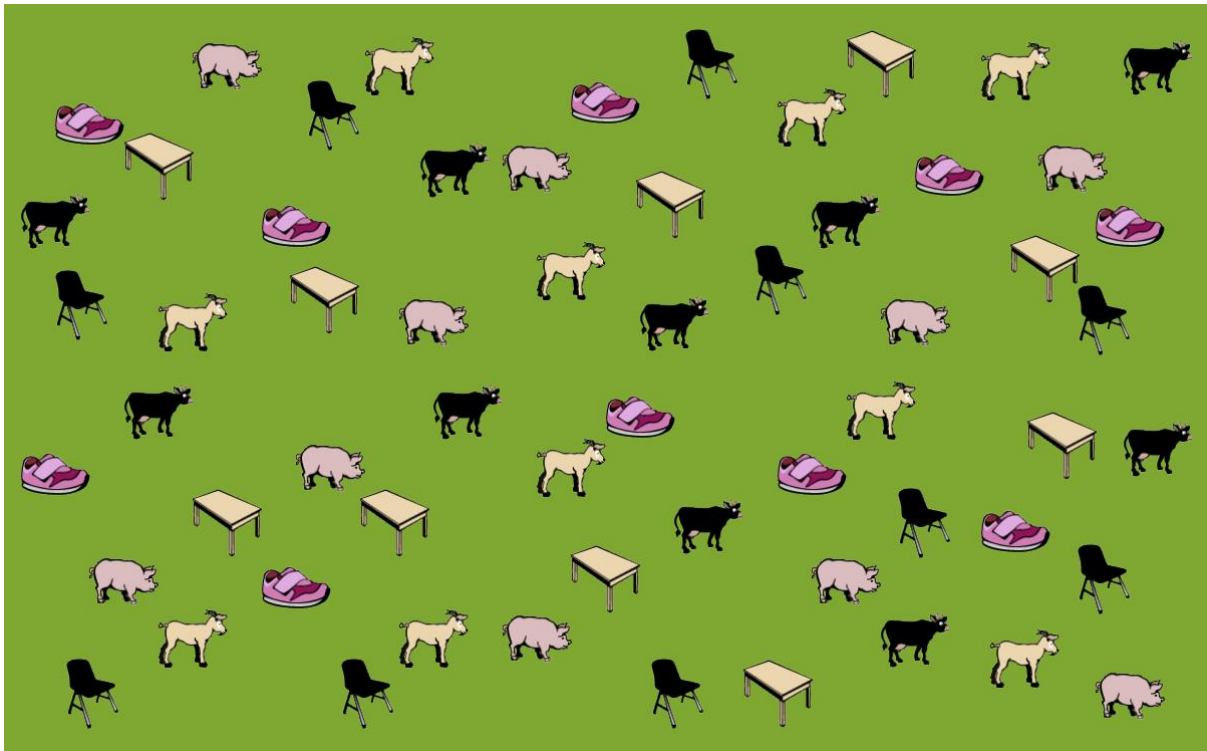


Figure 3.12 Run with multiple targets and distractors.

Selective attention data management

The data was captured and stored as raw data on the tablet that could be downloaded as a CSV file. The data was then processed using a customised Matlab script, and a customized R script designed to extract multiple indices of search performance. For the current study, variables included an index of search efficiency (Q-score) and an index of search strategy (intersection rate, both after; Dalmaijer et al., 2015; Woods, Göksun, et al., 2013).

3.3.4 School readiness

The current study aimed to assess the cognitive components of school readiness (pre-academic skills). To assess this, the Herbst Early Childhood Development Criteria test (ECDC) was used (Herbst & Huysamen, 2000). The ECDC was developed for and validated in the South African context to assess the cognitive, fine motor and gross motor development skills believed to underlie school readiness in 3- to 6-year-old children. The test is child-centred, as well as culturally and contextually relevant for use in a South African setting. Although the test is made up of three subsections (cognitive, fine motor, gross motor), only the cognitive subsection was used for this study given its focus on the cognitive skills that underlie school

readiness (Herbst & Huysamen, 2000) The cognitive subsection includes 10 subscales that assess the following areas of cognitive development:

1. *Incomplete man* assesses body part awareness. The child is required to use a pencil (or crayon, depending on his or her age and fine motor skills) to add missing body parts to an incomplete drawing of a human figure. The child receives a point for every body part that is added (with both arms counting as 1, likewise with both legs) with a maximum score being 8.
2. The *visual-motor integration (VMI)* task requires the child use a pencil to copy lines and geometric figures from individual plastic stimulus cards. There are 10 figures (trials) and a point is awarded for every figure that is drawn correctly.
3. *Block building* assesses visual discrimination, fine-motor coordination and spatial concepts. Using red blocks, the child must copy the examples built by the tester. There are 8 constructions (trials) and a point is given for every construction that is copied correctly.
4. *Stick figures* assesses spatial concepts and VMI, while minimising fine-motor coordination demands that may be unfamiliar to the child. Lines and geometric figures have to be copied from stimulus cards by arranging red plastic sticks on the test table. There are 10 figures to copy (10 trials) and a point is given for correct figure arranged.
5. In the *direction and similarities* task, the child is asked to identify which (out of four) block or drawing is facing a different direction to the other three. There are 12 trials, and a point is awarded for each trial that is answered correctly.
6. In the two- and three-dimensional *form concept* task, the child is required to match 2D and 3D shapes. In total, there are 17 shapes to sort, with points given depending on how many shapes have been sorted in a specific amount of time. The maximum score is 6.
7. In the *colour concept* task, the child is required to match and name certain colours and arrange colours according to shades. Points are given based on the number of colours that can be identified. If a child can correctly identify 8 colours, they progress to a task in which they grade colour intensity. The maximum score is 6.
8. To assess *numerical and counting concepts*, the child is required to count plastic sticks, moving each one of them while counting. A maximum of 6 points is awarded if the child can correctly count above 13 sticks.

9. The *Picture puzzles* task required children to build two- to six-piece yellow 2D puzzles with simple line drawings printed in black. Each puzzle had to be built within a fixed time-limit to match a stimulus picture. There are 7 puzzles (trials) and a point is awarded for each puzzle that is built correctly.
10. *Picture perception* assesses visual discrimination by asking the child to correctly indicate the picture that exactly resembles an item pointed out to him or her on a large stimulus card. There are 12 trials, with half a point awarded for each correct trial.

ECDC data management

Norms for the ECDC are expressed in terms of percentile ranks and a z-score. These norms are based on South African children and compare performance against the child's age, population group and educational status (whether the child attends a preschool or not). The percentile ranks are given for each subtest, the z-score is based on the overall score. These Z-scores are categorised into normal, high, very high, low and very low. The normal category shows that a child is performing as expected for age and educational status; high or very high means children are performing better than expected; and low and very low indicates that children performing worse than expected and are experiencing significant delays in the subtests.

3.3.5 Objectively measured physical activity

Physical activity in early childhood can be measured using both objective and subjective instruments. Subjective methods generally refer to interviews or self-report methods, which for preschool-age children are reported by parents or caregivers (Welk, Corbin, & Dale, 2000). When subjective methods are chosen, this is often because they are easy to administer, low in cost and low in participant burden. However, these methods fall short because they rely on parents' or caregivers' fallible recall, as well as their often non-complete awareness of all activities that their child has participated in (e.g., at preschool or creche) (Freedson, 1991; Ruch et al., 2016).

In contrast, objective measures have shown far greater accuracy. Among the objective measures, accelerometers are the most common method for measuring physical activity levels in preschool-aged children (Oliver, Schofield, & Kolt, 2007). Accelerometers are

monitors that quantify the intensity of movement by recording counts from accelerations within a selected epoch (generally 15 s for preschool-aged children, due to the spontaneous nature of physical activity at this age). Previous research in South African low-income urban and rural settings showed the viability of this approach, in that participants demonstrated high levels of compliance when it comes to wearing the accelerometers and reported minimal hinderance to the children (Draper et al., 2017; Tomaz, 2018). Therefore, accelerometry was considered a feasible method to measure physical activity in this sample.

The ActiGraph GT3X+ accelerometer was used in the current study. It is a small, red monitor about the size of a wrist watch. The accelerometer was attached to an elasticated band and placed around the participants' waist, with the device in line with the right hip. Participants were instructed to wear the accelerometer for 24 hours a day for seven days, and to only remove the device during water activities such as swimming or bathing. A smiley face sticker was placed on the device to remind the participant how to orientate the device. Participants, their parents and caregivers and the teachers received verbal and written information explaining what the device was, how to wear it and how to look after it.

Accelerometry data management

Accelerometry counts were recorded at 15-second epochs. Non-wear time was defined as 10 minutes of consecutive zeros, and a valid day included at least 7 hours of wear time. Accelerometry data was analysed using ActiLife version 6 software (ActiGraph, Pensacola, FL, USA). Initially, data was included if a participant had a minimum of 4 valid days, 3 week days and 1 weekend day. However, these stringent criteria lead to high numbers of participant loss (10%). Instead, data was included for participants that had any three days of valid data, including at least 1 week day. This was deemed appropriate as leaders in the field of physical activity measurement have used as little as 1 day of accelerometry data (e.g. Collings et al., 2013). Age-appropriate cut points were used to calculate physical activity intensities (X. Janssen et al., 2013). These included light-intensity physical activity (LPA; 37-419 counts.15s-1), moderate-intensity physical activity (MPA; ≥ 420 -841 counts.15s-1) and vigorous-intensity physical activity (VPA; ≥ 842 counts.15s-1). Total physical activity (LMVPA) and moderate- to vigorous-intensity physical activity (MVPA) were then generated based on these cut points.

3.3.6 Gross motor skill proficiency

GMS proficiency can be assessed using instruments that evaluate either the process and/or the outcome of gross motor skills (GMS). Process evaluation places more emphasis on the qualitative aspects of a skill (e.g. how the ball was thrown), whereas outcome evaluation places more emphasis on the outcome or quantitative aspects of a skill (e.g. how far a ball was thrown). Common instruments used to assess GMS in preschool children include the Test of Gross Motor Development – Version 2 (TGMD-2; Ulrich, 2000), the Bruininks-Oseretsky Test of Motor Proficiency – Version 2 (BOT-2; Bruininks & Bruininks, 2005), The Movement Assessment Battery for Children Version 2 (MABC-2; Henderson, DA, & AL, 2007) and Peabody Developmental Motor Scales (PDMS-2; Folio & Fewell, 2000). Of these, the TGMD-2 was chosen to assess GMS in the current study because it was relatively inexpensive (does not require specialised equipment) and because previous research in similar settings have successfully used the TGMD-2, therefore enabling comparison of results from the current study with previous findings (Draper et al., 2017; Tomaz, 2018). The TGMD-2 is a process-based assessment and comprises two subtests, namely locomotor and object control. Each subtest is made up of six skills. The six locomotor skills are run, gallop, hop, leap, horizontal jump and slide. The six object control skills are striking a stationary ball, stationary dribble (bounce), kick, catch, overhand throw, and underhand roll. Performance is analysed according to a set of established and validated performance criteria (Ulrich, 2000).

For testing, children were divided into groups of four to six, and participants were instructed to watch as a trained assessor (CC) demonstrated each skill. The participants then attempted the skill, one at a time. In the case that a participant performed a skill incorrectly, the assessor demonstrated the skill again to ensure the participants that followed did not follow the incorrect demonstration. After the skill demonstration, participants were given two opportunities to perform the skill (2 trials per skill) and were encouraged to perform their best. The testing was video-recorded by another member of the research team (CD), which allowed the assessor (CC) more time to score the tests and scrutinise children's performance (Cliff et al., 2012).

TGMD-2 data management

Following the TGMD-2 manual, raw scores, standard scores and gross motor quotient (GMQ) were determined for each participant. Raw scores represent the total performance criteria that were achieved for each skill and can be put together to perform a combined raw score for each subtest (locomotor skills and object control skills), and a total raw score, combining the two subtests. Standard scores provide a score based on age and sex norms. The GMQ is a combined score for both subtests, and it takes into account the raw score, age and sex of the participant. Furthermore, GMQ can be used to rank performance according to seven descriptive categories of gross motor proficiency: very poor, poor, below average, average, above average, superior and very superior. Norms for the TGMD are based on American children in the absence of South African norms. However, using these norms for standardised scores and GMQ has been deemed valid and reliable in diverse contexts, including: Scotland (Johnstone, Hughes, Janssen, & Reilly, 2017), Italy (Cristina, Panebianco, Polman, & Stagni, 2017), Singapore (Mukherjee, Ching, Jamie, & Fong, 2017), Australia (Barnett, Salmon, & Hesketh, 2016), Japan (Aye et al., 2018), Myanmar (Aye, Oo, Khin, Kuramoto-Ahuja, & Maruyama, 2017) and Brazil (Valentini, Rudisill, Bandeira, & Hastie, 2018). Standardised scores and GMQ (based on norms) are only used in Chapter 4, as it aims to describe GMS performance. However, for subsequent chapters that aim to investigate associations between GMS and other components, only the raw scores (locomotor raw scores, object control raw scores and sum of raw scores) are used.

3.3.7 Anthropometric measurements

Anthropometric measures included height and body weight. Participants were instructed to remove shoes and any heavy clothing prior to measurement. Height was measured using a portable stadiometer (Leicester 214 Transportable Stadiometer; Seca GmbH & Co, Hamburg, Germany). Height was measured to the nearest millimetre and an average of two measurements was taken. If these measurements differed by more than 5 millimeters, a third measurement was taken, in which case the average of the two closest measurements were reported. Body weight was measured using a calibrated electric scale (Soehnle 7840 Mediscale Digital; Soehnle Industrial Solutions GmbH, Backnang, Germany). Weight was measured twice, with the average of the two measures being reported. As with height, if the

two measurements differed by more than 0.5kg, a third measurement was taken and the average of the two closest measurements was reported. CC conducted all the measurements to ensure consistency. CC was trained by an anthropometrist at the Sports Science Department at the University of Stellenbosch.

Anthropometric measurement data management

Data on height, age and sex were entered into the World Health Organisation's AnthroPlus software (WHO, 2009), which calculated body mass index (BMI), BMI for age (BAZ), weight for age (WAZ) and height for age (HAZ). Additionally, the International Obesity Task Force (IOTF) cut-offs (Cole & Lobstein, 2012) were used to categorise participants as either level 1, 2, or 3 thinness, normal weight, overweight, obese or morbidly obese.

All measures described in this chapter are summarised in Table 3.1.

Table 3.1 Summary table of the variables measured

Main outcomes	Tool	Variables/subscales
Executive function	Early Years Toolbox: Go/No-Go, Card Sorting, Mr Ant Cronbach's α s for Go/No-Go = >0.84	<ul style="list-style-type: none"> • Inhibition • Shifting • Working memory
Self-regulation and social development	Early Years Toolbox: Child Self-regulation and Behavior Questionnaire All Cronbach's α s = >0.80	<ul style="list-style-type: none"> • Cognitive self-regulation • Emotional self-regulation • Behavioural self-regulation • Sociability • Prosocial behaviour • Externalising problems • Internalising problems
Selective attention	Visual search task: Home before dark	<ul style="list-style-type: none"> • Quality of search score • Intersections rate (search organisation)
School readiness	Early childhood development criteria (Herbst Test)	<ul style="list-style-type: none"> • Subtest scores and percentiles • Incomplete man • Visual motor integration • Block building • Stick figures • Direction and similarities (3D and 2D) • Form concept (3D and 2D) • Colour concept • Numbers and counting • Picture puzzles • Picture perception • School readiness total score • School readiness descriptive categories
Physical activity	Accelerometry (ActiGraph GT3X)	<ul style="list-style-type: none"> • Light physical activity intensity • Moderate physical activity intensity • Vigorous physical activity intensity
Gross motor skills	Test of Gross Motor Development - 2 nd Edition Cronbach's α s = between 0.85 and 0.91	<ul style="list-style-type: none"> • Locomotor skills (raw & standard scores) • Object control skills (raw and standard scores) • Total gross motor skills (raw and standard scores) • GMQ
Anthropometric measurements	Portable stadiometer and electric scale	<ul style="list-style-type: none"> • Height • Weight • BMI, HAZ, BAZ, WAZ

3.4 Data collection: procedure

All measures apart from the CSBQ were administered by a trained researcher (CC) with the assistance of a trained, local fieldworker from each setting who could communicate in participants' home language. All children were fluent enough to complete the testing in one of the three main languages (Sotho, Zulu and Xitsonga) and the field worker was generally able to converse in other languages when needed. The CSBQ was administered by a trained research (CD; principal investigator of the study) who went through the questions with each ECD practitioner. The ECD practitioners were able to speak and understand English however, if there were any uncertainties, the fieldworker helped to explain in their home language. Data were collected at each study site over the course of one month in each setting: August 2016 for the urban study site and March 2017 for the rural study site. As far as possible, testing took place at the preschools during school hours (\pm 8:30am to 4:30pm for the urban preschools and 8:00am to 3:00pm for the rural preschools). However, as is expected with field work, there were some unexpected circumstances in the rural settings that prevented some of the testing from happening in the preschools. This included protests in the village that resulted in it being dangerous for children to attend school, as well as school holidays that coincided with data collection. In these cases, children were tested in alternative locations made available by the research office. These locations approximated testing conditions at the preschools.

Measures were taken in the same fixed order to all children at each study site. However, physical activity was measured at different time points over the month due to the limited number of Actigraph GT3X accelerometers therefore, only a certain number of participants could wear the accelerometers at one time. This meant that participants were wearing the accelerometers at the same time that the other data was being collected. The order was as follows: The first group of children received accelerometers at the start of data collection while the second group half-way through to allow time to charge and re-calibrate the accelerometers. School readiness testing also began on the at the start of data collection and took three days per preschool to complete. After this, gross motor skill testing (TGMD-2) and anthropometric measurements were conducted. This took one day to complete per preschool. Thereafter, EF and selective attention measures began, these were completed on

the same day for each participant. Selective attention was assessed first, followed by a 25-minute break before the EF tasks (EYT). EF tasks were completed in the same order for each participant: Go/No-Go first, Card Sort, and Mr Ant. At the same time, the teacher interviews for the CSBQ were conducted by another member of the research team (CD).

3.5 Statistical analyses

Tests for normality were conducted prior to analyses and either parametric or non-parametric statistical tests were chosen accordingly. In Chapter 4, where differences between groups are investigated, some groups did not have normally distributed data and therefore non-parametric tests were conducted. For Chapters 5-8, in which the full sample is analysed, parametric tests are conducted as the data is normally distributed. The statistical methodology is provided in further detail under the Statistical analyses heading in each results chapter.

3.6 Ethics

Ethical approval was obtained from the University of Cape Town Human Research Ethics Committee (Ref: 053/2015), and the Human Research Ethics Committee (Medical) at the University of the Witwatersrand (Ref: M160534), and permission was given by the Mpumalanga Provincial Department of Health Research Committee. This study adheres to the guidelines outlined in the Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects. Parents provided written informed consent for each participant, including specific permission for their child to be video-recorded for the TGMD-2 testing. Participation in the study was completely voluntary; children and parents were allowed to withdraw from the study at any point. Children's willingness to participate, as indicated verbally or non-verbally, was monitored by the data collector (CC) and fieldworker. Unwillingness to participate was characterised as: a child refusing to participate; a child being non-responsive; a child showing signs of anxiety or distress (e.g. excessive sweating, breathing hard, crying); or when it was clear that the child was not capable of completing the test (e.g. lacking comprehension or becoming increasingly distracted). If any of these signs were

observed, the fieldworker would ask the child if they no longer want to participate, if the child said or indicated yes, testing was terminated. One child in the sample cried when testing commenced, and six children were non-responsive on commencement of testing. Testing was discontinued for these participants.

CHAPTER 4: DESCRIBING COGNITIVE AND PHYSICAL OUTCOMES

4.1 Introduction

As mentioned in Chapter 2, South Africa is an understudied low- and middle-income country (LMIC) with unique social-cultural factors and challenges particularly in the low-income settings. Chapter 2 also highlighted the lack of research on cognitive development and the limited evidence for components of physical development in the preschool years, emphasising the need for further research in these settings. Furthermore, differences between urban and rural low-income settings in South Africa were highlighted in Chapter 3 and included factors such as geographical location, access to utilities and resources, language, population density, and land space. Considering these differences, it would be expected that these settings might have differential effects on cognitive and physical development in early childhood. Although limited, there is some evidence to show this.

For example, there is research to suggest that children from rural settings in South Africa may be at risk for poorer cognitive development as shown by the poor school outcomes (Spaull, 2013). Data has shown that by grade 4, children from rural settings are already 2 years behind urban children in reading abilities (Howie, Van Staden, Tshele, Dowse, & Zimmerman, 2012). While the causes of this discrepancy are not yet conclusive, that rural settings are known to be among the most underserved and under-resourced settings in South Africa (Carter & May, 1999), is proposed to contribute to this finding. For example, research has found that children in remote rural areas are among the most vulnerable as they have limited access to essential services including good quality education (due to poor and infrequent support from the government, limited educational resources and poor quality teacher training; Biersteker, 2012).

Differences between the settings have also been found for physical development, including nutritional status, levels of physical activity and gross motor proficiency. For example, previous research has shown the higher prevalence of undernutrition, specifically stunting, in

rural settings compared to urban settings (Kimani-Murage et al., 2010; Smith, Ruel, & Ndiaye, 2005). Local studies have also shown that rural children from low-income settings engage in high volumes of physical activity, particularly at a low intensity (Draper et al., 2017; Tomaz, Pioreschi, et al., 2019). Moreover, local research (Draper et al., 2019; van Zyl et al., 2012), and research from other African countries (Sobngwi et al., 2002), have consistently found that higher volumes of physical activity are performed in rural settings compared to urban settings. Rural children have also been found to demonstrate superior gross motor proficiency compared to urban children (Tomaz, Hinkley, et al., 2019).

Investigating the differences between boys and girls is commonly seen in research on early childhood development. The literature on sex differences in cognitive development (including academic achievement) is mixed (Matthews, Ponitz, & Morrison, 2009). Where differences are found, they tend to favour girls (Duckworth & Seligman, 2006; Kochanska, Coy, & Murray, 2001; Silverman, 2003). Moreover, research has indicated that boys are more susceptible to externalising disorders, of which behavioural regulation, attention and inhibition are key components (Lemery, Essex, & Smider, 2002). Researchers have suggested that this superior cognitive performance by girls may be due to better self-discipline (Duckworth & Seligman, 2006), ability to delay gratification (Silverman, 2003), and/or ability to regulate behaviour and emotions (Else-Quest, Hyde, Goldsmith, & Van Hulle, 2006). Fundamental to each of these abilities are EF and self-regulation, which are further influential to academic success. In addition to being mixed, the evidence for sex differences is mostly derived from high-income countries (HICs) and Western Educated, Industrialised, Rich and Democratic (WEIRD) contexts, while sex differences in cognitive development remain largely unstudied LMICs and non-WEIRD contexts.

Research investigating the sex differences for components of physical development, specifically physical activity and gross motor proficiency, has reported more consistent results. Literature from as far back as the 1970s (Maccoby & Jacklin, 1974) revealed that boys are generally more active than girls. Additionally, a systematic review by Tucker (2008) revealed that 16 out of the 18 empirical studies on this topic in the early years reported that boys were more active than girls in the preschool period as well. However, recent research from South African settings have found no differences at any intensity of physical activity

between boys and girls (Tomaz, Prioreshi, et al., 2019). On the other hand, research has consistently shown that boys demonstrate better gross motor proficiency, specifically when it comes to object control or ball skills, compared to girls. Researchers have suggested both biological and sociological factors to explain these findings. Biological differences in pre-maturation, including size and strength, might favour boys in terms of their object control skills (Butterfield, Angell, & Mason, 2012). Regarding socialisation factors, many studies have reported that boys are expected to participate in more sports or sports-related activities compared to girls (Blatchford, Baines, & Pellegrini, 2003; Eccles & Harold, 1991). As a result, boys often receive more encouragement and opportunities to practice and develop these skills. Although there is some research from LMICs and South African low-income settings, this evidence is limited and therefore, additional research is needed in these types of settings to determine whether the effects of sex found in HICs apply to LMIC and non-WEIRD settings as well.

Therefore, this chapter aimed to address some of the gaps in local and LMIC research and to build on the limited local evidence. In other words, the aim of this Chapter is of an exploratory; to describe components of cognitive development and components of physical development in preschool-aged children from urban and rural low-income settings in South Africa (the first aim listed in Chapter 2). The components of cognitive development included executive function (EF), self-regulation, selective attention and school readiness and components of physical development included physical activity levels, gross motor skills (GMS) and anthropometric measurements. The specific objectives of this aim included to (a) describe differences between urban and rural settings and (b) differences between boys and girls. In doing this, this chapter is an important prelude to the narrower hypothesis-driven analyses that follow in the subsequent chapters.

4.2 Methods

4.2.1 Measures

Outcome variables and demographic variables presented and analysed below are described in Chapter 3.

4.2.1 Statistical methodology

All analyses were conducted using IBM SPSS Statistics version 25 for Mac (IBM Corp, Armonk, NY). Data on all the outcome variables as well as age and adiposity are presented in descriptive tables or bar charts, stratified by both setting and sex. Means and standard deviations are presented for parametric data. Non-parametric data are reported as medians and interquartile ranges. For uniformity and comparison, in a table that includes non-parametric data, both the mean and standard deviation as well as the median and interquartile range is presented in the table. Categorical data are presented as the proportion of sample per category. Differences between settings (i.e., urban, rural) and child sex were investigated using independent t-tests (for normally distributed, continuous variables), Mann-Whitney U tests (for continuous variables that were not normally distributed), Chi-square tests for independence (for categorical variables) and Wilcoxon Signed Rank Tests (for related variables that were not normally distributed). The level for significance was set at $p < 0.05$.

4.3. Results

4.3.1 Participant characteristics

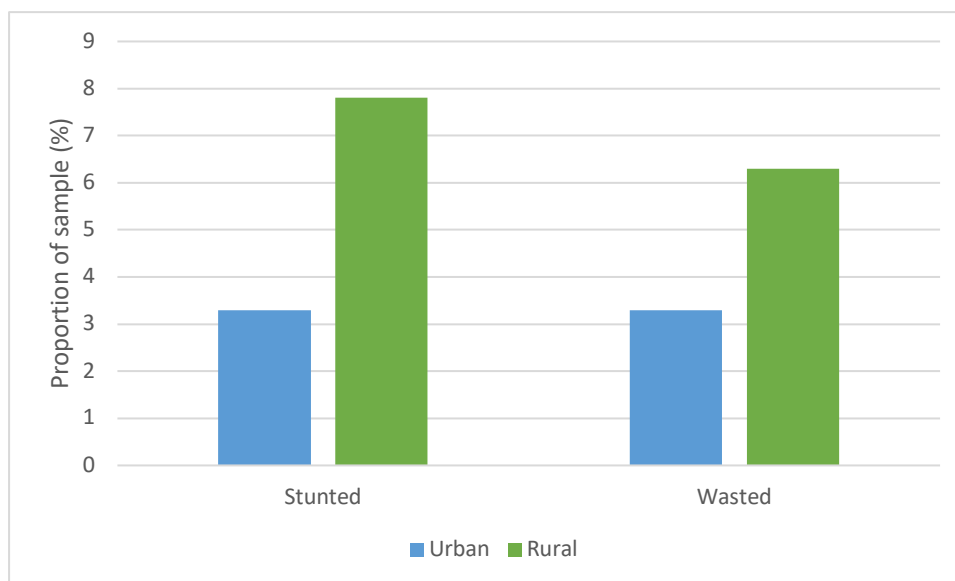
Age and anthropometric measurements (i.e., BMI, BAZ, HAZ and WAZ) are reported in Table 4.1. Independent t-tests revealed significant differences between urban and rural settings for age ($p = 0.008$), BMI ($p = 0.018$) and BAZ ($p = 0.024$). Urban children, on average, were older and had higher average BMI. The proportion of children per weight status category, based on the IOTF cut-offs (Cole & Lobstein, 2012), showed that more than 75% of the total sample were classified as normal weight. The Chi-square test for independence indicated no significant differences between settings for IOTF categories. However, these results show that overweight and obesity were more prevalent (but not significantly) in the urban children (13%), while thinness was more prevalent in the rural children (17.2%). There was no significant difference between girls and boys for any of these variables.

Table 4.1 Participant characteristics

	Total (n=126)	Urban (n=62)	Rural (n=64)	Girls (n=66)	Boys (n=60)
Age (Months)	50.7±8.3	52.6±10.4*	48.8±4.8*	50.6±7.2	50.8±9.4
BMI (kg.m ⁻²)	15.7±1.4	16.0±1.5*	15.4±1.3*	15.7±1.6	15.8±1.2
BAZ	0.2±0.9	0.4±0.9*	0.1±0.9*	0.2±1.1	0.3±0.8
WAZ	-0.2±0.9	-0.1±0.9	-0.3±0.9	-0.2±1.0	-0.1±0.9
HAZ	-0.5±1.0	-0.5±1.0	-0.5±1.0	-0.5±1.0	-0.5±0.9
IOTF weight status (%)					
Thinness	11	4.9	17.2	15	7
Normal weight	79	82	78.1	73	87
Overweight/obese	10	13.1	4.7	12	6

Note: Data are represented as mean ± standard deviation *indicates a significant difference between urban and rural groups ($p < 0.05$)

Figures 4.1 and 4.2 show the proportion of children classified as stunted (a HAZ score more than two standard deviations below the WHO Child Growth Standards median) or wasted (a WAZ score more than two standard deviations below the WHO Child Growth Standards median (WHO, 2009)). Results showed that only 6% of the total sample were classified as stunted while 5% were classified as wasted thin for their age. Although the prevalence of stunting and wasting was higher in rural children compared to urban children, a Chi-square test for independence revealed that the difference was not significant. Similarly, there was no significant difference between girls and boys.

**Figure 4.1** Proportion of urban and rural children classified as stunted or wasted

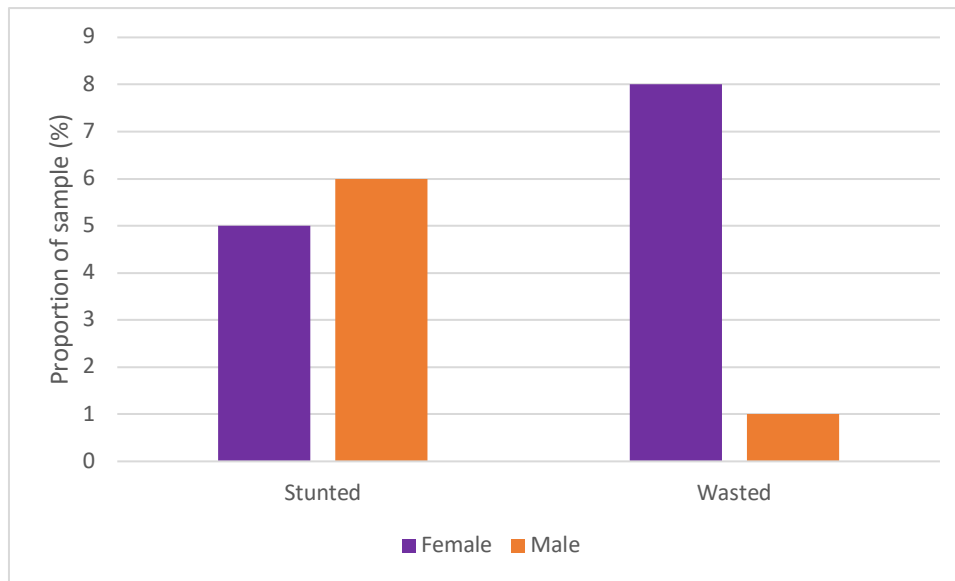


Figure 4.2 Proportion of female and male children classified as stunted or wasted

4.3.2 Executive function

Table 4.2 indicates the scores for each task on the EYT. On average, children in both settings performed at or above established norms for this age group on these tasks (based on results with Australian children; Howard & Melhuish, 2017). Performance at floor was extremely low on each of these measures demonstrating that, despite the tools' development in Australia, their South African adaptations generated data with very good distributional properties. For example, there were no participants who were unable to pass level 1 of Card Sort (the pre-switch trials), no participants who were completely unable to complete the inhibition task, and only 1.6% of participants who were unable to perform at least one working memory trial correctly. Distributions on all EF tasks were normal, and their inter-task and age correlations provided evidence of convergent validity of the tasks. Inter-task correlations are presented in Chapter 5.

Table 4.2 Performance on each executive function task on the Early Years Toolbox

	Total (n=124)	Urban (n=62)	Rural (n=62)	Girls (n=65)	Boys (n=59)
Inhibition	0.7±0.2 0.7(0.5-1.0)	0.7±0.2* 0.7(0.6-0.9)	0.6±0.2* 0.7(0.5-0.8)	0.7±0.2 0.7(0.6-0.8)	0.7±0.2 0.7(0.5-0.8)
Shifting	5.7±3.1 4.0(3.0-9.0)	6.42±3.07* 8.0(4.0-9.0)	5.0±2.97* 3.5(3.0-8-3)	6.0±3.1 4(3-9)	5.4±3.1 4(3-9)
Working memory	1.7±0.8 1.7(1.0-2.3)	2.0±0.8* 2.0(1.7-2.3)	1.3±0.7* 1.2(1.0-2.0)	1.6±0.8 1.7(1-2)	1.8±0.9 2(1-2.3)

Note: Data are represented as mean ± standard deviation and median (inter-quartile range). η indicates normally distributed data. *indicates a significant difference between urban and rural groups (p<0.05). #indicates a significant difference between girls and boys (p<0.05).

On all EF tasks, Mann-Whitney tests revealed that urban children demonstrated significantly better performance (inhibition: $p=0.035$, shifting: $p=0.007$, working memory: $p=0.003$). However, as these scores are not normalised for age, the differences observed between the settings may be due to the difference in age between the groups (rural group younger on average). EF performance did not differ between girls and boys. Linear regression analyses were used to determine whether setting or sex was a significant predictor of EF after controlling for age. Setting was only a significant predictor for working memory ($\beta=-0.30$, $p<0.001$) while sex was not a significant predictor for any of the EF skills.

4.3.3 Self-regulation

The average teacher ratings of participants' self-regulation are presented in Table 4.3. These average ratings all fell within the normal ranges (BSR: 2.75 - 5.00, CSR: 2.83 - 5.00, and ESR: 2.86 - 5.00) based on the Australian norms (Howard & Melhuish, 2017). Mann-Whitney tests showed that the average ratings for all three self-regulation outcomes differed significantly by setting, such that rural children had higher ratings compared to urban children ($p<0.001$). The proportion of children who had ratings within the normal range is also reported in Table 4.3. Chi-square test for independence revealed that a significantly greater proportion of the rural children were in the normal range for BSR compared to urban children, $X^2(3)=14.39$, $p=0.002$. This was not significant for CSR and ESR. Once again, the proportion of children in the normal range did not significantly differ by sex for any of the self-regulation variables. Differences between settings were investigated further using linear regression analyses. After controlling for age, setting was a significant predictor of BSR ($\beta=0.43$, $p<0.001$), CSR ($\beta=0.42$, $p<0.001$) and ESR ($\beta=0.48$, $p<0.001$). Sex was only a significant predictor of ESR ($\beta=-0.16$, $p=0.04$).

Table 4.3 Scores for teacher-rated self-regulation

	Total (n=124)	Urban (n=62)	Rural (n=62)	Girls (n=65)	Boys (n=59)
Behavioural	3.8±0.9 3.9(3.4-5.0)	3.4±0.9* 3.6(2.6-4.0)	4.2±0.7* 4.4(3.8-4.8)	4.0±0.8# 4(3.6-4.6)	3.6±1.0# 3.6(2.8-4.5)
<i>% in normal range</i>	84.7	72.6*	96.8*	90.8	78
Cognitive	3.7±1.1 4.0(3.0-4.5)	3.3±1.2* 3.3(2.5-4.3)	4.0±0.9* 4.3(3.7-4.7)	3.8±1.1 4.3(3.2-4.7)	3.5±1.1 3.8(2.8-4.3)
<i>% in normal range</i>	79.8	71	88.7	83.1	76.3
Emotional	4.0±0.9 4.1(3.4-4.8)	3.6±0.8* 3.6(3.0-4.1)	4.5±0.7* 4.7(4.1-5.0)	4.2±0.8# 4.3(3.6-5)	3.8±0.9# 3.9(3.3-4.7)
<i>% in normal range</i>	90.3	83.9	96.8	93.8	86.4

Note: Data are represented as mean ± standard deviation and median (inter-quartile range) or as a percentage of the sample. η indicates normally distributed data. *indicates a significant difference between urban and rural groups ($p < 0.05$). #indicates a significant difference between girls and boys ($p < 0.05$).

The distribution of ratings differed substantially between the urban and rural settings. For example, rural setting teachers put >90% of children in the top half of the scale for behavioural self-regulation, >70% for cognitive, and >90% for emotional. Urban teachers only placed between 60% and 70% of children in the top half of the scale.

4.3.4. Selective attention

Table 4.4 presents indices from the selective attention task, namely: the quality of search scores (Q score); and search organisation (intersections rate). Wilcoxon Signed-Ranks Test was used to investigate the differences between runs. Results showed that children performed better on the baseline run (no distractors) compared to runs requiring selective attention (given that targets were embedded among distractors) for both exemplar ($Z = -8.61$, $p < 0.001$) and category ($Z = -9.56$, $p < 0.001$) runs. This was expected given that there is no selective attention demand in the baseline runs, whereas the distractor runs challenged children's selective attention skills. Also, as is typical in this task, children performed better on the exemplar search (1 target, 3 distractors), in which targets and distractors did not share common features, compared to the category search (3 targets and 3 distractors, targets and distractors shared common features; $Z = -9.57$, $p < 0.001$). These findings indicate that, in the current setting, the task is performing as one would expect even though it originated from a HIC context. Differences between settings were observed for the baseline Q scores (exemplar: $p = 0.037$; category: $p = 0.003$) and distractor run Q scores (exemplar: $p = 0.001$; category: $p < 0.001$), but not for intersections rate. There were no significant differences between girls and boys.

Table 4.4 Selective attention scores

	Total (n=123)	Urban (n=61)	Rural (n=62)	Girls (n=64)	Boys (n=59)
Feature search					
Q score baseline	1±0.32 1(0.79-1.17)	1.05±0.35* 1.04(0.81-1.12)	0.93±0.55* 0.9(0.78-1.13)	1.01±0.27 1.03(0.8-1.17)	0.98±0.35 0.94(0.74-1.2)
Q score distractor runs	0.79±0.29 0.74(0.58-0.98)	0.88±0.32* 0.91(0.67-1.12)	0.7±0.22* 0.66(0.53-0.87)	0.81±0.27 0.77(0.62-0.97)	0.78±0.31 0.71(0.49-1)
Intersections rate	0.19±0.15 0.15(0.08-0.26)	0.20±0.19 0.15(0.08-0.26)	0.17±0.11 0.14(0.09-0.26)	0.17±0.14 0.13(0.07-0.25)	0.21±0.17 0.17(0.08-0.27)
Conjunction search					
Q score baseline	0.83±0.27 0.78(0.63-1.02)	0.91±0.31* 0.92(0.69-1.17)	0.76±0.22* 0.73(0.6-0.89)	0.85±0.27 0.8(0.6-1.02)	0.82±0.29 0.78(0.6-1.02)
Q score distractor runs	0.49±0.19 0.47(0.34-0.57)	0.56±0.22* 0.55(0.39-0.66)	0.42±0.12* 0.41(0.34-0.5)	0.48±0.17 0.47(0.35-0.57)	0.51±0.21 0.46(0.34-0.61)
Intersections rate	0.32±0.2 0.28(0.1-0.42)	0.34±0.23 0.28(0.17-0.45)	0.31±0.17 0.27(0.2-0.41)	0.34±0.22 0.28(0.17-0.48)	0.31±0.18 0.28(0.21-0.39)

Note: Data are represented as mean ± standard deviation and median (inter-quartile range). *indicates a significant difference between urban and rural groups ($p < 0.05$).

Linear regression analyses were conducted to determine whether differences for sex and setting remained after controlling for age. Results revealed that setting was a significant predictor of Q score distractor runs for feature search ($\beta = -0.19$, $p = 0.009$) and for the conjunction search ($\beta = -0.23$, $p = 0.002$), as well as intersections rate for the feature search ($\beta = 0.18$, $p = 0.04$). Sex was not a significant predictor for any of the attention variables.

4.3.5 School readiness

Table 4.5 presents the scores for the ECDC, including the school readiness total score (raw), and percentiles for each subtest. Mann-Whitney tests revealed that urban children performed significantly better than rural children ($p < 0.001$) based on the total school readiness score. However, since this presents a raw score, age is not taken into consideration. Therefore, additional linear regression analyses were conducted to determine whether setting and sex are significant predictors of school readiness after controlling for age. Results revealed that setting ($\beta = -0.31$, $p < 0.001$), but not sex, remained a significant predictor of school readiness. On the other hand, the subtest percentiles have been adjusted for age. Nevertheless, urban children still performed significantly better than rural children in the incomplete man ($p = 0.003$), VMI ($p = 0.021$), form concept ($p < 0.001$), colour concept ($p = 0.011$) and number counting tasks ($p < 0.001$).

Table 4.5 School readiness total score and percentile scores for each subtest

	Total (n=129)	Urban (n=64)	Rural (n=65)	Girls (n=68)	Boys (n=61)
School readiness total	26.2±13.6 25(17-35)	32.4±14.7* 31.5(22-41.8)	20.1±8.9* 20(13-27)	26.6±12.7 25(17.3-32.8)	25.6±14.5 23(13.5-36)
Subtest percentiles					
Incomplete man	51.1±35.4 56(24-86.5)	60.5±36.0* 73(25-94)	41.9±32.5* 25(20-75)	54.2±35.1 62(25-87)	47.6±35.7 42(20-86)
VMI	49.0±35.2 49(11-80)	55.6±32.4* 56(21.8-80)	42.5±36.9* 49(6-75)	53.7±35.4 52.5(14-92)	43.7±34.5 49(6-76)
Block building	44.5±36.4 35(2-4)	51.9±36.3 57(19-85.5)	37.2±35.2 20(9-78)	46.7±38.4 35(9-85.5)	42.1±34.1 33(14-79.5)
Stick figures	48.9±33.5 56(20-80)	54.5±35.9 56(20-88)	43.4±30.2 40(20-61)	48.2±33.7 40(14-82.3)	49.7±33.5 56(20-80)
Direction similarities	58.0±33.1 61(32-88)	58.0±33.2 61.5(30.5-88)	58.0±33.3 61(32-88)	61.9±30.6 65(40-88)	53.6±35.5 61(23.5-88)
Form concept	43.2±33.0 36(18-62)	56.8±35.7* 57(34-96)	29.7±23.5* 36(6-46)	43.5±30.8 36(18-62)	42.8±35.5 36(9.5-80.5)
Colour concept	64.3±31.1 80(43.5-91)	67.7±33.1* 84(29-94)	61.0±28.9* 61(61-80)	66.4±30.2 80(61-93.8)	62±32.3 80(19-86)
Number counting	39.5±38.2 17(6-81)	58.3±39.2* 57.5(9.3-100)	21.0±26.5* 7(6-29)	41±38.4 28.5(6-81.8)	37.8±38.3 16(6-81)
Picture puzzles	64.5±27.2 72(42-78)	66.9±28.3 72(42-95)	62.1±25.9 72(41.5-78)	64.4±29.2 72(42-90)	64.5±24.9 72(49-78)
Picture perception	80.5±29.9 98(71-100)	80.9±30.5 98(75-100)	80.0±29.5 98(71-99)	85.6±26.6# 72(42-90)	74.7±32.3# 88(63-98.5)

Note: Data are represented as mean ± standard deviation and median (inter-quartile range). η indicates normally distributed data. *indicates a significant difference between urban and rural groups (p<0.05). #indicates a significant difference between girls and boys (p<0.05).

Figures 4.3 and 4.4 show the proportion of the urban and rural children, as well as girls and boys, per ECDC descriptive category. As mentioned in Chapter 3, the normal category shows that a child is performing as expected for age and educational status; high or very high means children are performing better than expected; and low and very low indicates that children performing worse than expected and are experiencing significant delays in the subtests. Chi-square tests for independence showed a significant difference between urban and rural children, $X^2(6)=23.93$, $p=0.001$, while there was no significant difference between girls and boys ($p = 0.683$). Children from the urban setting demonstrated better school readiness than those from the rural setting, with 68% of the urban children falling in the normal, high or very high categories compared to only 38% of rural children.

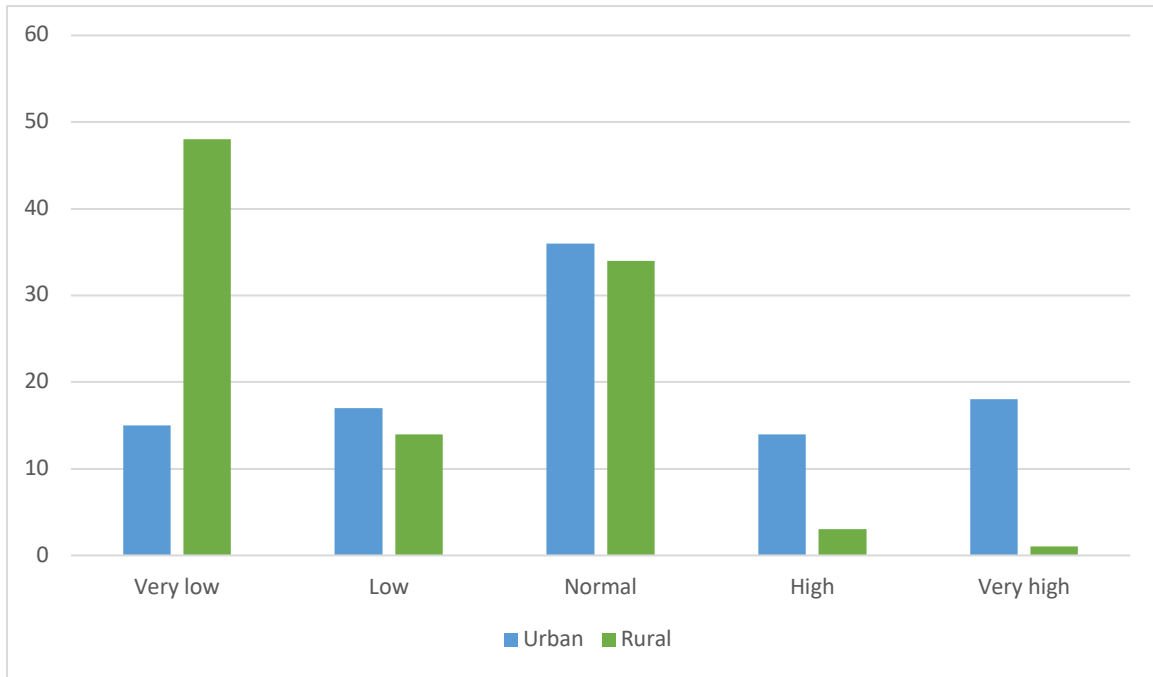


Figure 4.3 Proportion of urban and rural children per ECDC descriptive category

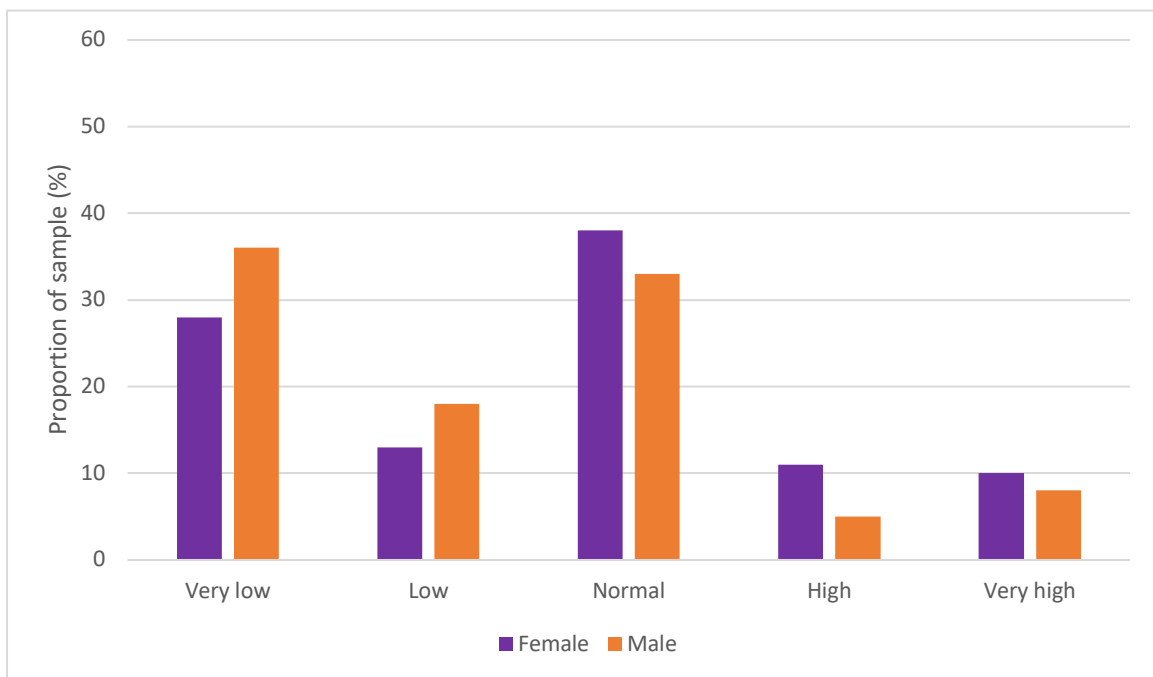


Figure 4.4 Proportion of female and male children per ECDC descriptive category

4.3.6 Physical activity

The average time spent in physical activity per day is shown in Table 4.6. On average, participants showed high levels of physical activity, far exceeding the guidelines (Laureus, 2019; Okely et al., 2017; Tremblay et al., 2017; World Health Organization, n.d.) that stipulate 180 minutes of physical activity in any intensity (light-, moderate- and vigorous-intensity physical activity; LMVPA) per day, with at least 60 minutes being in MVPA (moderate- and vigorous-intensity physical activity or ‘energetic play’). Specifically, 96% of the total sample (100% of the urban sample and 94% of the rural sample) were meeting both these guidelines; all of the children were meeting the LMVPA guideline while 3% of the sample did not meet the MVPA guideline. Differences between the settings were investigated using Mann-Whitney tests and t-tests (for MVPA). Results revealed significant differences for light-intensity physical activity (LPA; $p < 0.001$) and LMVPA ($p < 0.001$), with children from the rural setting spending more time in LPA than children from the urban setting. With regards to sex differences, girls engaged in significantly more LPA than boys ($p = 0.038$), while boys engaged in significantly more vigorous-intensity physical activity (VPA) than girls ($p = 0.002$).

Table 4.6 Average time spent per day in each physical activity intensity

	Total (n=122)	Urban (n=58)	Rural (n=64)	Girls (65)	Boys (57)
LPA	351.7±55 349.7 (322.4-391.2)	332.4±37.1* 333 (315.8-350.4)	369.3±62.4* 379 (346.2-408)	362.5±45.8# 358.3 (330.2-398)	339.5±62# 346.2 (304.1-380.6)
MPA	85.3±20.9 84.75 (69.4-100.9)	83.4±17.4 83.9 (69.4-93.5)	87±23.6 87 (68.6-103.9)	83.5±18.3 84.8 (69.3-94.6)	87.3±23.5 84.1 (68.9-102.3)
VPA	24.3±10.8 23.1(31.5-16.1)	25.4±11.4 23.5(16.5-31.9)	23.3±10.2 22.9(15.7-31.3)	21.1±7.9# 21.1(15-26.8)	28±12.5# 26.8(18.2-37)
LMVPA	461.3±71.5 464.5 (421.2-511.2)	441.2±47.9* 442.6 (415.1-465.6)	479.6±83.9* 493.7 (441.5-530.7)	467.±58.31 467.7 (429.5-513.5)	454.1±84.1 457.1 (396.2-508.4)
MVPA	109.6±30.2 108.5 (84.8-130.2)	108.8±27.5 108.6 (85-125.1)	110.4±32.6 108.4 (84.7-136.5)	104.6±25.2 108 (83.7-123.6)	115.4±34.3 110.9 (85.7-141.4)

Note: Data are represented as mean ± standard deviation and median (inter-quartile range). *indicates a significant difference between urban and rural groups ($p < 0.05$). #indicates a significant difference between girls and boys ($p < 0.05$). LPA = light intensity physical activity; MPA = moderate intensity physical activity; VPA = vigorous intensity physical activity; LMVPA = total physical activity; MVPA = moderate and vigorous intensity physical activity.

Table 4.7 presents the average time spent in physical activity intensities on a weekday (Monday – Friday). Differences between settings and sex were similar to those found for overall physical activity levels such that urban children engaged in significantly higher

volumes of LPA and LMVPA compared to rural children, and boys engaged in higher volumes of LPA and VPA compared to girls.

For average weekdays, 96% of the total sample (98% of the urban sample and 94% of the rural sample) were able to meet both the guidelines. More specifically, only one child failed to meet the LMVPA (rural) guideline while four (1 urban and 3 rural) children did not meet the MVPA guideline on average weekdays.

Table 4.7 Average time spent in physical activity on a weekday

	Total (n=119)	Urban (n=55)	Rural (n=64)	Girls (n=63)	Boys (n=56)
LPA	353.93±57.3 360.6 (323.5-390)	330.8±38.6* 333.2 (309.1-354.6)	373.8±63.3* 381.8 (353.2-409.1)	366.5±43.8# 368.7 (333.5-398.8)	339.7±67.1# 344 (308.6-380.9)
MPA	83.3±22.4 82.7 (67.6-97.6)	79.5±21 80.83 (60.2-89.7)	86.6±23.1 85.9 (71.5-102.5)	83.4±19.3 84.4 (71.4-96)	83.2±25.6 82.5 (63.9-100.1)
VPA	23.4±11.1 21.1(14.6-29.9)	24.1±12 20.8(14.6-30.6)	22.8±10.3 21.4(14.1-29.7)	21±9.5# 20.3(13.7-26.5)	26±12.2# 25(16.4-35.6)
LMVPA	460.6±76.3 466.2 (410.6-510.5)	434.3±56.9* 429.6 (402.4-470.4)	483.1±83.7* 504.2 (452.8-534.9)	471±56.2 476.4 (433.5-511)	448.9±93 451.8 (387.1-507.7)
MVPA	106.7±31.8 106 (83.8-124.1)	103.6±31.7 104.6 (77.5-119.1)	109.3±31.9 109.1 (86.7-126.3)	104.4±27.6 104.7 (84.8-119.1)	109.2±36 108.2 (81.7-137.9)

Note: Data are represented as mean ± standard deviation and median (inter-quartile range). *indicates a significant difference between urban and rural groups (p<0.05). #indicates a significant difference between girls and boys (p<0.05). LPA = light intensity physical activity; MPA = moderate intensity physical activity; VPA = vigorous intensity physical activity; LMVPA = total physical activity; MVPA = moderate and vigorous intensity physical activity.

Table 4.8 summarises the daily average spent in physical activity on a weekend day (Saturday or Sunday). Once again, rural children performed significantly more LPA and LMVPA than urban children (p=0.001) and boys performed significantly more LPA and VPA than girls (p=0.005).

For average weekend days, 94% of the total sample (96% of the urban sample and 92% of the rural sample) met both the guidelines. More specifically, only two children did not meet the LMVPA (one urban and one rural) guideline while five did not meet the MVPA guideline (one urban and four rural) on average weekend days.

Table 4.8 Average time spent per in physical activity on a weekend day

	Total (n=115)	Urban (n=55)	Rural (n=60)	Girls (n=61)	Boys (n=54)
LPA	359.1±60.3 357 (327.4-396.8)	346.3±51.2* 338.3 (322.6-368)	370.8±65.8* 383.4 (342.4-413.9)	362.5±60.3 360.6 (329.6-396.4)	355.2±60.6 353.6 (314.6-398.1)
MPA	93.1±29.1 87.6 (74.5-109.8)	95.7±28.3 90.8 (74.9-110)	90.6±29.8 85.7 (71.7-105.5)	87.9±28.2 88 (70.6-106.2)	98.9±29.2 85.6 (75.5-120.1)
VPA	29.9±14.3 24.5(17-33.3)	28.8±15.9 24.5(19.5-34.8)	25.6±12.7 24.4(15.5-32.1)	22.8±11# 22.8(13.6-30.3)	31.5±16.3# 26.6(19.6-38.2)
LMVPA	482.1±89 481.4 (433-532.6)	470.8±83.4 476 (421.8-518.8)	486.6±93.3 492.1 (444.1-553.9)	473.2±80.4 482 (441.3-523.2)	485.6±98.4 481.3 (425.6-542.4)
MVPA	123±42.5 113.1 (91.9-144.9)	124.5±41.6 115.4 (92.3-145.1)	116.2±43 111.5 (86.4-134.5)	110.7±37.9 112 (86.1-131.4)	130.4±45.7 114.3 (94.8-161.5)

Note: Data are represented as mean ± standard deviation and median (inter-quartile range). *indicates a significant difference between urban and rural groups (p<0.05). #indicates a significant difference between girls and boys (p<0.05). LPA = light intensity physical activity; MPA = moderate intensity physical activity; VPA = vigorous intensity physical activity; LMVPA = total physical activity; MVPA = moderate and vigorous intensity physical activity.

Figure 4.5 indicates the differences between weekday (Monday to Friday) and weekend days for the total sample. Time spent in MPA (p<0.001), VPA (p=0.002), LMVPA (p=0.009) and MVPA (p<0.001) was found to be significantly higher on weekend days.

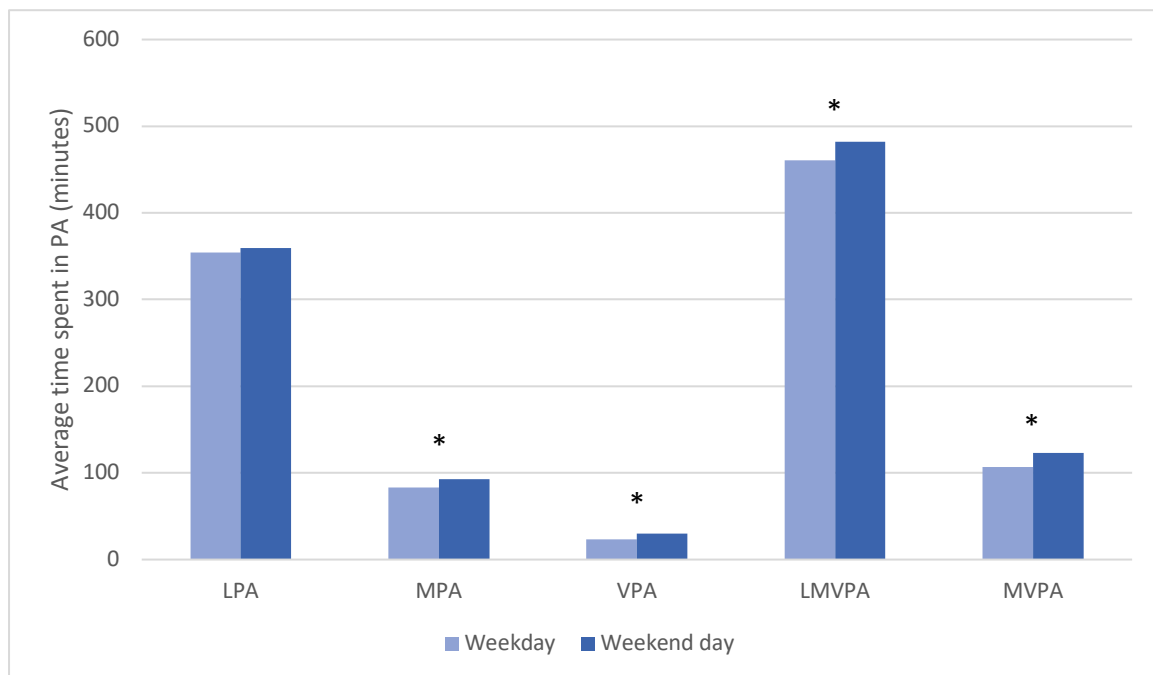


Figure 4.5 Graph showing differences between time spent in physical activity on weekdays vs. weekend days for the total sample

When looking at these differences in each setting, only the urban sample showed significant differences between week and weekend days. The urban children were engaging in significantly more LMVPA ($p=0.001$), MPA ($p<0.001$), VPA ($p=0.004$), and MVPA ($p<0.001$) on weekdays than on weekend days. Conversely, in the rural setting, there were no significant differences between weekday and weekend days. For girls, no differences were observed between weekday and weekend days. Whereas boys showed significant differences for MPA ($p<0.001$), VPA ($p=0.006$), LMVPA ($p=0.004$), and MVPA ($p<0.001$). Results indicated that boys were engaging in more physical activity on weekend days compared to weekdays.

4.3.7 Gross motor skill proficiency

The locomotor and object control raw and standard scores, as well as the GMQ scores are presented in Table 4.9. T-tests revealed that when comparing standard scores (adjusted for age and sex), rural children demonstrated significantly better object control skills compared to urban children ($p<0.001$). However, the norms used to these determine standard scores are based on the assumption that boys will naturally have better GMS. Therefore, to evaluate differences as a function of child sex, raw scores were used to provide a better comparison without that assumption. Resultant Mann-Whitney tests conducted on the raw scores revealed that boys demonstrated significantly better object control skills compared to girls ($p<0.001$); however, as noted, raw scores are not adjusted for age. As such, to determine whether these differences remained significant after controlling for age, linear regression analyses were conducted. Sex ($\beta=0.33$, $p<0.001$) and setting ($\beta=0.33$, $p<0.001$) remained significant predictors of raw scores for object control skills. While only setting ($\beta=0.19$, $p=0.01$) remained a significant predictor of raw scores for the sum of raw scores.

Table 4.9 Raw and standardised scores for gross motor skills

	Total (n=125)	Urban (n=61)	Rural (n=64)	Girls (n=66)	Boys (n=59)
Locomotor raw score [§]	30.7±9.8 33(24-38)	31.7±10.8 35(24.3-40)	29.7±8.7 29(24-36.8)	31.1±10.1 32.5(24-38)	29.5±10.2 32.5(23.3-37)
Object control raw score [§]	23.7±6.4 25(20-28)	22.6±6.8 23.5(17.3-28)	24.7±5.9 25.5(21-29)	21.8±5.8 22(17.5-29)	25.6±6.6 [#] 27(23-31)
Locomotor standard score ^{§§}	11.6±3.1 11(10-13)	11.7±3.4 12(9-14)	11.5±2.8 11(10-13)	11.9±3.5 12(10-14)	11.3±2.6 11(9-13)
Object control standard score ^{§§}	10.1±2.1 10(9-11)	9.4±2.2* 9(8-11)	10.9±1.74* 11(10-12)	10±2.2 10(9-11)	10.2±2.0 10(8-12)
Sum of raw scores	54.3±14.3 57(46-65)	54.3±15.9 58.5(45-66.5)	54.4±12.7 56.5(47-63.8)	52.9±14.1 56(44.8-61)	55.8±14.7 60(48-66)
Sum of standard scores ^η	21.8±4.4 22(19-25)	21.1±4.8 21(17-25)	22.4±3.8 23(20-24.8)	21.9±4.8 22(19-24.3)	21.5±3.8 22(18-25)
GMQ ^{§§§}	105.3±13.0 106(97-115)	103.3±14.5 103(91-115)	107.1±11.3 109(100-114.3)	105.7±14.5 106(97-112.8)	104.5±11.3 106(94-115)

Note: Data are represented as mean ± standard deviation and median (inter-quartile range). *indicates a significant difference between urban and rural groups (p<0.05). #indicates a significant difference between girls and boys (p<0.05). §Raw scores (locomotor and object control) calculated as 'out of 48'. §§Standard scores (locomotor and object control) between 8-12 are regarded as 'average', 13-14 as 'above average' and >15 as 'superior' or very superior. §§§GMQ scores between 90-110 is regarded as 'average', 111-120 as 'above average' and >121 as 'superior' or very superior. GMQ = gross motor quotient.

Gross motor proficiency based on the TGMD-2 rankings is indicated in Figures 4.6 and 4.7. These figures show the proportion of children per ranking. For the total sample, the majority of the children (86%) achieved an average or higher ranking. Although Figure 4.4 showed that more rural children (93%) had average and higher ranking than urban children (77%), Chi-square test for independence revealed that this difference was not significant (p=0.101). Similarly, there was no significant difference between girls and boys even though more girls (85%) had an average or higher ranking than boys (67%; p=0.346).

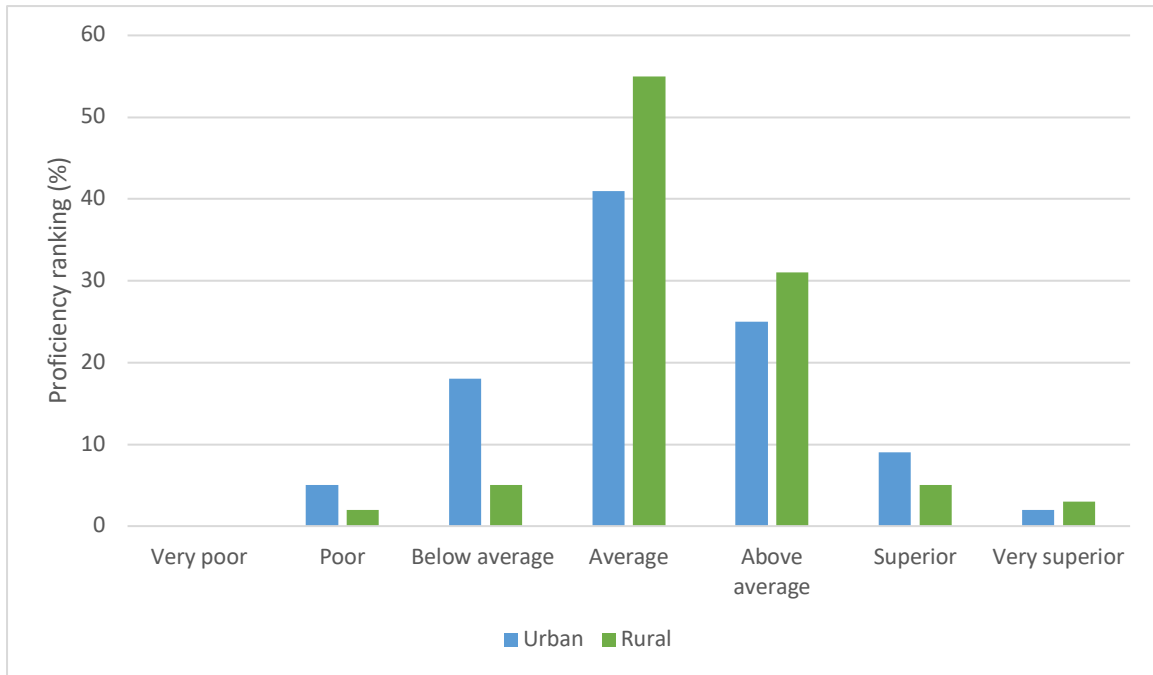


Figure 4.6 Proportion of urban and rural children per gross motor skill ranking category

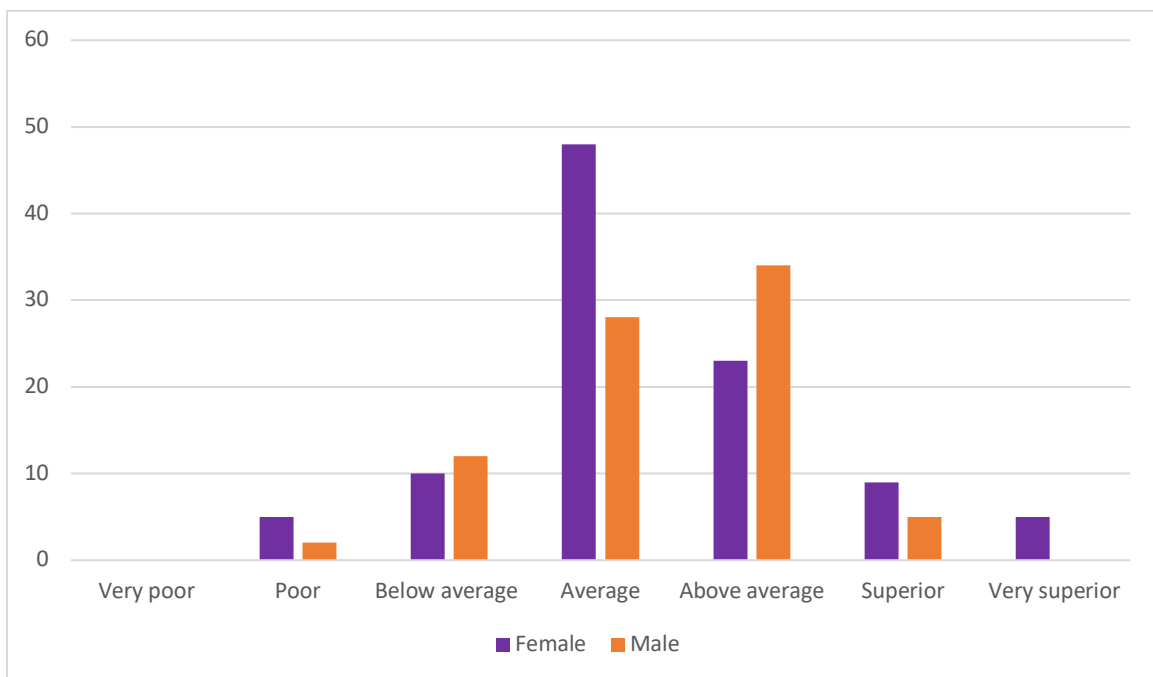


Figure 4.7 Proportion of female and male children per gross motor skill ranking category

4.4 Discussion

The current analyses sought to present the descriptive levels of preschool children's cognitive control, physical activity and GMS in a diverse LMIC sample. Despite the intent that the sample be diverse in terms of geographic setting, to aid generalizability, potentially interesting differences as a function of setting and child sex were also investigated. Results showed that children in urban settings tended to have higher levels of cognitive ability (EF, selective attention and school readiness). Children from the rural setting tended to have better self-regulation, engage in higher volumes of physical activity and demonstrate better GMS. Further, boys tended to engage in higher volumes of physical activity and have superior object control skills, while girls tended to have better self-regulation ratings. Together, these results support the intended diversity of the recruited sample, while indicating some distinct differences between subgroups of this sample.

4.4.1 Cognitive development of the full sample

As with most LMICs, there is limited research on early childhood development – particularly cognitive development – in South Africa. This study is the first to investigate many of these cognitive outcomes in typically developing preschool children from low-income settings in South Africa. For this reason, comparing results is difficult as there are no South African norms (or descriptive statistics from other research in this context) against which to contrast these results. Nevertheless, there is evidence from the current analysis of the suitability of these measures. Specifically, that scores were either at or above norms, there were no floor or ceiling effects and age relations were as they would be expected. Further, while the developmental progress for some outcomes was concerning (such as school readiness), others (such as EFs, PA) appeared advanced relative to international referents from HICs.

Executive function

It appeared that, on average, the children in this study displayed particularly good EF skills as indicated by sample means and the extremely low percentage of performance at floor levels and when compared to preliminary Australian norms for this age group (Howard & Melhuish, 2017). Performance on the EYT in the current sample was compared to Australian norms, as these are currently the only data available for benchmarking. The Australian norms were

based on a sample of 1764 preschool-aged children ranging from 3-5 years of age, and from diverse geographic, familial and socioeconomic backgrounds. The finding that children in the current sample performed better than the Australian norms for their age, was unexpected considering the vast evidence showing that children from low-income settings are at risk for poor EF (Farah et al., 2006; Fitzpatrick, McKinnon, Blair, & Willoughby, 2014; Hackman et al., 2015; Lawson & Hook, 2014). However, as discussed in Chapter 2, some studies have shown superior EF in children from low-income settings in LMICs (Turkey and China) compared to HICs (United States; Gonen et al., 2018; Sabbagh, Xu, Carlson, Moses, & Lee, 2006).

Although more research is necessary to investigate these findings, researchers have suggested certain pathways through which underlying cognitive development (EF and self-regulation) might be fostered in low-income groups from LMICs. The literature on street children (Dahlman, Bäckström, Bohlin, & Frans, 2013; Pluck et al., 2017) presents a possible explanation for good EF skills in children from low-income settings. This has revealed that facing challenges and having to problem solve might be beneficial to cognitive development as these exercise and develop their EF skills. For example, a study on street children in Bolivia found that boys living on the street were superior to their housed counterparts on measures of EF flexibility and planning tasks (Dahlman et al., 2013). Another study found that street children from Ecuador had surprisingly good EF skills (Pluck et al., 2017). Considering children living in low-income settings may potentially face more challenges than children from high-income settings, it is possible that this presents more opportunities for children to exercise their EF skills.

Moreover, differences in social-cultural contexts may present another explanation for these findings. Previous research has highlighted the mediating effects that social-cultural factors play in the development of EF skills (Chasiotis et al., 2006; Haft & Hoefft, 2017; Sabbagh et al., 2006). For example, it is possible that in the low-income settings in South Africa, certain social-cultural factors, challenges or activities that children in these settings are exposed to may indeed be EF (or self-regulation) promoting. For example, in the South African culture there is a prevalence and emphasis on routines and rituals (e.g., attendance of church, community events, singing). These types of activities have been recognised as potentially EF promoting (Rybanska et al., 2017). Other social-cultural factors that might be EF promoting in the South

African culture is the meaningful roles and responsibilities given to young children (e.g., walking to school from a young age, looking after younger siblings, respecting seniors, etc.). Finally, these low-income settings may present challenges and opportunities for problem solving and creativity. Although the results from this study cannot provide clarity on this, further investigation in these settings might suggest low-cost and routine opportunities that can support children's early cognitive development in other disadvantaged contexts.

Self-regulation

Overall, teacher-ratings of self-regulation fell within the 'average' range based on Australian norms (Howard & Melhuish, 2017), with teachers putting around 80% of children in the top half of the scale – suggesting strong self-regulatory skills in the current sample. This is not the first time research has shown strong self-regulatory and compliance abilities in children from challenging settings. An example of this is the literature on street children discussed earlier (Dahlman et al., 2013; Pluck et al., 2017). Alternatively, the high proportion of children placed in the top half of the rating scale might be an artefact of the subjective nature of the measure. It may be that teachers use differing reference points when rating children's self-regulation; that is, despite group-level differences in objective self-regulation abilities, educators in each context rate children as below, at or above average relative to children in that context (and for that age). This might also explain why these measures have often found sex differences in self-regulation, which are not replicated using more-objective measures (Howard, Neilsen-hewett, Rosnay, & Williams, 2019).

Selective attention

While there are no standardised norms for the selective attention task, a large-scale longitudinal study in the United Kingdom (UK) has used the same task and reported on the Q score (but not intersections rate) for 3 and 4 year olds (Scerif et al., 2019). Compared to the mean Q score from the UK sample ($M=0.61$, $SD=0.19$), children in the current sample showed slightly lower Q scores ($M=0.49$, $SD=0.19$). Evidence from an attention-related ERP study showed that preschool-age children from low-income settings have difficulty ignoring distracting stimuli and focusing on relevant stimuli and therefore, demonstrate poorer performance on selective attention tasks compared to children from high-income settings (D'Angiulli, Herdman, Stapells, & Hertzman, 2008). Therefore, it is expected that children

from the UK study (a HIC and high- and middle-income settings) would perform better on selective attention compared to children from the current study (a LMIC and low-income settings). However, the conclusions that can be drawn from this comparison are limited in the current study for a few reasons. Firstly, there is no very low-income group in the UK sample that would be an equivalent income bracket to the current sample. Instead, the UK sample that was used for comparison was on average from a vastly higher income group compared to the South African children in the current study. And Secondly, the exploration of all the variables emerging from the multi-target cancellation task (used to assess selective attention) is largely limited.

Notable however, is that the results followed the expected patterns. This includes improved performance from the baseline run to the trial run. This was expected as the attentional demands in the baseline run are minimal (no distractors), compared to the trial runs that have distractors and thus place a higher demand on the attentional resources. Indeed, one would expect performance to decrease (longer time to complete, less accuracy and less organised search) when demands are higher. Likewise, because the conjunction search might require additional attentional and cognitive resources compared to the feature search (Luria & Vogel, 2011; Treisman & Gelade, 1980), one would expect performance to be greater in the feature search. And indeed, this was the case in the current study, thereby demonstrating suitability of this task in the current settings.

School readiness

Unlike the other cognitive outcomes measured in this study, school readiness was relatively poor in this sample. This is consistent with a previous study in South Africa (Draper et al., 2012; Sherry & Draper, 2013). Indeed, Chapter 2 outlined the poor school achievement of children from low-income settings in South Africa, as well as the stark achievement gap between children from high- and low-income settings (Spaull, 2015). Some of this evidence indicates that this poor achievement may start before children even enter formal schooling, with children from low-income areas starting school with less pre-academic skills and less preparedness for school (Spaull & Kotze, 2015). Some of the more common factors associated with poor school readiness and school achievement in low-income settings include a lack of educational resources at the home and school, low levels of parental education, low parental

engagement and stimulation, and poor health (Duncan et al., 2007; Hair et al., 2015; Holliday, Cimetta, Cutshaw, Yaden, & Marx, 2014; Janus & Duku, 2007). Future research is needed to investigate the factors responsible for school readiness skills in South African low-income settings, especially given the higher EF and self-regulation (often considered domain-general resources that support learning) in this sample.

4.4.2 Physical outcomes for the full sample

Physical development

The anthropometric measures in this study showed that under- and overnutrition are evident in this sample. The results showed some similarities and differences compared to a previous study (Draper et al., 2019), and the SANHANES-1 (Shisana et al., 2013), which is currently the most nationally representative data for under- and over-nutrition in South African preschool children. Levels of stunting, as well as overweight and obesity, were lower in the current sample (stunting = 6%; overweight and obesity = 10%) compared to SANHANES-1 (stunting = 11.5%; overweight and obesity = 22.2%). However, the percentage of wasting and underweight was slightly higher in the current sample (wasting = 5%; underweight = 9%) compared to SANHANES-1 (wasting = 1.8%; underweight = 4.3%). The higher percentage of undernutrition in the current sample could indicate a potentially more disadvantaged sample than might be expected in the broader population. More plausible however, is that this discrepancy may be due to the difference in sample size and that the level of difference may not even be statistically significant when this is taken into account.

Physical activity

The results from the current study contribute to the growing evidence indicating that South African preschool children from low-income settings engage in high amounts of physical activity (Draper et al., 2017; Tomaz, Prioreshi, et al., 2019) and have high gross motor proficiencies (Draper et al., 2017; Tomaz, Hinkley, et al., 2019). While the high levels of physical activity are in alignment with other research in South Africa, it is in stark contrast to international benchmarks. For example, the current study showed that children were engaging in almost 2.5 times more than the LMVPA guideline (180 minutes per day; Laureus, 2019; Okely et al., 2017; Tremblay et al., 2017; World Health Organization, 2019) and 1.7

times more than the MVPA guideline (60 minutes per day; Okely et al., 2017; Tremblay et al., 2017). This is in contrast to international research on preschool children from HICs, which routinely finds that children are largely not meeting daily recommendations for physical activity (Beets et al., 2011; Chaput et al., 2017; Hinkley, Salmon, Okely, Crawford, & Hesketh, 2012).

Significant differences were found between weekday and weekend days, for the amount of time spent engaging in each physical activity intensity (LPA, MPA, VPA, LMVPA and MVPA). Some research has found that children are very sedentary during the preschool day (Jones et al., 2014; Van Cauwenberghe, Jones, Hinkley, Crawford, & Okely, 2012); therefore, it may be that children spend more time being active on the weekends because they have more time for free play. However, it is also important to consider the absolute difference, and whether this is practically significant as well as statistically significant. For the different intensities, the biggest difference was seen for MPA where children spent around 10 minutes more engaging in MPA on a weekend day. When looking at the combined intensities, LMVPA and MVPA, the absolute difference was around 20 minutes. Considering this difference is less than either of the recommended guidelines for this age-group (180 minutes LMVPA and 60 minutes MVPA; Laureus, 2019; Okely et al., 2017; Tremblay et al., 2017; World Health Organization, 2019), and that the vast majority of this sample was already meeting and exceeding these guidelines, the absolute difference between weekday and weekend days may have little practical significance, and may have limited or no effects on correlates of physical activity.

Gross motor skills

Likewise, the results for GMS contradicts international research, particularly from HICs. Children from low-income settings generally display poorer gross motor proficiency (Barnett, Lai, et al., 2016; Morley et al., 2015). This research has suggested that limited exposure to high quality teaching, practice and reinforcement of GMS in low-income settings potentially explains the lower proficiency levels found in low-income settings. However, the majority of children (86%) in the current study demonstrated average or above levels of gross motor proficiency, despite having little exposure to relevant high-quality teaching, practice or reinforcement (Tomaz, Hinkley, et al., 2019). While the exact mechanisms are unknown, there are some contextual factors that may contribute to this result. For example, Tomaz et al.

(2019) proposed that while there is no formal teaching of GMS, unstructured free play may be contributing more to the development of GMS than was once thought. Considering children in these settings are engaging in high volumes of physical activity, most of which is in the form of unstructured free play, this may indeed be the case. Additionally, in these settings it is common for younger children to play with older siblings and friends and, as a result, might observe and learn GMS from the older peers who are likely to have more mature GMS.

4.4.3 Differences between urban and rural settings

Differences between urban and rural settings for cognitive outcomes

Chapter 3 outlined the similarities and differences between the urban and rural settings in this study. Although both settings are considered low-income settings in South Africa, there are contextual and possibly social-cultural differences that may impact differently on certain aspects of early childhood development.

On average, children from the urban setting showed better performance in the measures of cognitive development compared to children in the rural settings. Considering the strong linear associations between age and EF (Best & Miller, 2010), it is possible that these differences were largely due to the discrepancy in age between the urban (older) and rural (younger) setting. After controlling for age however, children from the urban setting were still showing greater performance on working memory scores. Moreover, urban children also outperformed rural children in school readiness outcomes, with the subtest percentiles revealed that rural children seem to be falling behind in key pre-academic skills such as visual-motor integration, knowledge of colours and shapes and number counting.

Although the current study cannot identify the exact factors that may be contributing to poorer performance of the rural children, factors mentioned earlier might also contribute to the findings in the current study. Such as limited access to essential services (Biersteker, 2012) including good quality education. Considering the salience of preschool quality, teacher quality, teacher-child interactions and access to stimulating resources in fostering school

readiness (Holliday et al., 2014; Keys et al., 2013; Magnuson, Meyers, Ruhm, & Waldfogel, 2004), this may account for poorer performance in rural children.

In contrast, however, results indicated that rural children showed stronger self-regulation scores. Yet given self-regulation was measured by teacher-report, it is possible that these differences are due to factors such as observer bias, rather than better self-regulation of the rural children per se. For instance, educators may differ in their expectations of what good self-regulation can and will look like, and what average levels of self-regulation entail. For this reason, research has shown that teacher ratings often rely heavily on their personal reference points (McClelland & Cameron, 2012), which can be influenced by factors such as race (Downney & Pribesh, 2004) and gender (Beaman, Wheldall, & Kemp, 2006). Furthermore, the self-regulation ratings in the current study showed problematic distributions, with teachers from the rural setting placing over 90% of children in the top half of the scale for behavioural and emotional self-regulation and 87% for cognitive self-regulation. This distribution is unlikely to be an accurate reflection of child abilities, and suggests that whatever reference points teachers are using, it is skewing a majority of these children as above or well above average. In contrast, ratings from the urban setting showed a somewhat more realistic (albeit still unexpectedly positive) distribution with teachers placing around 90% of the children in the top half of the scale for behavioural and cognitive self-regulation and 81% for emotional self-regulation. Teachers' different reference points may also explain the low agreement of self-regulation scores with EF and school readiness.

Results for selective attention were similar to those found in EF, such that children from the urban setting showed significantly better selective attention when looking at the quality of search score. However, there were no differences for the intersections rate, a measure of search organisation that is often associated with EF. Of note, while both indices are taken as representative of efficient search (Dalmaijer et al., 2015), Q score combines speed- and accuracy-based indicators of performance, whereas intersection rate is an unspeded measure of search organization. Poorer performance on Q score, specifically for children the rural compared to urban setting, may indicate slower processing speed or planning in motor responding overall. Indeed, the two groups differed also on the baseline runs, and these do not include a selective attention requirement, bolstering the suggestion that selective

attention or EF differences may also be accompanied by less efficient and slower overall motor control. These similarities and differences across measures need further investigation against appropriately normed data.

Differences between urban and rural settings for physical outcomes

The distribution of under- and overnutrition was as expected in each setting, as research has highlighted the higher prevalence of undernutrition, specifically stunting, in rural settings compared to urban settings (Kimani-Murage et al., 2010; Smith et al., 2005). The prevalence of stunting in the rural settings provides further evidence showing that rural low-income settings remain under-served and highly at-risk in the South African context. Although urban low-income areas have a unique set of problems as well, urban areas are generally in a more favourable socio-economic position (Draper et al., 2019).

The finding that rural children performed higher volumes of physical activity, particularly low-intensity compared to urban children is in alignment with the evidence mentioned earlier (Draper et al., 2017; Tomaz, Prioreshi, et al., 2019). Although this supports previous findings, reasons for this discrepancy have not been conclusively determined. One possible explanation to methods of transport in the respective settings. Considering that walking contributes to the time spent in low intensity physical activity, it is plausible that the high volumes of LPA performed in rural settings is, at least in part, due to increased time spent walking (e.g., to preschool). Studies in adults have shown that walking is used as a primary method of transport in rural South African settings (Cook, Alberts, Brits, Choma, & Mkhonto, 2010) and suggested that walking is not as commonly used for transport in urban settings as they have more access to public transport (van Zyl et al., 2012).

Patterns of weekend versus weekday physical activity also differed in urban and rural settings: there were no significant differences between weekdays and weekend days in the rural setting, whereas there were significant differences for all intensities of physical activity in the urban setting. While the exact reasons for this disparity are unclear, it is possible that the preschool settings provide a potential explanation. As can be seen from the photos included in Chapter 3, the preschools in the urban setting were very small in comparison to the rural preschools. They had small classrooms and almost no outdoor space or play equipment.

Additionally, children in the urban setting generally spent the majority of their day at preschool as parents or caregivers were likely to have a job in the city and no one at home to take care of the children during the day. Therefore, children stayed at preschool until parents or caregivers could pick them up. In contrast, the rural preschools had ample space both inside the classrooms and outside, as well as play equipment. Rural children also tended to leave school earlier as they were able to walk home and were likely to have a relative at home during the day (in this context, most likely the grandmother). Despite the limited space and play equipment at urban preschools, the majority of children were still meeting or exceeding the guidelines on a weekday.

Results for GMS align with a recent study conducted in similar settings (mentioned earlier) that reported better GMS (specifically object control skills) in rural children compared to urban children (Tomaz, Hinkley, et al., 2019). The authors of this study provided a potential explanation proposing that because rural children engaged in higher amounts of physical activity, this might be beneficial to the development of GMS as more time spent in physical activity means more opportunities to practice GMS. Further, based on the suggestion that GMS (and particularly object control skills) need to be taught (Barnett, Lai, et al., 2016), this finding is also contradictory as children in the rural area were not exposed to any formal teaching of GMS (i.e., had no access to extra-curricular activities) and had minimal access to equipment. Indeed, there may be some additional factors contributing to the high levels of gross motor proficiency that have not yet been identified by previous research. These might include home and neighbourhood factors such as activities or games played at home that require GMS, or that preschool children might be spending a large portion of their time outside of school playing games with older siblings or older children who might be providing some sort of GMS instruction. However, more research is needed to explore these findings.

Summary of effects of setting

Overall, the urban children seem to be outperforming rural children in EF, selective attention and school readiness, but not self-regulation. Therefore, apart from self-regulation, it seems that there is agreement between the components of cognitive development, as has been found in international literature (Roebbers, 2017). In terms of physical development, rural children were demonstrating better GMS and were engaging in higher volumes of physical

activity, particularly LPA. This suggests low levels of agreement between components of physical development and cognitive development. These results provide initial contrast to some of the recent evidence suggesting a beneficial association between physical activity, GMS and cognition (Willoughby et al., 2018). Yet the slightly higher prevalence of underweight and stunting in the rural setting may provide a possible explanation, with previous research indicating that stunting in early childhood has a detrimental effect on cognitive development. Therefore, the higher levels of underweight may conflate genuinely beneficial (or null) associations between physical activity, GMS and cognitive development. While these are just speculations, more rigorous and comprehensive research is needed to investigate the nature of these relationships. Subsequent chapters have attempted to address some of these issues.

4.4.4 Differences between boys and girls

Differences between girls and boys for cognitive outcomes

The results in the current study generally aligned with the evidence that does not find a sex difference in these cognitive outcomes. Girls and boys did not differ in either EF or attention, and only in one subtest of the school readiness assessment (picture perception). They showed significant differences in self-regulation ratings (behavioural and cognitive), but this can potentially be explained by typical gender biases when adults rate children's self-regulation (such that girls are typically rated as better self-regulators than boys, even when this is not supported by more objective measures; Howard et al., 2019; Beaman et al., 2006; Else-Quest et al., 2006). Of the limited research available in similar contexts, a recent study of preschool children in Kenya found no associations between child sex and EF (Willoughby et al., 2019).

Differences between boys and girls for physical outcomes

Although the current study showed no differences in total physical activity, the finding that boys were spending more time in vigorous physical activity, and less time in light physical activity, aligns somewhat with international evidence that boys are more active than girls (Tucker, 2008), but is in contrast to recent local evidence that found no differences (Tomaz, Pioreschi, et al., 2019). Considering differences have not been found in these settings before, mechanisms behind these differences have not yet been investigated. But, there are

suggestions from studies in HICs that this may be as a consequence of socialisation patterns. For example, if you observe children on a playground in low-income areas of South Africa, boys are often more likely to be running around after a ball whereas girls might be more likely to be playing more calm, sedentary games such as clapping games. Studies have shown that edboys take more steps than girls, and are more likely to engage in sport-related activities compared to girls (Cardon, Van Cauwenberghe, Labarque, Haerens, & De Bourdeaudhuij, 2008; O'Connor, McCormack, Robinson, & O'Rourke, 2017). Boys are more prone to hyperactivity and impulsivity compared to girls, which may also contribute to the increased vigorous physical activity observed in boys (Gershon & Gershon, 2007).

As shown in the results, boys were found to have superior object control skills. However, when comparing the standard scores that control for age and sex, this difference was no longer significant. This is because the TGMD-2 norms inherently assume that boys perform better than girls. This finding is in alignment with both local (Tomaz, Hinkley, et al., 2019) and international research (Barnett, Lai, et al., 2016; Morley et al., 2015), including other LMICs (Aye et al., 2017; Famelia, Tsuda, Bakhtiar, & Goodway, 2018). Indeed, the biological and sociological factors favouring the development of these skills in boys mentioned earlier might explain the findings from the current study as well. However, socialisation factors (boys are expected to participate in more sports or sports-related activities; Blatchford, Baines, & Pellegrini, 2003; Eccles & Harold, 1991), might differ in the current settings and age-group as children do not readily have access to organised sport. Nevertheless, boys in these settings might still be choosing to participate in more sports-related play (e.g. soccer) compared to girls.

Summary of effects of sex

Overall, boys were engaging in higher volumes of physical activity and had better object control skills. Girls had higher ratings of self-regulation and performed significantly better on the picture perception subtest on the school readiness assessment. These findings mostly aligned with previous research, but whether relationships between these factors align with previous research regarding the beneficial relationship between components of physical development and cognitive development is currently unknown and will be addressed in subsequent chapters.

4.5 Conclusion

In summary, the current sample had good EF and self-regulation, adequate attention skills, as well as good GMS and high levels of physical activity. However, the sample had low levels of school readiness. While more research is needed to understand the cause of the divergence between apparent high EF and low school readiness skills, it is possible that the children in the current study have the cognitive building blocks for learning (EF) but not the content or pre-academic knowledge to fully leverage these abilities. Although the results indicated some differences between the urban and rural settings, this study is not statistically powered to investigate these settings separately. For this reason, in the subsequent chapters the settings are pooled into a single, broadly representative sample (of low-income South African contexts). Where applicable, setting and sex are covaried. This resulting sample represents a diverse group of preschool children from low-income settings in South Africa. Considering the differences that were found between the urban and rural children, as well as the contextual differences that exist between the settings, future work should aim to investigate these settings separately.

These results provide a strong rationale for further investigation of inter-relations between these outcomes, to investigate the nature of the relationships between these factors and how they interact. For example, to what extent does EF relate to school readiness, given low agreement between these factors (e.g. poor school readiness but good EF)? Do components of physical development relate to each other, and how do they relate to adiposity in light of the high volumes of physical activity, good GMS and prevalence of stunting? Does physical activity and development relate to foundational aspects of cognitive development, such as EF and attention? Are the high volumes of physical activity and good GMS associated with good EF and self-regulation skills in these settings? While international research has provided some evidence for these associations, these factors are rarely considered all together, and even less is known about the unique characteristics of these associations in the current setting. The current study aimed to address such questions and the results are reported in the chapters that follow.

CHAPTER 5: EXPLORING ASSOCIATIONS BETWEEN COMPONENTS OF COGNITIVE DEVELOPMENT

5.1 Introduction

It has been well established that executive function (EF), self-regulation and attention are integral to a child's cognitive development and are known to impact health, wealth, and well-being across the lifespan (Dempsey, Dyehouse, & Schafer, 2011; Dohle et al., 2017; McClelland & Cameron, 2012; Moffitt et al., 2011). While most agree that these components are related, they have historically been studied in different disciplines, with little consideration or reference to each other (Kaplan & Berman, 2010; Zhou, Chen, & Main, 2012). However, research has begun to identify areas of overlap between these components and highlighted the need to study them together (Blair & Razza, 2007; Scerif & Bull, 2001; Senn, Epsy, & Kaufmann, 2004).

Theoretical associations and areas of overlap

As mentioned in Chapter 2, self-regulation has been defined and described differently within the literature (Burman, Green, & Shanker, 2015). While these conceptualisations are broadly similar, the definition and description of the top-down processes that enable successful self-regulation differ across accounts. For example, effortful control is identified as a mechanism for top-down control in the temperament literature (Rothbart & Bates, 2006). In contrast, cognitive neuroscience disciplines identify EF and related terms (executive attention, cognitive control, supervisory attention system) as the top-down cognitive process involved in self-regulation. Although these theories differ in nomenclature and definitions, there are commonalities and areas of overlap that suggest genuine relationships between these constructs (Nigg, 2017; Zhou et al., 2012)). However, the nature of these associations has not yet been empirically investigated, and remain limited to theoretical suggestions of the primacy and directionality of these associations. For example, Posner and Rothbart argue that there are associations between effortful control (measured as individual differences in temperament through parental report) and executive attention (measured through experimental tasks; Rothbart & Posner, 2006); however, there is limited empirical evidence

from which to suggest these constructs as distinct and, if so, which is primary. This highlights the lack of clarity across these often-distinct literatures and the need to measure associations between these diverse components in the same sample.

Specific associations between executive function and attention

Evidence suggests bivariate associations between EF and attention, and attention and EF have been uniquely linked in the literature. Attention, and particularly selective attention, has been found to be a key building block for the development of EFs (Garon et al., 2008; Hendry, Jones, & Charman, 2016; Veer, Luyten, Mulder, van Tuijl, & Slegers, 2017). This has been demonstrated in longitudinal studies that have found selective attention in infancy to be predictive of inhibition and working memory in toddlerhood (Holmboe, Fearon, Csibra, Tucker, & Johnson, 2008; Johansson, Marciszko, Brocki, & Bohlin, 2015). Shifting has also been uniquely associated with selective attention, such that flexible shifting involves the ability to shift the focus of attention (Benitez, Vales, Hanania, & Smith, 2017; Hanania & Smith, 2010). Some researchers have suggested that attention is more than just a building block; rather, EFs are the mechanisms to control attention (attention is a resource used by EFs; Kaplan & Berman, 2010). In other words, EFs control attention in a stimulus-rich world. For example, working memory permits activation of information within the scope of attention while inhibition narrows this attentional focus, whereas shifting enables flexible redirection of attention as needed.

While most of studies linking these aspects of cognition were conducted mainly in high-income settings, a recent study (Veer et al., 2017) extended these findings to a heterogeneous sample including participants from low, middle and high SES settings (in a high-income country). Results from this study revealed that selective attention at two and a half years of age was uniquely related to inhibition and working memory at three years of age after controlling for SES. While this has been shown in a low-SES sample, this has not been investigated in low-SES settings in a LMIC context.

Specific associations between executive function and self-regulation

Hoffman et al. (2012) emphasise the connection between EF and self-regulation. Their review illustrated how EFs support self-regulatory mechanisms (for example, inhibition facilitating

the suppression of pre-potent/unwanted behaviours and replacing them with appropriate goal-directed behaviours; shifting allowing the ability to switch between different goals; and working memory for keeping goals and standards in mind). They also highlighted instances in which the training or improving of EFs led to better self-regulation (for example, training EF improved self-regulated eating behaviours; Dohle et al., 2017). In the same way, they illustrate how impaired EF (i.e., executive dysfunction) is implicated in cases of poor self-regulation such as alcohol intoxication (Hofmann & Friese, 2008). Neurodevelopmental disorder studies emphasise this further, as poor self-regulation and poor performance on EF tasks are characteristic within atypical development, such as autism spectrum disorder (ASD; Sinzig, Vinzelberg, Evers, & Lehmkuhl, 2014) and attention-deficit/hyperactivity disorder (ADHD; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005).

Taken together, the evidence above suggests that EF, attention and self-regulation are related and that they function together in a purposeful and goal-directed manner. However, very few studies have empirically explored all three components (and their sub-components) in the same sample. Therefore, the aim of this chapter is to explore the underlying structure and cross-sectional associations between these key components of cognitive development in the same sample. Specifically, to determine inter-relations between individual EF components (inhibition, shifting and working memory), teacher-reported self-regulation, and attention thereby addressing aim 2 stated in Chapter 2. Moreover, this chapter aims to contribute to the literature by extending this research to an understudied low-and middle-income context.

5.2 Methods

5.2.1 Measures

Variables included in the current analyses are: the three components of EF (N=124), namely inhibition, shifting and working memory; three teacher-reported self-regulation subscales (N=124), consisting of behavioural (BSR), cognitive (CSR) and emotional self-regulation (ESR); and two selective attention variables (N=123) from the conjunction search; quality of search score (Q score) and intersections rate. Only the conjunction search was included in these analyses as it required greater attentional demands compared to the feature search (see

Chapter 4 for details); therefore, it is more likely to show associations with other cognitive components. Refer to Chapter 3 for full details on measures, participants and procedures.

5.2.2 Statistical analyses

IBM SPSS statistics version 25 for Mac (IBM Corp, Armonk, NY) was used to conduct correlations and Exploratory Factor Analysis (EFA) on EF, self-regulation and attention variables. Full and partial correlations were explored using Pearson's correlations. More specifically, partial correlations explored the associations between these outcomes after controlling for age, sex and setting. EFA was then used to explore these relationships further using Maximum likelihood estimation and direct oblimin factor rotation, given the expectation that the variables will be correlated. The level for significance was set at $p < 0.05$.

5.3 Results

5.3.1 Correlations

Full and partial correlations are presented in Table 5.1 for completeness; however, only partial correlations are discussed. The results from the partial correlations revealed mostly significant, positive inter-task (and subscale) correlations. For EF, working memory was significantly associated with both inhibition ($p < 0.001$) and shifting ($p = 0.023$), although there were no significant associations between inhibition and shifting. For self-regulation, all three subscales showed strong, significant associations with each other (BSR and CSR: $p < 0.001$; BSR and ESR: $p < 0.001$; CSR and ESR: $p < 0.001$). Both attention variables were also strongly, negatively associated ($p < 0.001$). The negative correlation between attention indices was expected as a lower intersections rate score indicates better performance, while a higher Q score indicates a better performance.

These results also highlight the individual associations between tasks and indices. For example, inhibition was significantly associated with both the attention variables (Q score: $p < 0.001$; intersections rate: $p = 0.009$). Working memory was also significantly correlated with all three self-regulation subscales (BSR: $p = 0.009$; CSR: $p = 0.014$; ESR: $p = 0.001$), whereas inhibition was only significantly associated with CSR ($p = 0.005$) and shifting showed no

significant correlations with any self-regulation variables. Both attention variables were significantly correlated with BSR (Q score: $p=0.001$; intersections rate: $p=0.048$), CSR (Q score: $p<0.001$; intersections rate: $p=0.05$) and ESR (Q score: $p=0.022$; intersections rate: $p=0.047$).

Table 5.1 Bivariate and partial correlations between EF, self-regulation and selective attention measures

	1	2	3	4	5	6	7	8
1. Inhibition	-	0.08	0.312*	0.175	0.262*	0.147	0.367*	0.243*
2. Shifting	0.06	-	0.206*	0.044	0.065	0.027	-0.04	0.001
3. Working memory	0.312*	0.206*	-	0.236*	0.222*	0.292*	0.258*	-0.180*
4. BSR	0.175	0.04	0.236*	-	0.591*	0.766*	0.286*	-0.185*
5. CSR	0.262*	0.07	0.222*	0.591*	-	0.514*	0.326*	-0.181*
6. ESR	0.147	0.03	0.292*	0.766*	0.514*	-	0.209*	0.183*
7. Attention Q score	0.367*	-0.04	0.258*	0.286*	0.326*	0.209*	-	0.510*
8. Attention int. rate	-0.243*	0.001	-0.180*	-0.185*	-0.181*	-0.183*	-0.510*	-

Note: Full correlations are presented in the top right of the table and partial correlations (controlling for age, sex and setting) are presented in the bottom left of the table. BSR = behavioural self-regulation, CSR = cognitive self-regulation, ESR = emotional self-regulation, Q score = quality of search score, int. rate = intersections rate. * $p<0.05$.

5.3.2 Exploratory factor analysis

In order to further explore the associations between measures of EF, self-regulation and attention, these measures were entered into an EFA with maximum likelihood estimation and direct oblimin rotation. The number of factors was determined by eigenvalues greater than 1 and inspection of the scree plot. Factor loadings from this EFA are presented in Table 5.2. The analysis yielded two factors that cumulatively accounted for 54.8% of the variance. The scree plot also supported the extraction of two factors. Self-regulation variables (BSR, CSR and ESR) loaded strongly on Factor 1, with factor loadings ranging from 0.66 to 0.93. EF and attention variables loaded strongly on Factor 2. Correlation between the factors was 0.111.

Table 5.2. Exploratory Factor Analysis 1: EF, self-regulation and attention

	Rotated component matrix	
	Factor 1 (26.5%) Self-regulation	Factor 2 (28.3%) EF and attention
Inhibition	0.11	0.75
Shifting	-0.04	0.39
Working memory	0.02	0.66
BSR	0.93	0.02
CSR	0.66	0.42
ESR	0.88	-0.59
Attention Q score	0.05	0.83
Attention int. rate	-0.24	-0.53

Note: Proportion of variance accounted for by each factor and loading of each measure are provided. BSR = behavioural self-regulation, CSR = cognitive self-regulation, ESR = emotional self-regulation, Q score = quality of search score, int. rate = intersections rate. Bold numbers indicate the variables that load strongly with each factor 1 or 2. * $p < 0.05$.

A second EFA was attempted with only EF variables (inhibition, working memory and shifting) and selective attention variables (Q score and intersections rate). Self-regulation variables were removed as the initial EFA revealed that they formed an independent factor. This was most likely due to the different format of the measure (teacher-rated compared to direct measures), rather than suggesting that self-regulation is genuinely poorly related to EF and selective attention. Factor loadings for this second EFA are presented in Table 5.3. This time only one factor was extracted and accounted for 42.4% of the variance.

Table 5.3 Exploratory factor analysis 2: EF and attention

	Rotated component matrix
	Factor 1 (46.6%) executive/attention
Inhibition	0.73
Shifting	0.38
Working memory	0.68
Attention Q score	0.84
Attention int. rate	-0.53

Note: Proportion of variance accounted for the factor and loading of each measure are provided. BSR = behavioural self-regulation, CSR = cognitive self-regulation, ESR = emotional self-regulation, Q score = quality of search score, int. rate = intersections rate. * $p < 0.05$.

5.4 Discussion

This chapter aimed to investigate associations between components of cognitive development and their underlying structure in a South African sample. The results revealed variables of EF and attention formed a single factor. Self-regulation subscales, while modestly correlated with EF and attention indices, formed a separate factor. The high pattern of correlations and expected loadings also indicate the suitability of these measures to the South African context (i.e., a form of construct validity) given that the measures behaved as expected. However, the comparatively poor correlations with shifting may be as a result of the lack of variability in the shifting scores against which the other tasks could correlate. For example, participants were generally able to complete the first two levels (simple switching), while very few were able to complete the third level (flexible switching), as would be expected in their age-group. Therefore, the Card-Sort task may not be sensitive enough to detect progress that occurs between the ability to perform a simple switch and a flexible shift, limiting the variability of the scores.

5.4.1 Executive function and selective attention loading onto a single factor

Previous research has shown that EF and selective attention are intrinsically related, with some suggesting that selective attention is a key building block for EFs (Garon et al., 2008; Hendry et al., 2016; Veer et al., 2017), and others suggesting that EF skills are there to direct and control attention resources (Kaplan & Berman, 2010). The results from the current study provide further evidence for the inextricable link between attention and EF. Specifically, that attention and EFs are so strongly related, they are likely an interconnected system.

The finding that all three EFs are related and load on to the same factor was expected, and supports the well-known theory that while EFs show both unity and diversity (Miyake & Friedman, 2012), research with younger children tends to indicate more unity (Hughes & Ensor, 2011; Wiebe et al., 2011). On the other hand, the indices of selective attention measured in the current study are not as well-known or understood in the preschool age-group. The two indices derived from the multiple target visual search task (used to assess selective attention) both indicated different aspects of search efficiency. These included the quality of search score (Q score) that was based on speed and accuracy, and the intersections

rate that was based on search organisation (or search strategy). The current findings are in contrast to a previous study that showed selective attention (a speed and accuracy based index) and EF clustered into separable factors in children between 7 and 12 years of age (Klenberg, Korkman, & Lahti-, 2010). Indeed, this was only tested in older children and therefore, the results of the current study may be explained by the children being younger (3-5 years) than those in the study, and that potentially, in the younger years, performance on these tasks is linked.

Regarding search organisation (intersections rate), while there is very little empirical evidence linking search organisation and EF, there is some evidence to suggest an association. That is, research has revealed that age-related improvements in search organisation follows a similar developmental trajectory to EF and prefrontal cortical areas implicated in EF (Woods et al., 2013). Based on these findings, it was proposed that age-related performance on search organisation may be associated with EF. The current study provided some evidence for this relationship as intersections rate (search organisation) was significantly associated with EF in the expected direction. In other words, a more organised search was associated with better EF.

5.4.2 Self-regulation forming a separate factor

While correlation analyses revealed significant, positive associations between components of self-regulation, attention and EF, self-regulation formed a separate factor in the EFA. While self-regulation is distinct (indeed, superordinate) from EFs, this result aligns with theories that EFs represent one (capacity) component of self-regulation (e.g., Hofmann, Schmeichel, & Baddeley, 2012). Moreover, the current results may be influenced by the nature of the self-regulation measure. In the current study, EF and attention were measured more objectively through task-based assessments, while self-regulation was measured by subjective teacher ratings. One possibility is thus that subjective measures load together and are not as highly associated with objective measures. For instance, there is evidence that educators rely more on instances of dysregulated, externalising behaviours when evaluating child self-regulation (Papadopoulou et al., 2014), whereas EF and attention measures would focus more highly (and precisely) on aspects of cognitive control. This suggests that relying on teachers for

sensitive developmental information may in fact be problematic. Instead, direct measures would provide more sensitive and objective indications of children's development. On the other hand, a review by Toplak et al. (2013) concluded that performance based measures of cognitive development may be capturing different aspects of cognitive development compared to subjective measures (Toplak, West, & Stanovich, 2013). Therefore, may be that while EF skills do contribute to self-regulatory abilities, the measures used to capture each of these constructs precludes any association between them.

Another potential explanation for these results is that educators may not be reliable in their estimates of children's self-regulation. As discussed in Chapter 4, this may be due to the subjective nature of the measure resulting in possible educator bias. That is, teachers might be rating children based on their feelings towards the child or how compliant the child is rather than rating their self-regulatory abilities. The low agreement between performance-based measures of EF and subjective ratings of self-regulation presented in Chapter 4 and this chapter provide some support for this explanation. Despite the reservations regarding the integrity of this construct, it was nonetheless included given the a priori analytic plan. However, this analysis was interpreted with caution, and these results gave cause for subsequent removal if necessary.

5.5 Conclusion

These results are the first to provide evidence for the relationships between these core components of cognitive development in South African, low-income settings. More specifically, these results suggest close links between EF (particularly inhibition) and attention, and that self-regulation, while still related, may be capturing different artefacts because of the method of measurement. These results highlight the complexity and interconnectedness of components of cognitive development and the influence of the method of measurement in capturing specific cognitive skills. Despite these associations, however, when considering outcomes associated with these abilities (e.g., academic performance, physical activity, etc.), it is important to consider that each construct may show different developmental trajectories (Klenberg et al., 2010) and therefore, may associate with

different outcomes. This chapter also highlights the lack of consistency in definitions and measures of cognitive development in the early years. This has made comparing results and drawing concrete conclusions difficult. Future efforts should be aimed at combining disciplines and determining the 'gold standards' for measuring these complex components of cognitive development.

CHAPTER 6: MODELLING THE ASSOCIATIONS OF EXECUTIVE FUNCTION AND SELF-REGULATION WITH SCHOOL READINESS

6.1. Introduction

International literature has highlighted the importance of executive function (EF) and self-regulation for school readiness and later academic achievement (Becker, Miao, et al., 2014; Fitzpatrick et al., 2014; Nayfeld, Fuccillo, & Greenfield, 2013; Pellicano et al., 2017; Willoughby, Magnus, & Blair, 2016). Although robust relationships between EF skills and these newer and more exploratory measures of attentional skills were presented in Chapter 5, the vast majority of the literature testing correlates and predictors of self-regulation and school-readiness has focused on EF skills alone. Therefore, in order to more easily relate the findings of the current study in low- and middle-income country (LMIC) settings to the pre-existing literature, this chapter included EF skills and not attentional skills. Future research will aim to answer questions on selective attention with school readiness and self-regulation.

School readiness

As discussed in Chapter 2, there are a range of views regarding the skills that comprise school readiness. Some have suggested pre-academic skills are essential precursors to ‘readiness’ (e.g., knowledge of numbers and letters, vocabulary; Duncan et al., 2007), while others have suggested behaviours and skills that enable children to learn (e.g., self-regulation skills, EF; Blair & Raver, 2015; Duncan, Schmitt, Burke, & McClelland, 2018; Heaviside & Farris, 1993; Lin, Lawrence, & Gorrell, 2003). In the current study, the school readiness skills measured are pre-academic skills, with self-regulation and EF representing these additional behaviours and skills that might contribute to school readiness skills, rather than being considered as school readiness per se.

Self-regulation

Self-regulation has been found to be distinct from, but both concurrently and longitudinally associated with, school readiness and academic success (Bandura, 1991; Becker, McClelland,

Loprinzi, & Trost, 2014; Blair, Ursache, Greenberg, & Vernon-Feagans, 2015; Duncan et al., 2018; Posner & Rothbart, 2007). That these results have permeated the early years education sector is suggested by findings that many early childhood development practitioners believe self-regulation skills to be better predictors of school readiness and later achievement than even academic skills at school entry (Heaviside & Farris, 1993; Lin et al., 2003). This is likely due to the breadth of situations for which self-regulation is essential: it permits control over automatic urges and impulses to instead regulate attention (e.g., sustain attention and resist distraction in a learning task), thinking (e.g., remain cognitively engaged in a task), behaviour (e.g., delay gratification, take turns), emotions (e.g., resist tantrums) and social interactions (e.g., considering others' perspectives) in the pursuit of a goal (Blair & Ursache, 2011).

Executive function

EFs are also considered essential for school readiness and academic success through their contributions to directing, maintaining and controlling attention and thinking. EFs have been independently associated with school readiness (Pellicano et al., 2017; Willoughby et al., 2017), and early literacy and numeracy (Blair & Razza, 2007; Clark et al., 2013; Ribner et al., 2017; Scerif & Bull, 2001). Indeed, EFs have been shown to be a stronger predictor of academic performance than even IQ (Blair & Razza, 2007; Bull et al., 2008). Moreover, EFs have not only been associated with school readiness, but are speculated to underpin self-regulation as well (Hofmann et al., 2012). This evidence suggests a strong link between school readiness, self-regulation and EF, yet how these factors interact remains unclear.

Investigations into these issues are particularly sparse in LMIC contexts, which is problematic given evidence that findings from 'western, educated, industrialised, rich and democratic' (WEIRD) countries may not unconditionally transfer to LMIC contexts. Indeed, to date, most of the evidence for the interplay between school readiness, self-regulation and EF comes from high-income countries (HICs), or low-income populations within HICs, with little evidence from LMICs. A better understanding of cognitive development and early school readiness is vital in understudied and unique countries such as South Africa, which is characterised by poor educational outcomes (Spaull, 2015).

Therefore, this chapter addressed aim 3 in Chapter 2 by examining the associations between EF, self-regulation and school readiness in a low-income sample in South Africa. This chapter also addressed the objectives of aim 3 by firstly, identifying the direction and strength of associations between different components of EF and self-regulation with school readiness; and secondly investigating the latent structure of EF and self-regulation.

6.2 Methods

6.2.1 Measures

The variables included in the current analyses were: the three components of EF (inhibition, shifting and working memory), three teacher-reported self-regulation variables (behavioural, cognitive and emotional self-regulation – BSR, CSR and ESR respectively); and school readiness. All valid data points were included in the analyses; 124 for EF and self-regulation and 129 for school readiness. Missing data was due to participant absenteeism. Refer to Chapter 3 for full details on measures, participants and procedures.

6.2.1.1. Statistical analyses

Data were explored using IBM SPSS Statistics version 25 for Mac (IBM Corp, Armonk, NY). Path analyses were used to determine direct and indirect associations of EF, mediated by self-regulation, on school readiness. This was run using AMOS v23. Given the presence of distinct indices of EF dimensions, models were evaluated for their prediction of school readiness when: (1) the indices were modelled separately; and (2) when these EF indices were combined into a latent variable, in line with previous findings in HICs with this age group. In the first instance, the CSBQ's cognitive self-regulation subscale was used as a mediator, given previous findings from Australia that this factor uniquely and exclusively predicted school readiness (Howard et al., 2019). In the final model, a latent variable of self-regulation was evaluated. Model fit was assessed using several indices of relative and absolute fit: χ^2 statistic, Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA). The level for significance was set at $p < 0.05$.

6.3 Results

Bivariate correlations between path-modelled variables are presented in Table 6.2. Results indicated strong correlations between school readiness and EF components. Correlations for self-regulation were inconsistent and, where present, modest. Results of the path analyses are presented in Figures 6.1 to 6.33. Model 1 considered the direct paths for each EF to school readiness, as well as indirect effects through cognitive self-regulation. Model 2 evaluated direct and indirect paths as well, although now considering EFs as a latent variable. Finally, Model 3 sought to evaluate whether model fit was improved when a latent self-regulation variable was modelled. A model was considered to have good fit if the χ^2 test was non-significant (i.e., a p-value greater than .05, indicating that the data did not significantly differ from the structure of the specified model), CFI greater than or equal to 0.90 and RMSEA less than 0.08 (Hooper, Coughlan, & Mullen, 2008).

Table 6.1 Bivariate correlations between school readiness, self-regulation and executive function

	1	2	3	4	5	6	7
1 School readiness	1						
2 Inhibition	0.64*	1					
3 Shifting	0.48*	0.32*	1				
4 Working memory	0.67*	0.50*	0.40*	1			
5 BSR	-0.12	0.04	-0.05	-0.05	1		
6 CSR	0.30*	0.36*	0.15	0.18*	0.61*	1	
7 ESR	-0.17	-0.01	-0.09	-0.05	0.83*	0.55*	1

Note: BSR = behavioural self-regulation, CSR = cognitive self-regulation; ESR = emotional self-regulation. *p<0.05

For Model 1 (Figure 6.1), a significant chi-square result indicated absolute fit of the model to the data was poor, $\chi^2(3) = 61.28, p < 0.001$. However, the null hypothesis evaluated by this statistic – of no statistically significant difference between the specified model and optimal (saturated) model – is influenced by a range of factors (e.g., sample size, normality) and therefore is often rejected on the basis of inappropriate model evaluation (Bentler, 1990; Smith & McMillan, 2001). As such, the model was also evaluated by relative fit indices, to determine whether the model fit the data on a descriptive or approximate basis. Relative fit statistics were also poor, suggesting misfit to the data: RMSEA = 0.40; CFI = 0.50. Examining specific paths loadings – albeit with poor fit of the model as an overarching caveat to these examinations – working memory and inhibition showed significant direct paths to school

readiness, whereas shifting did not. Inhibition was unique in its direct association with cognitive self-regulation. The path from self-regulation to school readiness was also non-significant. Overall, this model provided a poor fit to the data and could not be advocated.

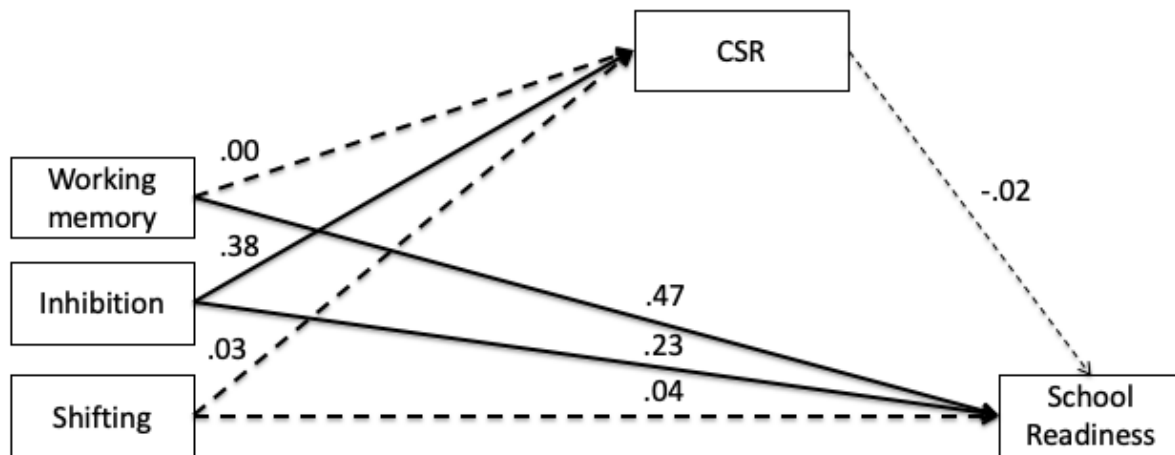


Figure 6.1 Model 1 showing independent associations of executive function latent variable with cognitive self-regulation and school readiness. CSR = cognitive self-regulation.

Model 2 (Figure 6.2) integrated the EF indices as a latent variable. This model provided better fit to the data. Absolute fit was achieved, as evidenced by a non-significant chi-square statistic, $\chi^2(4) = 8.64, p = 0.071$. Relative fit indices indicated reasonable to good fit with the data: CFI = 0.961, RMSEA = 0.097. Inspection of significant paths indicated that EF had strong direct paths to school readiness and cognitive self-regulation. However, the path from cognitive self-regulation to school readiness was again non-significant.

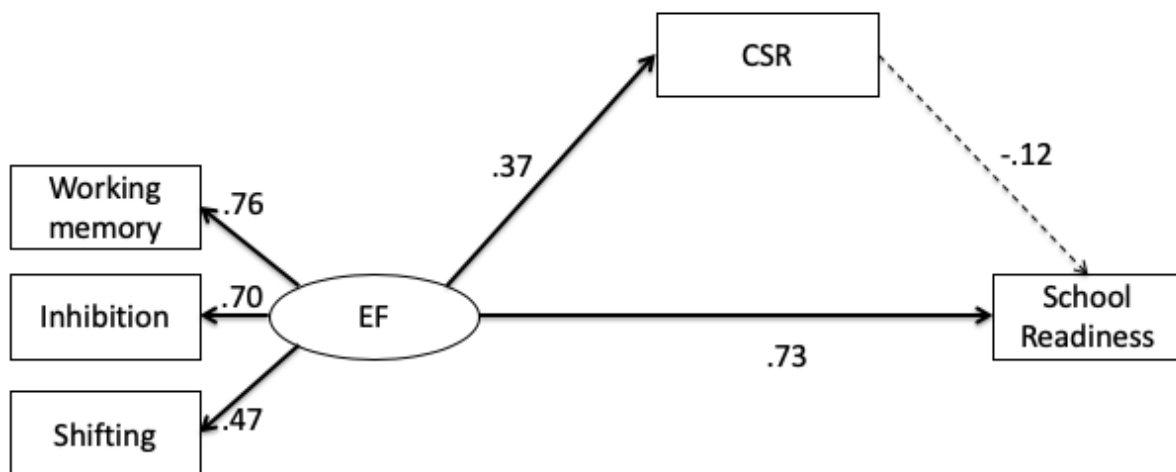


Figure 6.2 Model 2 showing associations of the executive function latent variable with cognitive self-regulation and school readiness. EF = executive function; CSR = cognitive self-regulation.

Model 3 (Figure 6.3) evaluated whether this model would be improved by incorporating the other two self-regulation dimensions (i.e., behavioural, emotional) as a latent variable. The self-regulation components combined to create a successful latent variable, although this inclusion reduced model fit. Chi-square statistic was significant, $\chi^2(4) = 33.35$, $p = 0.001$, and relative fit indices were poor, CFI = 0.12, RMSEA = 0.93 indicating poor absolute fit. While EF still displayed a direct path to school readiness, the path from EF to self-regulation was no longer evident.

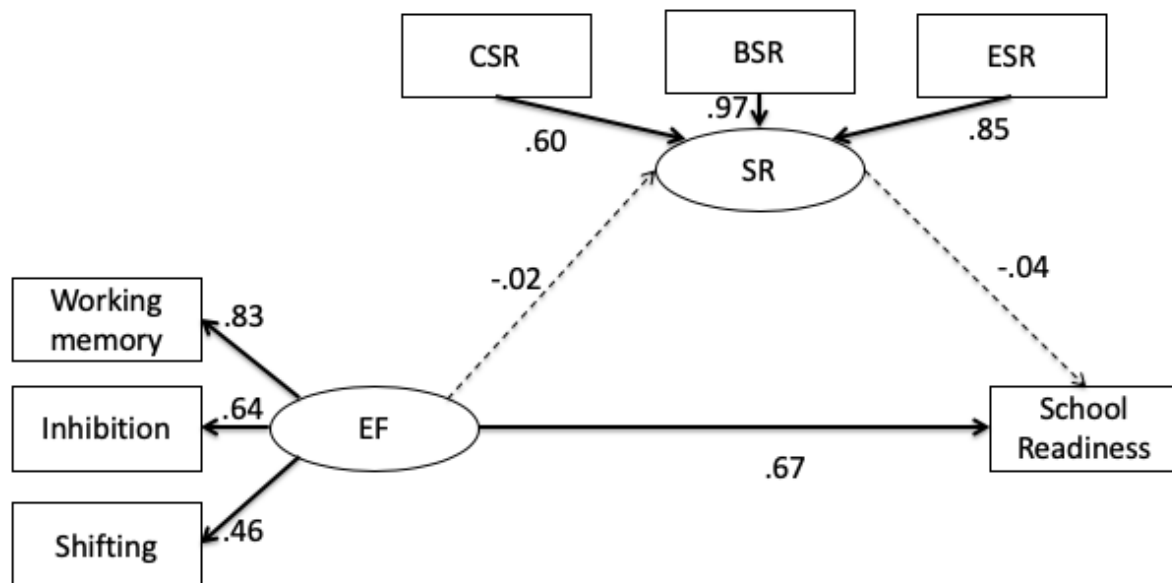


Figure 6.3 Model 3 showing executive function and self-regulation latent variables with school readiness. EF = executive function; CSR = cognitive self-regulation; BSR = behavioural self-regulation; ESR = emotional self-regulation.

6.4 Discussion

This chapter sought to examine the associations of EFs with school readiness – both direct, and indirect via self-regulation – in a diverse sample of South African preschoolers from low-income LMIC settings. EFs showed a strong degree of association with school readiness, and especially so when combined as a latent variable. In contrast, EFs showed only a moderate degree of association with cognitive self-regulation, which was similarly improved when EFs were considered as a single latent factor. Self-regulation did not significantly predict school readiness over and above that already accounted for by EFs. While associations of EF with school readiness extend this robust finding from HICs to this low-income LMIC context, it is unclear whether the lack of association for self-regulation should be considered at face value or perhaps as an artefact of its method of assessment, as discussed in previous chapters.

6.4.1 Associations between EF and school readiness

In the current study, results from both the correlations and path analyses indicated a strong association between executive function and school readiness. This result builds on previous studies demonstrating the importance of these early cognitive skills for school entry and later

achievement (Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008; Fitzpatrick et al., 2014; MacDonald et al., 2016; Pellicano et al., 2017), in a LMIC context. Specifically, these findings align with a recent study a low-SES sample in Ghana (a LMIC; Wolf & McCoy, 2019) that found moderate to strong correlations between EF and numeracy and literacy scores using the IDELA. This is an important finding given that education in low-income settings in South Africa is characterised, on average, by poor academic performance and high dropout rates (see Chapter 2; Fleisch, 2008; Pretorius & Naudé, 2002; Spaull, 2015; Spaull & Kotze, 2015). As discussed in Chapter 2, there is also evidence to suggest this poor performance starts before school. Studies in South Africa revealed that children from low-income settings experience barriers to the acquisition of pre-academic skills (Draper et al., 2012; Pretorius & Naudé, 2002). Examples of these barriers include lack of stimulating play materials (such as books) in the household (Herbst & Huysamen, 2000; Katz, 2005; Pretorius & Naudé, 2002), and low quality preschools (Richter & Samuels, 2018). South Africa is not the only LMIC that experiences challenges and barriers when it comes to academic achievement, many other low-income settings in LMIC's are also synonymous with poor school readiness and academic achievement. Considering the growing pool of evidence indicating an association between EF and school readiness in preschool-age children from LMICs, including African LMICs, more research needs to be done to understand this relationship and investigate how EF can be leveraged to improve school readiness and academic achievement in these settings.

Results thus suggested that although this sample had fairly poor school readiness, children with better EFs tended to have better mastered a subset of knowledge and skills believed to be important for starting school. While the current study is unable to suggest whether these advantages are maintained, or extended, given previous findings of low levels of academic success in South Africa, these advantages are potentially important antecedents to initial and sustained school readiness, adjustment and success.

6.4.2 Associations between EF and self-regulation

While all three dimensions of self-regulation combined to create a successful latent variable, associations of EF with self-regulation were apparent only for cognitive self-regulation. This is aligned with proposals of EFs as the cognitive control capacities that underlie self-regulation

(Hofmann et al., 2012), which may apply more highly or exclusively (e.g., unconfounded by the social demands of the situation) to cognitive dimensions of self-regulation. Additionally, items that are captured in cognitive self-regulation subscales align well with EF skills, namely: the ability to pay attention and avoid distractions; persist with difficult tasks; and problem solve on their own. This finding is also in line with studies in which early EF skills uniquely predicted the more cognitive aspects of self-regulation in preschool age children (Vernon-Feagans et al., 2016) and adolescence (Shoda, Mischel, & Peake, 1990).

6.4.3 Associations between self-regulation and school readiness

In the current study, self-regulation did not predict school readiness in any of the models. Taken at face value, these findings suggest that self-regulation does not contribute directly or uniquely (over and above EFs) to the pre-academic skills that underlie school readiness, at least for preschoolers from low-income South African settings. This is contrary to much of the current literature that shows strong associations between self-regulation and academic success, including school readiness (Howse et al., 2003; Ursache et al., 2012; Williams, Nicholson, Walker, & Berthelsen, 2016). However, one must consider that school readiness, as measured in the current study, is highly focused on the knowledge, skills and abilities that require good cognitive control to acquire. In contrast, it does not take into account behavioural and social-emotional aspects of school readiness, such as positive adjustment to school (e.g., school liking, peer relationships) that are also considered to be vital to successful school transitions (Lin et al., 2003).

Once again, these findings could also be explained by the measurement method used for each cognitive skill. While EF and school readiness were measured using objective, performance-based assessments, self-regulation was assessed using subjective teacher-report methods. As discussed in Chapter 4, teacher reports may be sensitive to rater-bias as answers can be influenced by a variety of factors (Downer, Booren, Lima, Luckner, & Pianta, 2010). This may result in the disagreement between teacher-reported self-regulation, and direct assessments of children's cognitive and regulatory skills. Furthermore, the problematic distribution of self-regulation data shown in Chapter 4 may also explain the non-significant associations between school readiness and self-regulation. It is thus possible that the behavioural and social-

emotional components of self-regulation are indeed vital for school readiness in this context, yet the current study was not able to detect these associations.

6.4.4 Latent structure of EF

Results also suggested that, at least at this early age, EFs are better construed as a single set of highly related skills, rather than clearly separable functions, amongst low-income South African pre-schoolers. This confirms the findings in the previous chapter, and is aligned with prior research suggesting a one-factor EF solution in the preschool years (Wiebe et al., 2011; Wiebe, Espy, & Charak, 2008). As with that research in the early years from HICs, this contrasts the three-factor models that emerge in later childhood and adulthood (Friedman & Miyake, 2004; Miyake et al., 2000; Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001). Indeed, model fit, and predictive strength was improved when EF was modelled as a single latent factor rather than individual EFs. However, shifting was not as strongly correlated with the latent factor. Previous research has suggested that shifting may emerge after the maturation of working memory and inhibition, as shifting ability relies on these two skills (Diamond, 2013; Garon et al., 2008; Hughes, 2002). Therefore, it is possible that in this age-group, shifting is not as developed and for that reason does not load as strongly. Closer inspection of the shifting scores revealed that although the majority of children demonstrated the ability to shift, only 11.3% of the sample demonstrated the ability to shift back and forth, providing further justification to this explanation.

6.5 Conclusion

In summary, the results from this chapter contribute to a growing pool of evidence for the associations of EF with school readiness, with the current study being the first to extend this to the South African context. Although the cross-sectional nature of these data cannot show causality or directionality (e.g., whether EFs potentiate learning, learning strengthens EFs or there is some third factor influencing both), it remains clear that EF and school readiness are strongly linked. This provides a strong rationale for further longitudinal research to examine the direction and predictive nature of these associations for transition to school and across the student's full academic journey. This chapter also provides further reason to take

measurement methods into consideration when interpreting findings, specifically when it comes to subjective measures.

CHAPTER 7: ASSOCIATIONS OF PHYSICAL ACTIVITY AND GROSS MOTOR SKILLS WITH ADIPOSITY

7.1 Introduction

The rise in paediatric obesity levels has not been limited to high-income countries (HICs); in fact, children in low- and middle-income countries (LMICs) make up 76% of overweight children under the age of 5 years (de Onis et al., 2010). As a result of this, research has focussed on identifying correlates of adiposity, a measure that is generally indicated by body mass index (BMI) in adults and BMI z-score in children. However, as mentioned in Chapter 2, the rise in overweight and obesity in LMICs is accompanied by persistent underweight/undernutrition (Tzioumis & Adair, 2014) resulting in a double burden of over- and underweight. This was illustrated in the most recent nationally representative data reporting under and overnutrition in South Africa (Shisana et al., 2013). Consequently, correlates of adiposity may differ in settings experiencing this double burden (mostly LMICs) compared to settings that do not experience this double burden (mostly HICs).

As mentioned in Chapter 2, physical activity and gross motor skills (GMS) have both been identified as correlates of adiposity. This literature suggests a beneficial (negative) relationship between physical activity and adiposity (Lin, Cherg, & Chen, 2017; Timmons et al., 2012; Trost, Sirard, Dowda, Pfeiffer, & Pate, 2003), such that children who engage in higher amounts and intensities of physical activity have lower (healthier) adiposity levels and are less likely to be overweight and obese. A review investigating associations between objectively measured physical activity and adiposity in children and adolescents found that the majority of studies (79%) reported negative associations between physical activity and adiposity (Jiménez-Paín, Kelly, & Reilly, 2010). However, a more recent review has indicated that this relationship might not be as simple as previously thought as the evidence presented is of a mixed nature (Carson et al., 2017). Still, in studies where associations were found, they were mainly negative in nature, once again indicating that increased physical activity is associated with decreased adiposity.

Missing from the current evidence, however, is consideration of data from LMICs, in which populations with over- and undernutrition may be prevalent. This lack of consideration is at least partly due to the prevailing point of view of physical activity for preventing overweight and obesity. Even in the (few) studies from LMICs included in recent reviews (De Carvalho Cremm et al., 2012; Huynh, Dibley, Sibbritt, Tran, & Le, 2011; Kain & Andrade, 1999), the focus of included studies is overweight and obesity, and the samples mostly consist of either normal weight, or overweight and obese.

However, research from South Africa has suggested that this relationship may differ and be more complex in a sample that includes over- and under-weight children (Draper et al., 2019; Jones et al., 2014). For example, Jones et al. (2014) found that both underweight and obesity was associated with a decreased likelihood of engaging in physical activity. These results suggested that children with a healthy body weight are more likely to engage in physical activity. Draper et al. (2019) found a positive association between physical activity and adiposity (as opposed to the negative association routinely found in HIC-based studies). Considering this sample had very low levels of overweight and obesity (8.96%), and a relatively high prevalence of underweight (thinness: 19.4%, stunting: 4.1% and wasting: 3.4%), the results also suggested that children with a healthy body weight (higher BMI z-score in this case) are more likely to engage in more physical activity.

Similarly, the relationship between GMS and adiposity has shown to be beneficial with the majority of studies indicating a negative association between these factors (Castetbon & Andreyeva, 2012; D'Hondt et al., 2013; D'Hondt, Deforche, De Bourdeaudhuij, & Lenoir, 2009; Nervik, Martin, Rundquist, & Cleland, 2011). However, the significance of this relationship in previous research was mostly found in studies that had participants who were overweight or obese, indicating that these children had a lower gross motor proficiency compared to their normal weight peers. These relationships have seldom been considered with underweight children in mind.

More than just being correlates of adiposity, physical activity and GMS are also known to be associated. Rather than suggesting a single (potentially causal) pathway, previous research (mostly from HICs) has indicated a bi-directional relationship between physical activity and

GMS (Barnett, Salmon, et al., 2016; Figueroa & An, 2017). To explain this finding, it has been speculated that spending more time engaging in physical activity allows more opportunities to develop and practice GMS. In the same way, children with greater GMS proficiency might choose to engage in more physical activity than children who have a lower GMS proficiency (Williams et al., 2008; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006). The evidence above suggests that physical activity, GMS and adiposity might be mutually influential.

As mentioned previously, there is limited research on the associations between physical activity, GMS and adiposity (or body composition more broadly) in LMIC contexts, particularly contexts that experience the double-burden of over- and undernutrition. Therefore, there is reason to be cautious in extending the findings from HICs to LMICs. Additionally, the evidence that does exist from LMIC contexts also suggests beneficial relationships between these factors, but in the opposite direction to what is found in HICs. This chapter addressed aim 4 in Chapter 2: investigating the associations between physical activity, GMS and adiposity. Therefore, this chapter builds on the limited evidence in this context and establishes whether the results from South Africa are replicated, or whether they conform to the more established evidence from HICs.

7.2 Methods

7.2.1 Measures

Variables of physical activity included in this chapter is the daily average of time spent in total physical activity (LMVPA) and moderate- to vigorous-intensity physical activity (MVPA). GMS variables include the raw scores for object control skills, locomotor skills and total GMS (raw scores for object control and locomotor skills combined). Adiposity measures include height-for-age z-score (HAZ), weight-for-age z-score (WAZ), and BMI-for-age z-score (BAZ) were included in this chapter. To maximise sample size, all valid data points for each variable were included and analysed using pairwise deletion. Valid data points were as follows: 122 for physical activity and 125 for GMS and anthropometric measures. Missing data was due to participant absenteeism on the day of testing and failure to meet the wear-time requirements

for accelerometry. Complete descriptions of measures, participants and procedures are provided in Chapter 3.

7.2.2 Statistical analyses

Analyses were conducted using IBM SPSS Statistics 25. Associations between the analytic variables were analysed further using linear hierarchical regression analyses. BAZ was the main outcome variable as it is known to be a good indicator of adiposity, while HAZ and WAZ are better indicators of nutritional deficits. Demographic variables including age, setting and sex, were included as covariates in the regressions. This was necessary given that the results from Chapter 4 indicated associations between demographic variables and the analytic variables of interest. Physical activity and GMS were included as predictors. However, due to issues of collinearity, only one physical activity variable could be included in the regression. Regressions were run with both MVPA and LMVPA as independent predictors however, the model including MVPA showed better model fit and therefore presented below. Similarly, total GMS could not be in the same regression model as locomotor and object control skills. Initial regression models were run with total GMS, but this was not found to be a significant predictor of adiposity and therefore locomotor and object control skills were not regressed. Models were constituted as follows: demographic variables (age, sex, setting) were included in step 1 as covariates, total GMS was included in step 2 and MVPA was included in step 3. The level for significance was set at $p < 0.05$.

7.3 Results

7.3.1 Bivariate correlations

Bivariate correlations were conducted to investigate underlying associations between adiposity, GMS and physical activity variables. These results, presented in Table 7.1, highlighted significant associations between aspects of physical activity and GMS. As expected, adiposity variables (HAZ, WAZ and BAZ) were significantly associated with each other. Likewise, locomotor and object control skills were significantly associated ($p < 0.001$). MVPA was significantly, positively associated with all GMS variables (locomotor skills: $p = 0.04$, object control skills: $p = 0.005$ and total GMS: $p = 0.008$). LMVPA was also associated with object

control (p=0.019) and total GMS (p=0.038); however, associations were slightly weaker compared to MVPA. LMVPA was not associated with locomotor skills. BAZ was significantly associated with GMS (object control skills and total GMS), but not with physical activity. Neither HAZ nor WAZ were associated with any physical activity or GMS variables.

Table 7.1 Correlations between anthropometric measures, physical activity and GMS

	1	2	3	4	5	6	7	8
1. HAZ	-							
2. WAZ	0.75*	-						
3. BAZ	0.23*	0.76*	-					
4. Locomotor	0.14	-0.01	-0.13	-				
5. Object control	0.06	-0.10	-0.24*	0.55*	-			
6. Total GMS	0.11	-0.06	-0.19*	0.93*	0.82*	-		
7. LMVPA	-0.14	-0.06	0.05	0.13	0.21*	0.19*	-	
8. MVPA	-0.01	0.06	0.12	0.18*	0.25*	0.24*	0.67*	-

Note: HAZ = height-for-age; WAZ = weight-for-age; BAZ = body mass index-for-age; GMS = gross motor skills; LMVPA = total physical activity; MVPA = moderate and vigorous intensity physical activity. *p>0.005.

7.3.2 Regression analysis

To examine predictors of BAZ, total GMS and MVPA were regressed onto BAZ (step 2 and 3), while controlling for age, sex and setting, and results are presented in Table 7.2. The overall model was significant, $F(5,114)=3.38$, $p=0.007$, and showed that MVPA ($\beta=0.182$, $p=0.049$), but not total GMS ($\beta=-0.123$, $p=0.280$), significantly predicted BAZ. Step 1, with only the demographic variables, explained 31% of the variation in BAZ scores. Step 2 with the addition of GMS, and step 3 with MVPA explained 32% and 36% of the variance respectively. This indicates that the covariates, particularly setting, contribute largely to the explanatory strength of the model, and total GMS and MVPA, although significant, added little explanatory strength to the model.

Table 7.2 Hierarchical regression models predicting BAZ score

Predictors	B	SE B	β	<i>p</i>	Adj. R ²	ΔR^2
Step 1					-	0.094
Age	-0.028	0.010	-0.239	0.009*		
Sex ^a	0.050	0.170	0.010	0.769		
Setting ^b	-0.484	0.174	-0.253	0.006*		
Step 2					0.004	0.096
Age	-0.022	0.013	-0.189	0.102		
Sex ^a	0.067	0.172	0.035	0.699		
Setting ^b	-0.457	0.179	-0.240	0.012*		
GMS	-0.005	0.007	-0.081	0.473		
Step 3					0.030	0.130
Age	-0.022	0.013	-0.188	0.101		
Sex ^a	0.010	0.172	0.005	0.953		
Setting ^b	-0.471	0.177	-0.247	0.009*		
GMS	-0.008	0.008	-0.123	0.280		
MVPA	0.006	0.003	0.182	0.049*		

Note: The change in r^2 and R^2 are presented for each model, as well as the unstandardised beta coefficient, standard error coefficient, standardised beta and the significance value. ^a0 = female, 1 = male; ^b0 = rural, 1 = urban. * $p < 0.05$. GMS = gross motor skills; MVPA = moderate and vigorous intensity physical activity.

7.4 Discussion

The aim of this chapter was to examine the associations of physical activity and GMS with adiposity. Overall, results showed that children who were more active (at higher intensities) demonstrated better GMS (as indicated by bivariate correlations), and had higher adiposity (as indicated through linear regression). Additionally, GMS were not uniquely associated with adiposity.

7.4.1 Physical activity and GMS

The positive association between physical activity and GMS found in international (Figueroa & An, 2017) and local research is replicated in the current study, with the strongest relationships found between higher intensity physical activity (MVPA) and object control skills. Although the context of participants' physical activity was not recorded in this study, previous research in similar South African settings suggests that most of this physical activity

is unstructured or free play, with little teacher involvement (Draper et al., 2017; Tomaz, 2018). As such, it is possible then that children with greater object control skills are more likely to engage in active play as they can participate in play more confidently. This is supported by research showing that children who display good GMS proficiency, or at least perceive themselves as competent, are more likely to engage in physical activity (Famelia et al., 2018; Robinson et al., 2015). On the other hand, it could be that children who were more active were spending more time in free play activities that develop object control skills. For example, a popular activity played in the current settings includes rolling a car tire around using two sticks to control speed and direction. This activity is mostly done at a moderate or vigorous intensity and involves object manipulation, thereby challenging object control skills. Soccer is also a very popular activity in these settings, and if children have access to a ball, they might choose to play soccer or soccer-related activities that challenge and develop object control skills. The finding that both locomotor and object control skills showed stronger associations with MVPA compared to LMVPA is important in light of the recent guidelines (Laureus, 2019; Okely et al., 2017; Tremblay et al., 2017; World Health Organization, 2019) that specify the inclusion of at least 60 minutes of MVPA within the recommended 180 minutes of total physical activity (LMVPA). Thus, these findings highlight the confluence of MVPA in the development of GMS.

7.4.2 Correlates of adiposity

Physical activity

While bivariate correlations did not show associations of physical activity with adiposity, significant associations were found after controlling for age, setting and sex in regression analyses. The resultant positive association found between MVPA and BAZ opposes the negative or inverse association found in international literature (Carson et al., 2017). Instead, the current results suggest that engaging in higher amounts of physical activity is associated with a higher adiposity amongst preschool children from low-income SA settings. These results are similar to those of the local studies in similar settings mentioned earlier that also reported a positive association between physical activity and adiposity (specifically BMI and BAZ), and concluded that children who were more active had BMI scores in the healthy range (i.e. not underweight or overweight; Draper et al., 2019; Jones et al., 2014).

The Life History Theory (LHT) literature provides a potential explanation for lower levels of physical activity in children who are underweight (Howard, Cook, Said-Mohamed, Norris, & Draper, 2016). LHT proposes that individuals have a finite amount of resources, including energy resources, and that these resources are allocated according to life history stages with more resources being allocated to physical and brain growth in the early years (Bogin, Silva, & Rios, 2007). Therefore, if energy resources are low, as would be in an underweight child, it is possible that available energy would be directed toward growth and development, leaving less energy resources for physically active pursuits. These results infer a complex, bi-directional relationship between physical activity and adiposity such that participating in more physical activity can lower adiposity (specifically BMI) and, that weight status, particularly underweight, can lead to less participation in physical activity.

Gross motor skills

While small but significant positive associations were found between BAZ and GMS in the correlation analyses, after controlling for age, sex and setting these associations were no longer significant. Other studies including the local study mentioned earlier (Draper et al., 2019) and another LMIC (Catenassi et al., 2007) also reported null associations between GMS and adiposity. This, however, differs from international evidence indicating beneficial (negative) associations between GMS and adiposity (Barnett, Lai, et al., 2016; D'Hondt et al., 2009, 2011; Okely, Booth, & Chey, 2004). As previously mentioned, most of this international evidence is driven by the link between GMS and overweight/obesity, and does not consider undernutrition (D'Hondt et al., 2009, 2011; Okely et al., 2004). This association may have not been found in the current study, and the other local study (Draper et al., 2019), as the prevalence of overweight and obesity was extremely low in these samples. Draper et al. (2019) suggested that the high GMS proficiency in LMIC contexts may have been one of the reasons for the null association. Considering the current sample also displayed high levels of GMS proficiency, this could be true for the current study too.

7.5 Conclusion

This study contributes to the small pool of evidence investigating the associations between physical activity, GMS and adiposity in South African low-income settings. Replication with similar samples is important to confirm these patterns in this understudied context. The double burden of over- and undernutrition in South Africa is characteristic of a transitioning LMIC and therefore, understanding how physical activity and GMS affect adiposity is not only important for South Africa, but for other transitioning countries in which the relationships may be more complex and where research is scarce. More specifically, in settings where underweight is prevalent, guidelines and interventions for physical activity should not be a one-size-fits-all, but rather tailored to the needs of the individual child or setting. For example, prescribing physical activity with low energy demands might allow underweight children to receive the benefits of engaging in physical activity (psychosocial, cognitive, health benefits) without negatively impacting on their energy supply (Howard et al., 2016).

CHAPTER 8: INVESTIGATING THE ASSOCIATIONS OF PHYSICAL ACTIVITY AND GROSS MOTOR SKILLS WITH COMPONENTS OF COGNITIVE DEVELOPMENT

8.1 Introduction

As described in Chapter 2, physical activity has been beneficially associated with physical health (Carson et al., 2017) and cognitive development (Carson et al., 2015). In addition to this, gross motor skills (GMS) have also been linked to physical health and cognitive development (Cameron et al., 2016; Oberer et al., 2017). Moreover, GMS are considered a core aspect of school readiness (High, 2008). As highlighted previously, the preschool years are a critical time for development in many areas, including cognitive, physical and motor domains (Daelmans et al., 2017). For this reason, understanding the nature of the relationships between these domains is vital to ensure that children maximise their developmental opportunities during this period.

In these preschool age groups, the relationship that has perhaps received the most attention in recent years is between physical activity and EF. While questions surrounding the type, duration and intensity of physical activity required to influence EF remain, the current evidence does point toward a positive association, indicating that physical activity may have a beneficial impact on EF (Best, 2010; Carson et al., 2015; Diamond, 2012). Similarly, research has indicated a beneficial relationship between GMS and EF as well (Stöckel & Hughes, 2016; van der Fels et al., 2015). Considering the centrality of EF to other components of cognitive and non-cognitive development, it would be expected that physical activity and GMS could have an impact on abilities related to self-regulation, attention and school readiness. Refer to Chapter 2 for more detailed descriptions of the current evidence for these relationships.

Although this research is accumulating, it is limited by the inconsistency of nomenclature, definitions and measurement of EF, attention, self-regulation and even GMS. Furthermore, most studies have looked at isolated associations, rather than considering them concurrently. Examples include studies look particularly at: EF and physical activity (Willoughby et al., 2018);

school readiness and GMS (Draper et al., 2012); attention and physical activity (Palmer, Miller, & Robinson, 2013); and more (see Chapter 2 for detailed evidence). In addition to this, the available evidence is predominantly from high-income countries, or contexts that are western, educated, industrialised, rich and democratic (WEIRD; Azar, 2010) as has been highlighted throughout this study. Yet there is evidence to suggest that findings from these contexts may not necessarily or uniformly generalise to LMIC contexts (Howard et al., 2019).

South Africa is an LMIC in which there has been no previous research investigating these relationships. However, Chapter 2 provided outlined reasons to believe that these relationships might look different in these novel settings. For example, South Africa has high levels of poverty with 1 out of every 5 adults, and more than a third of the child population living under the food poverty line (Statistics South Africa, 2018). To put it into perspective, the food poverty line represents around 30USD per person per month. International evidence has suggested that children growing up in poverty or low-income settings are more likely to have poor cognitive development compared to children from high-income settings.

This relationship has been particularly pertinent in the EF (Hackman et al., 2015) and school readiness (Janus & Duku, 2007; Vernon-Feagans et al., 2016) literature. And, while there is no previous evidence investigating cognitive development in South African preschool children from low-income settings, there is ample evidence demonstrating an academic achievement gap between children from high- and low-income settings (Spaull, 2015; Spaull, 2012). There is also evidence that children from low-income settings in South Africa are more likely to have poor school readiness (Bruwer, Hartell, & Steyn, 2014; Richter & Samuels, 2018; Sherry & Draper, 2013) and poor academic achievement (Pretorius & Naudé, 2002; Spaull, 2015). Results from Chapter 4 revealed that indeed, school readiness skills are at risk in this sample. Chapter 4 also revealed that the current sample appears to have good EF and self-regulation, contrary to expectations based on Australian norms (Howard & Melhuish, 2017), and relatively good selective attention compared to evidence from preschool-aged children in the United Kingdom (Scerif et al., 2019). Based on the evidence for the effect of poverty on cognitive development discussed above, these findings were unexpected.

Additionally, a small pool of evidence from South African settings, including the results from Chapter 4, reveal that South African preschool-aged children engage in very high levels of physical activity (Draper et al., 2019, 2017; Jones et al., 2014) and good gross motor proficiency. Therefore, the South African context presents complex, novel settings in which to investigate these relationships. For example, how would these relationships play out in a sample that appears to have good underlying cognitive capacities and behaviours (EF, attention and self-regulation), poor performance on cognitive school readiness indicators, yet engages in high levels of physical activity and demonstrates good gross motor proficiency?

This chapter aimed to address this by exploring associations between all of these outcomes in a sample of children attending preschool in diverse low-income settings in South Africa. This not only evaluates whether the associations found in high income countries are maintained in a LMIC, but it also seeks to better understand the components of physical activity and GMS that may be of particular interest in relation to cognitive development, and thus a plausible target for prevention, intervention and education.

Therefore, this chapter address the 5th aim listed in Chapter 2 and the specific objectives which are to examine whether and how components of naturally occurring physical activity (duration and intensities) and GMS (total, locomotor and object control skills) relate to:

- a) EF, comprised of indices of inhibition, shifting and working memory
- b) Self-regulation, comprised of indices of behavioural, cognitive and emotional self-regulation
- c) Selective attention, specifically the quality of search score for the conjunction search
- d) Cognitive school readiness, specifically the total raw score on a standardised school readiness assessment

8.2 Methods

8.2.1 Measures

Physical activity variables included in the analyses were total physical activity (LMVPA) and moderate- to vigorous-intensity physical activity (MVPA). GMS variables included the raw

scores for locomotor skills, object control skills, and total GMS (sum of the raw scores). EF variables include inhibition, shifting and working memory. Self-regulation consisted of teacher-ratings for behavioural, cognitive and emotional self-regulation (BSR, CSR and ESR respectively). Selective attention is indexed by the quality of search score (Q score) for conjunction search. School readiness is indicated by raw accuracy score on a standardised school readiness assessment. Demographic control variables –age, sex, height-for-age (HAZ) and setting (urban and rural) – were included in the analyses. Age, sex and setting were included as covariates as Chapter 4 revealed that these accounted for variance in aspects of physical and cognitive development. Additionally, HAZ was included as a covariate based on the literature that highlights the impact of stunting on cognitive development in South African literature (Casale & Desmond, 2015) and international literature (Dewey & Begum, 2011). Complete descriptions of measures, participants and procedures are provided in Chapter 3.

8.2.2 Statistical analyses

Results were analysed using IBM SPSS Statistics version 25 for Mac (IBM Corp, Armonk, NY). To maximise sample size, all valid data points for each variable were included and analysed using pairwise deletion. Valid data points were as follows: 122 for physical activity, 124 for GMS and anthropometric measures, 124 for EF and self-regulation, 123 for selective attention and 129 for school readiness. Missing data was due to participant absenteeism on the day of testing, and failure to meet the wear-time requirements for accelerometry. Linear regressions were conducted to determine whether independent variables (i.e., GMS: total GMS, locomotor skills and object control skills; physical activity: LMVPA and MVPA) accounted for significant variance in components of cognitive development (dependent variables) after controlling for age, sex, HAZ and setting. Due to issues of collinearity, LMVPA and MVPA could not be included in the same regression model. Therefore, separate regressions were conducted for these physical activity variables, and results are reported for the model with the best fit. Similarly, total GMS could not be analysed with locomotor and object control skills due to issues of collinearity. Therefore, initial regression models were conducted with total GMS only and the results reported in the text. If total GMS was significant in the model, subsequent regressions then assessed the relative contribution of locomotor and object control skills for each dependent variable. The level for significance was set at $p < 0.05$.

Associations with covariates were discussed previously in Chapter 4, and thus are not reiterated here.

8.3 Results

8.3.1 Physical activity, gross motor skills and executive function

Multiple linear regression analyses were used to assess the relative contribution of physical activity and GMS as predictors of EF, while controlling for age, sex, HAZ and setting. MVPA provided better model fit than those with LMVPA, and as such these models have been reported. Initial regressions investigating the extent to which total GMS predicted EF showed significant prediction of inhibition ($\beta=0.34$, $p<0.001$) and working memory ($\beta=0.29$, $p=0.002$), but not shifting. Subsequent regressions assessed the particular contribution of the locomotor and object control skills to EF (Table 8.1).

Table 8.1 Summary details of the multiple linear regression analyses predicting performance on executive function tasks

EF variables	Predictors	B	SE B	β	t	p	Adj. R ²	ΔR^2
Inhibition								
Model 1	Age	0.014	0.002	0.602	3.84	<0.001*	0.347	-
	Sex ^a	-0.004	0.030	-0.009	-0.126	0.900		
	HAZ	0.005	0.015	0.026	0.342	0.733		
	Setting ^b	-0.005	0.030	-0.013	-0.171	0.864		
Model 2	Age	0.009	0.002	0.368	4.046	<0.001*	0.434	0.098
	Sex ^a	-0.011	0.032	-0.029	-0.364	0.717		
	HAZ	-0.001	0.014	-0.005	-0.077	0.938		
	Setting ^b	-0.033	0.031	-0.084	-1.078	0.283		
	Locomotor	0.005	0.002	0.261	2.600	0.011*		
	Object control	0.006	0.003	0.192	1.932	0.056		
	MVPA	-0.001	0.000	-0.128	-1.761	0.081		

Shifting								
Model 1	Age	0.146	0.032	0.393	4.590	<0.001*	0.170	-
	Sex ^a	-0.786	0.515	-0.128	-1.526	0.130		
	HAZ	-0.245	0.268	-0.076	-0.914	0.363		
	Setting ^b	-0.928	0.528	-0.151	-1.757	0.082		
Model 2	Age	0.106	0.040	0.284	2.630	0.010*	0.181	0.031
	Sex ^a	-0.844	0.584	-0.137	-1.445	0.151		
	HAZ	-0.296	0.268	-0.092	-1.105	0.272		
	Setting ^b	-1.162	0.567	-0.189	-2.048	0.043*		
	Locomotor	0.033	0.036	-0.108	0.905	0.367		
	Object control	0.060	0.057	0.124	1.048	0.297		
	MVPA	-0.013	0.009	-0.124	-1.438	0.153		

Working memory								
Model 1	Age	0.045	0.008	0.451	5.896	<0.001*	0.351	-
	Sex ^a	0.138	0.123	0.084	1.123	0.264		
	HAZ	0.047	0.064	0.055	0.740	0.461		
	Setting ^b	-0.483	0.126	-0.295	-3.839	<0.001*		
Model 2	Age	0.028	0.009	0.279	3.017	0.003*	0.415	0.076
	Sex ^a	0.178	0.133	0.109	1.340	0.183		
	HAZ	0.023	0.061	0.027	0.383	0.703		
	Setting ^b	-0.535	0.129	-0.326	-4.135	<0.001*		
	Locomotor	0.021	0.008	0.255	2.502	0.014*		
	Object control	0.011	0.014	0.089	0.875	0.384		
	MVPA	-0.005	0.002	-0.184	-2.495	0.014*		

Note: The adjusted R² and change in R² (ΔR^2) are provided for each model as well as the unstandardised beta coefficients (B), standard errors (SE B), standardised beta (β) and significance values for all independent variables and controls. ^a0 = female, 1 = male; ^b0 = Urban, 1 = rural. * p < 0.05. HAZ = height-for-age; MVPA = moderate and vigorous intensity physical activity.

Inhibition

After accounting for covariates, the overall regression was significant, $F(7,11)=13.48$, $p<0.001$, and explained 43% of the variance in inhibition with the predictors accounting for an additional 10% ($\Delta R^2=0.10$ after inclusion of MVPA and GMS components). Only age and locomotor skills showed significant associations with inhibition. In other words, participants who were older and demonstrated greater locomotor skills showed greater performance on inhibition tasks.

Shifting

After accounting for covariates, the overall regression was significant, $F(7,111)=5.22$, $p<0.001$, and explained 18% of the variance in shifting with the predictors accounting for an additional 3% ($\Delta R^2=0.03$ after inclusion of MVPA and GMS components). However, only age and setting were significant predictors of shifting, such that children who were older and from the urban setting had better shifting performance.

Working memory

After accounting for covariates, the overall regression was significant, $F(7,111)=12.71$, $p<0.001$, and explained 41% of the variance in working memory with the predictors accounting for an additional 8% ($\Delta R^2=0.08$ after inclusion of MVPA and GMS components). Age, setting, locomotor skills and MVPA were all significant independent predictors of working memory. More specifically, participants who were older and from the urban setting showed greater working memory performance. Additionally, participants with better locomotor skills and lower levels of MVPA showed higher working memory performance.

8.3.2 PA, GMS and self-regulation

Multiple linear regression analyses were also used to assess the relative contribution of the physical activity and GMS as predictors of self-regulation, while controlling for age, sex, HAZ and setting. Total GMS was a significant predictor of BSR ($\beta=0.25$, $p=0.014$), CSR ($\beta=0.37$, $p<0.001$) and ESR ($\beta=0.21$, $p=0.035$). Subsequent regressions assessed the particular contributions of locomotor and object control skills to self-regulation. LMVPA showed better

model fit compared to MVPA and is therefore reported below. The results are presented in Table 8.2.

Table 8.2 Summary details of the multiple linear regression analyses predicting teacher-ratings of self-regulation

EF variables	Predictors	B	SE B	β	t	p	Adj. R^2	ΔR^2
BSR								
Model 1	Age	-0.003	0.009	-0.023	7.193	0.782	0.203	-
	Sex ^a	-0.291	0.149	-0.162	-1.956	0.053		
	HAZ	-0.008	0.077	-0.009	-0.105	0.917		
	Setting ^b	0.767	0.153	0.427	5.026	<0.001*		
Model 2	Age	-0.023	0.011	-0.214	-2.159	0.033*	0.318	0.128
	Sex ^a	-0.330	0.156	-0.184	-2.119	0.036*		
	HAZ	-0.073	0.073	-0.077	-0.995	0.322		
	Setting ^b	0.860	0.157	0.480	5.497	<0.001*		
	Locomotor	0.028	0.010	0.302	2.781	0.006*		
	Object control	0.009	0.015	0.065	0.593	0.554		
	LMVPA	-0.004	0.001	-0.311	-3.771	<0.001*		
CSR								
Model 1	Age	0.062	0.011	0.460	5.746	<0.001*	0.291	-
	Sex ^a	-0.179	0.174	-0.081	-1.032	0.304		
	HAZ	-0.077	0.091	-0.066	-0.848	0.398		
	Setting ^b	0.944	0.178	0.425	5.296	<0.001*		
Model 2	Age	0.027	0.012	0.202	2.223	0.028*	0.181	0.031
	Sex ^a	-0.262	0.177	-0.118	-1.481	0.141		
	HAZ	-0.156	0.083	-0.134	-1.886	0.062		
	Setting ^b	0.981	0.178	0.441	5.524	<0.001*		
	Locomotor	0.041	0.011	0.359	3.610	<0.001*		
	Object control	0.022	0.018	0.129	1.279	0.203		

	LMVPA	-0.004	0.001	-0.164	-3.496	0.001*		
ESR								
Model 1	Age	-0.005	0.009	-0.048	-0.601	0.549	0.282	-
	Sex ^a	-0.281	0.137	-0.161	-2.046	0.043*		
	HAZ	-0.115	0.072	-0.126	-1.606	0.111		
	Setting ^b	0.837	0.141	0.480	5.945	<0.001*		
Model 2	Age	-0.022	0.010	-0.205	-2.139	0.035*	0.360	0.092
	Sex ^a	-0.267	0.147	-0.153	-1.820	0.071		
	HAZ	-0.167	0.069	-0.183	-2.427	0.017*		
	Setting ^b	0.943	0.147	0.541	6.401	<0.001*		
	Locomotor	0.027	0.009	0.305	2.891	0.005*		
	Object control	-0.002	0.015	-0.014	-0.128	0.898		
	LMVPA	-0.003	0.001	-0.248	-3.105	0.002*		

Note: The adjusted R^2 and change in R^2 (ΔR^2) are provided for each model as well as the unstandardised beta coefficients (B), standard errors (SE B), standardised beta (β) and significance values for all independent variables and controls. ^a0 = female, 1 = male ^b0 = Urban, 1 = rural. * $p < 0.05$. HAZ = height-for-age; LMVPA = total physical activity; BSR = behavioural self-regulation; CSR = cognitive self-regulation; ESR = emotional self-regulation.

Behavioural self-regulation

After accounting for covariates, the overall regression was significant, $F(7,111)=8.845$, $p<0.001$, and explained 60% of the variance in BSR with the predictors accounting for an additional 13% ($\Delta R^2=0.13$ after inclusion of MVPA and GMS components). Of the independent variables, only locomotor skills and LMVPA were significant predictors of BSR. As expected, locomotor skills were positively associated with BSR ($\beta=0.302$, $p=0.006$) suggesting that teachers were more likely to rate children as more behaviourally self-regulated if they had better locomotor skills. LMVPA was negatively associated with BSR ($\beta=-0.311$, $p=0.001$), suggesting that children who engaged in higher amounts of physical activity were rated by educators as less likely to self-regulate their behaviour.

Cognitive self-regulation

After accounting for covariates, the overall regression was significant, $F(7,111)=9.691$, $p<0.001$, and explained 68% of the variance in CSR with the predictors accounting for an additional 3% ($\Delta R^2=0.03$ after inclusion of MVPA and GMS components). Results were similar to those of BSR, as locomotor skill was positively associated with CSR ($\beta=0.359$, $p<0.001$), LMVPA was negatively associated with CSR ($\beta=-0.164$, $p=0.001$) and object control showed no significant associations.

Emotional self-regulation

After accounting for covariates, the overall regression was significant, $F(7,111)=10.502$, $p<0.001$, and explained 63% of the variance in ESR with the predictors accounting for an additional 10% ($\Delta R^2=0.10$ after inclusion of MVPA and GMS components). Once again, results were similar to those of BSR and CSR, with positive associations for locomotor skills ($\beta=0.305$, $p=0.005$), negative associations for LMVPA ($\beta=-0.248$, $p=0.002$), and no significant associations for object control skills.

8.3.3 Physical activity, gross motor skills and selective attention

Multiple linear regression analyses were again used to assess the relative contribution of physical activity and GMS as predictors of selective attention, while controlling for age, sex, HAZ and setting. Total GMS was a significant predictor ($\beta=0.33$, $p<0.001$). Subsequent regressions then assessed the particular contribution of the locomotor and object control skills to self-regulation. MVPA showed better model fit compared to LMVPA and was therefore included in the regression models. The results are presented in Table 8.3.

Table 8.3 Summary details of the multiple linear regression analyses predicting teacher ratings on selective attention tasks

EF variables	Predictors	B	SE B	β	t	p	Adj. R ²	ΔR^2
Q score								
Model 1	Age	0.013	0.002	0.573	8.050	<0.001*	0.444	-
	Sex ^a	0.022	0.026	0.058	0.840	0.402		
	HAZ	0.015	0.014	0.075	1.078	0.284		
	Setting ^b	-0.088	0.027	-0.230	-3.221	0.002*		
Model 2	Age	0.008	0.002	0.365	4.348	<0.001*	0.511	0.077
	Sex ^a	0.027	0.028	0.071	0.964	0.337		
	HAZ	0.010	0.013	0.049	0.752	0.454		
	Setting ^b	-0.096	0.028	-0.253	-3.472	0.001*		
	Locomotor	0.006	0.002	0.328	3.556	0.001*		
	Object control	0.001	0.003	0.042	0.453	0.652		
	MVPA	<0.001	<0.001	-0.041	-0.610	0.543		

Note: The adjusted R² and change in R² (ΔR^2) are provided for each model as well as the unstandardised beta coefficients (B), standard errors (SE B), standardised beta (β) and significance values for all independent variables and controls. ^a0 = female, 1 = male; ^b0 = Urban, 1 = rural. * p < 0.05. HAZ = height-for-age; MVPA = moderate and vigorous intensity physical activity; Q score = quality of search score.

After accounting for covariates, the overall regression was significant, $F(7,110)=18.458$, and explained 74% of the variance in selective attention with the predictors accounting for an additional 8% ($\Delta R^2=0.08$ after inclusion of MVPA and GMS components). However, of the independent variables, only locomotor skills significantly predicted selective attention ($\beta=0.328$, $p=0.001$), such that children with better locomotor skills also demonstrated better selective attention.

8.3.4 Physical activity, gross motor skills and cognitive school readiness

Finally, multiple linear regression analyses were used to assess the relative contribution of physical activity and GMS as predictors of cognitive school readiness, while controlling for age, sex, HAZ and setting. Total GMS was a significant predictor ($\beta=0.29$, $p<0.001$). Subsequent regressions then assessed the particular contribution of the locomotor and

object control skills to self-regulation. MVPA showed better model fit compared to LMVPA and was therefore included in the regression models. The results are presented in Table 8.4.

Table 8.4 Summary details of the multiple linear regression analyses predicting school readiness

EF variables	Predictors	B	SE B	β	t	p	Adj. R ²	ΔR^2
School readiness								
Model 1	Age	1.043	0.100	0.638	10.415	<0.001*	0.581	-
	Sex ^a	-2.154	1.617	-0.080	-1.333	0.185		
	HAZ	-0.064	0.843	-0.005	-0.076	0.939		
	Setting ^b	-8.403	1.659	-0.311	-5.066	<0.001*		
Model 2	Age	0.750	0.118	0.459	6.377	<0.001*	0.635	0.061
	Sex ^a	-3.124	1.714	-0.116	-1.823	0.071		
	HAZ	-0.354	0.790	-0.025	-0.449	0.655		
	Setting ^b	-10.062	1.685	-0.373	-5.969	<0.001*		
	Locomotor	0.233	0.110	0.168	2.124	0.036*		
	Object control	0.404	0.168	0.191	2.396	0.018*		
	MVPA	-0.042	0.026	-0.094	-1.621	0.108		

Note: The adjusted R² and change in R² (ΔR^2) are provided for each model as well as the unstandardised beta coefficients (B), standard errors (SE B), standardised beta (β) and significance values for all independent variables and controls. ^a0 = female, 1 = male ^b0 = Urban, 1 = rural. * p < 0.05. HAZ = height-for-age; MVPA = moderate and vigorous intensity physical activity.

After accounting for covariates, the overall regression was significant, $F(7,112)=30.538$, and explained 66% of the variance in cognitive school readiness with the predictors accounting for an additional 6% ($\Delta R^2=0.06$ after inclusion of MVPA and GMS components). Of the independent variables, only locomotor ($\beta=0.168$, $p=0.036$) and object control skills ($\beta=0.191$, $p=0.018$) were significantly predicting school readiness, while MVPA showed no significant associations. These results indicated that children with better locomotor and object control skills also had better school readiness.

8.4 Discussion

This chapter sought to investigate relationships between essential components of cognitive development, physical activity and GMS in a cross-sectional sample of preschool children from low-income settings in South Africa. Overall results indicated that certain components of GMS (i.e., locomotor skills for virtually all cognitive outcomes assessed, object control skills for school readiness) and physical activity (i.e., LMVPA negatively) predicted EF, self-regulation, selective attention and school readiness. These patterns suggest that the associations between these physical and cognitive factors are more specific and nuanced, rather than generally and broadly applicable, in contrast to their current treatment in the literature.

8.4.1 Physical activity and cognitive development

Physical activity and executive function

Findings of the association between habitual physical activity and EF in the current study are in partial alignment with available evidence from HICs (Willoughby et al., 2018), that reported negative associations between EF and physical activity. Similarly, the current study found that physical activity was not associated with inhibition or shifting but was negatively associated with working memory. In the current sample, very few structured activities were observed, and instead children spent most of the day in free play (running around, playing with tyres, climbing fixed equipment). As such, a possible explanation for the lack of associations of physical activity with both inhibition and shifting is that unstructured physical activity may not, in and of itself, influence the development of EF. Instead, it has been suggested that *cognitively engaging* physical activity that engages and challenges EFs, such as structured physically active games and team sports, may be necessary to influence EF. As such, it is expected that relationships between EF and physical activity would be more likely for these types of physical activity (Diamond, 2012; Diamond & Ling, 2016).

Alternative explanations for the negative relationship between physical activity and working memory are suggested by Willoughby et al. (2018): that unmeasured hyperactivity-impulsive behaviours may have confounded this association, as children who exhibit these behaviours may also be characterised by executive dysfunction (Schoemaker, Bunte, Espy, Deković, &

Matthys, 2014) and/or may not be able to engage in EF-promoting activities in class (Howie, Brown, Dowda, McIver, & Pate, 2013). While possible, if this was the case an association with inhibition would also, or perhaps even more so, be expected.

It is notable that the physical activity levels were very high ($M_{\text{total}} = 454.21$ minutes per day) in the current study. As such, another possible explanation is that children were spending time in unstructured physical activity in place of time that can be spent on classroom activities that better support the development of EF (for example, see Tools of the Mind; Bodrova & Leong, 2007). Alternatively, it may be that the association between physical activity and EF is non-linear, such that its effects plateau after a certain level of activity. Again, however, that this pattern of results has been found even at lower levels of physical activity suggests it is more likely a case of *what* is being done during physical activity, than *how much* physical activity is being done. It is again unclear, however, why these effects should exclusively impact upon working memory. It is possible that there are other factors that buffer inhibition and shifting abilities. Perhaps time spent in unstructured free play still somewhat engages inhibition and shifting abilities, but not working memory. Instead, the high levels of physical activity might be taking time away from other activities that would engage and develop working memory skills more robustly, such as more sedentary, classroom based activities.

Physical activity and self-regulation

Unlike the other components of cognitive development, self-regulation showed better model fit with LMVPA (total physical activity) compared to MVPA. This is possibly because teachers often associate self-regulation with behavioural control and behaviour problems with behaviour. In a classroom setting, things like fidgeting or the inability to sit still (activities that might contribute to LPA) would often be seen as poor behavioural control and interpreted as low self-regulation. For that reason, teachers may be rating those children who are less still (even if that activity doesn't reach the level of MPA or VPA) as less regulated.

The results from the current study suggest that teacher-rated self-regulation was lower in children who were more active (at any intensity). As with EF, the evidence for this relationship is mixed. For example, one study found that preschool children who were more active in recess displayed better performance on a self-regulation task (Becker, McClelland, et al.,

2014). Another study in preschool children reported that in general, engaging in more MVPA in a day was not associated with self-regulation, but a small but negative association was found between MVPA and emotional self-regulation (Ludwig & Rauch, 2018). While the two studies above seem to contradict each other, there are important distinctions between them, such as the way in which self-regulation was measured and the time frame of physical activity measurement. In the first study, self-regulation was measured using a performance-based task (Head-Toes-Knees-Shoulders; Ponitz, McClelland, Matthews, & Morrison, 2009) and physical activity was only assessed during recess. In the second study, self-regulation was measured using parent-ratings, and physical activity accumulated throughout the day (habitual physical activity) was taken into account (Ludwig & Rauch, 2018).

Results from the current study align better with the second study, as both relied on subjective ratings rather than performance-based measures, and looked at habitual physical activity rather than an acute bout of physical activity. Moreover, a lack of association between physical activity and self-regulation has been found in other studies that assessed physical activity accumulated throughout the day (El Nokali, 2004; Schmutz et al., 2017). Taken together, it appears that when physical activity is measured throughout the day, it becomes difficult to find a direct positive association with self-regulation and it may be more susceptible to confounding factors that could lead to negative associations (Ludwig & Rauch, 2018). For example, a potential confounding factor is the effect that unmeasured hyperactivity-impulsive behaviours may have on physical activity levels. This effect may be even more pertinent when it comes to teacher ratings. This is because teachers often consider the inability 'sit still' (fidgeting, rocking on their chair, wanting to stand up or walk around, etc.) as an indication of poor self-regulatory abilities which could indeed be the case. Once again, this highlights the potential limitations (teacher bias) of teacher-report measures of self-regulating highlighted in previous chapters.

Physical activity and selective attention

Results for selective attention were similar to those of EF (specifically inhibition and shifting). This was expected considering that the results from Chapter 5 revealed strong links between selective attention and EF in this sample. Therefore, explanations for the non-association between EF and physical activity are applicable to selective attention as well. For example:

much of the physical activity was unstructured and lacked cognitive challenge, and for this reason may not have had an effect on cognition; children were spending substantial time engaging in physical activity, which possibly replaced time that otherwise would be spent on classroom activities that support cognitive development; and/or, the beneficial effects of physical activity for cognition may plateau after a certain amount of physical activity.

These results similarly contrast much of the literature that has shown a beneficial effect of physical activity on attention, however (de Sousa, Medeiros, Del Rosso, Stults-Kolehmainen, & Boullosa, 2018). Specifically, much of the previous research has shown that an acute bout of physical activity leads to enhanced attention performance. While the majority of studies that have found this are in older children (Drollette et al., 2014; Drollette, Shishido, Pontifex, & Hillman, 2012; Hillman et al., 2009) and adults (Sanabria et al., 2011; Sibley, Etnier, & Le Masurier, 2006), there has been one study with preschool-aged children (Palmer et al., 2013). That study found that an acute bout of physical activity improved selective attention capacity immediately after the activity. Important to note however, is that the acute bout of physical activity was structured, instructor-led and had a focus on improving motor skills. Therefore, there was increased expectation and impetus for children to be cognitively engaged and sustain attention during the physical activity session (Palmer et al., 2013). Since the current study investigated cross-sectional associations between habitual physical activity accumulated daily and selective attention performance, rather than the immediate effects of physical activity on attention, it may be that physical activity has the potential to improve attention capacity, but effects might be short-lived, and therefore not captured in the current study.

Physical activity and school readiness

School readiness was not associated with physical activity in the current sample, as was the case for EF (inhibition and shifting) and selective attention. While similar explanations for non-associations with physical activity can apply to EF and selective attention, they may not apply as uniformly to school readiness. This is because performance on school readiness tasks is dependent on the academic skills or knowledge that are normally taught to the child in an educational environment, through interactions with teachers, parents or caregivers. For example, a child is unlikely to learn basic counting skills unless intentionally and explicitly

embedded in teaching and learning activities. In comparison, EF and selective attention are cognitive capacities that are effectively content-free, and can be developed and promoted outside of an educational environment (e.g. Rybanska, Mckay, Jong, & Whitehouse, 2017). Therefore, the mechanisms through which physical activity may have an effect likely differ for these developmental outcomes (e.g., EF and attention may mediate any effects of physical activity on learning).

That is, considering the relationship between these underlying capacities and school readiness (Becker, McClelland, et al., 2014; Becker, Miao, et al., 2014; Blair, 2002; Pellicano et al., 2017), it is possible that physical activity could have an indirect effect on school readiness through its effects these underlying capacities. In fact, in the majority of research, beneficial effects of physical activity on school readiness and academic performance are mediated by other cognitive capacities that support learning, such as EF, self-regulation and attention (Donnelly et al., 2016; Howie, Schatz, & Pate, 2015). Physical activity has also been known to exert indirect effects on school readiness through its influence on motor skills (Becker, Miao, et al., 2014; Oja & Jurimae, 2002).

8.4.2 Gross motor skills and cognitive development

Gross motor skills and executive function

This study also examined relationships between GMS and early EFs. This is of interest given that motor skills have been found to be related to EF in previous research (Aadland et al., 2017; van der Fels et al., 2015), and that GMS are necessary for physical activity that involves complex movements (which has similarly been associated with EF; Chang, Tsai, Chen, & Hung, 2013). For instance, a recent study in preschool children showed that GMS had a greater association with EFs than did fine motor skills (Oberer, Gashaj, & Roebbers, 2018), suggesting that, in this age group, GMS and EFs may be somehow interrelated.

Results from this study showed that total GMS were significantly and positively related to both inhibition and working memory, but not shifting. These results extend the findings from other contexts (mostly HICs or WEIRD) to the South African context (LMIC and non-WEIRD), that there are positive associations between aspects of EF and GMS (Houwen, van der Veer,

Visser, & Cantell, 2017; Rigoli, Piek, Kane, & Oosterlaan, 2012). Evidence from neuroimaging studies provides further support for this relationship, in the form of their co-activation during task performance (Diamond, 2000). The null association with shifting may be explained by how GMS are operationalized in the TGMD-2 assessment, which might invoke inhibition and working memory, but does not place high demands on shifting. For example, in the TGMD-2, children are required to observe the demonstration of a skill (e.g. overhand ball throw), and then perform the skill themselves as accurately as possible. This would require inhibition control to ignore distractions and focus on the demonstration of the skill, and when performing the skill, inhibition would be required to avoid performing the skill in a way that comes naturally to them, (e.g. underhand throw), and instead perform the skill based on the demonstration (i.e., overhand throw). Working memory may also be required to keep the demonstration of the skill in mind before performing it themselves. However, shifting ability may not be necessary to perform well in this assessment.

Rather than a global association of GMS with EF, however, this result seemed to be largely driven by locomotor (and not object control) skills. Investigating the specific relationships between components of EF and gross motor skill dimensions – locomotor and object control – with EF speaks to a recent review indicating different patterns of association between component motor skills and higher-order cognitive skills, rather than a global link between motor and cognitive skills (van der Fels et al., 2015). Previous studies that have looked at distinct components of motor development have been inconsistent in the types of motor skills measured (Wassenberg et al., 2016) and, as such, very few conclusions have been drawn. The use of the TGMD-2 to assess GMS provided some insight into these associations: inhibition was associated with both locomotor skills and object control skills, whereas working memory was only associated with locomotor skills. Indeed, inhibition would be important to sustain focus and resist distraction during non-automated motor activities. Yet working memory appeared to be uniquely associated with locomotor skills, perhaps related to the memory demand of complex locomotor activities (such as those required in the TGMD-2). For instance, locomotor skills, such as the gallop and slide, require coordination demands (i.e., concurrent body movements, movement sequences) thereby placing a greater demand the activation and sequencing of this information in working memory (Alesi et al., 2016).

In fact, locomotor skills are central to many of types of physical activity that have been found to have an effect on EF, such as yoga (Gothe et al., 2013) and martial arts (Lakes & Hoyt, 2004). Yet the same level of working memory demand may not be inherent in object control skills such as catching a ball. This suggests that locomotor movement might be a characteristic of physical activity that has a positive effect on EF, perhaps due to its higher level of EF challenge. However, more research is needed understand how these different components of GMS relate to EF and cognitive development more broadly.

However, further studies are needed to identify plausible mechanisms that contribute to development in both of these areas. Also unknown is the direction of this motor-cognition link. The current study presents cross-sectional associations and therefore it is unclear as to whether better EF skills contributes to better GMS (e.g., better ability to mentally maintain and execute motor sequences), better GMS contributes to better EF (e.g., invokes cognitive challenge that promotes EF development), are mutually influential, or are both influenced by an unmeasured third factor (e.g., motivation, interest). Piaget (Piaget & Cook, 1953) suggests that better motor skills can promote cognitive development, as motor skills allow children to explore and learn from their environment. On the other hand, children with better EF (or cognitive development in general) may be better able to observe and learn motor skills. It could also be that these domains of development are reciprocal or show co-development. However, additional research is needed to investigate the nature and direction of this relationship.

Gross motor skills and self-regulation

The results from the current study suggest that children who had better locomotor skills also had higher teacher-ratings of self-regulation. Once again, there were no associations with object control skills. This provides partial support for the motor-cognition link mentioned earlier, extending this to self-regulation as well. Studies looking specifically at the relationship between GMS and self-regulation are limited. This is because the terms self-regulation and EF are often used inter-changeably, such that when studies use the term self-regulation, they are often measuring components of EF. For this reason, there is limited evidence regarding the specific relationship between GMS and self-regulation, as distinct from (or in relation to) its related abilities.

Although very few studies have examined longitudinal associations between self-regulation and GMS, one study has examined the predictive associations between self-regulation and sports participation (Howard et al., 2018). This study found significant, bidirectional associations; more specifically, that children with better self-regulation were more likely to participate in sports, and that children who participated in individual sports at a young age demonstrated slightly better self-regulation later on (Howard et al., 2018). While the cross-sectional associations in the current study limit such directional interpretations, it is possible that similar bidirectional associations occur in the current sample. For example, children with better self-regulation might have been more likely to have the desire (motivation and goal setting) to engage with new motor skills, and the perseverance to master them. On the other hand, it could be that the process of learning and practicing GMS might have fostered improved self-regulation skills, or that children with good GMS are less likely to experience frustration that could lead to behavioural problems and social difficulties (Pagani & Messier, 2012). Further research is required to investigate the directionality of these associations.

Gross motor skills and selective attention

The results for selective attention were similar to those for EF, with locomotor skills being positively associated, while object control showed no associations. Considering the results from Chapter 5—indicating the close relations between EF and attention—explanations for these associations are similar to those for EF and selective attention. Specifically, that positive relations between GMS and cognitive development (including selective attention) may relate to their co-activation of the same areas of the brain (Diamond, 2000). Exactly why this co-activation occurs and its implications for development, however, remain unclear.

At a cross-sectional behavioural level, as with EF, the nature of GMS assessment may explain some of the association between locomotor skills and selective attention. In other words, selective attention abilities may have been necessary to correctly observe and perform the locomotor skills as they were demonstrated during the GMS assessment. Selective attention demands may have been greater during the locomotor skills as they generally took longer to perform and involved repetitive movements. For example, the run, gallop, hop and slide had to be performed over a distance of around seven meters. With the slide in particular, children

often started out with the correct technique, but anecdotally lost the technique as their focus of attention was lost, resulting in a lower score. Therefore, children who were better able to attend to the relevant stimuli (the tester), and ignore distractions/irrelevant stimuli, may have performed the skills more proficiently resulting in better scores. In comparison, object control skills in the GMS assessment generally involved a single action (e.g. catching a ball, rolling a ball, striking a ball, etc.), rather than a complex sequence or repetitive action. For this reason, performance on object control skills may not have required the same degree of attentional capacity, and therefore was not related to selective attention performance.

Gross motor skills and school readiness

The finding that school readiness is not only associated with locomotor skills (as with the other cognitive components), but also with object control skills, suggests that a wide range of GMS are important for school readiness. Indeed, some school readiness task requirements (in parallel to classroom learning tasks) rely on spatial awareness and directionality, skills that are also necessary for GMS. For example, the direction similarities task asks children to identify one picture out of four that has an object facing the opposite direction to the other three, requiring directionality and spatial awareness. Object control requires also requires directionality and spatial awareness, for example, in the catching skill, a child needs to be aware of where their hands are in space, as well as where the ball is in space. Therefore, children with better developed spatial awareness and directionality are likely to score better on both GMS and school readiness tasks.

8.5 Conclusion

These results emphasise the complex relationship between physical activity and cognition. Specifically, physical activity appears was not linearly and unconditionally associated with EF, supporting suggestions that type and context of physical activity (e.g., structured activities, complex skills, etc.) are important considerations for this association and extends this finding to a South African (LMIC) sample. More specifically, this study showed that when physical activity levels are high, and largely consist of unstructured free play, associations with cognitive development are largely null. Further, under these conditions of extremely high

levels of physical activity, there is the possibility of negative associations (as found with working memory and self-regulation) suggesting that time spent in physical activity might take away from other activities that could promote other aspects of cognitive development.

This study also contributes to the international evidence linking gross motor and cognitive skills in preschool children. Indeed, Cameron et al. (2016) suggest a co-development in these domains, in saying: “Motor skills are not only the movement themselves, but include the cognitive processes that give rise to the movements” (Cameron et al., 2016, p. 2). However, this study uniquely found that the association of GMS with aspects of cognitive development was largely driven by an association with locomotor skills. This highlights locomotor skills as a viable candidate for further research into the characteristics of physical activity that successfully promote components of cognitive development. Further research with larger samples and designs that permit causal conclusions is needed to determine the consistency, direction and underlying mechanisms of these relationships in these novel settings, before interventions based on evidence from HICs or WEIRD settings are unconditionally applied to unique LMIC/non-WEIRD settings.

CHAPTER 9: CONCLUSION

9.1. Summary of findings

In its investigation of the levels and associations amongst physical and cognitive development in the early years in South Africa, the current study provided some support for robust findings from HICs (e.g., associations of EFs with school readiness; association of physical activity and GMS), but also provides unique findings and insights regarding LMIC contexts (e.g., high levels of physical activity and EFs; general lack of association between habitual physical activity and EF – and, where present, this association is negative).

Amongst its unique findings, which is distinct from evidence in HICs, this sample appeared to have strong cognitive capacities, wherein EF scores outpaced those reported in even high-income areas of HICs (Howard & Melhuish, 2017). This contrasts the implicit expectation from evidence of an EF-SES gradient—such that EFs increase along a gradient of increasing SES—that suggests performance in this should be poor (Hackman et al., 2015). It is likely these findings are genuine, as high performance on these tasks requires not only attention and compliance, but also sufficient EF capacity. Given that EFs have been implicated as essential for learning (Hughes & Ensor, 2011; Ribner et al., 2017), this suggests that children in the current sample have a good foundation upon which learning and development can take place. It might thus be expected that these children would also have good school readiness and a successful academic trajectory (Fuhs, Nesbitt, Farran, & Dong, 2014; Willoughby, Kupersmidt, & Voegler-Lee, 2012). Yet, this did not appear to be the case. Instead, this sample displayed relatively low school readiness skills. This is consistent with research that has shown children from low-income settings in South Africa do not experience academic success (Pretorius & Naudé, 2002; Spaul & Kotze, 2015). While the exact reason for the low levels of school readiness cannot be identified from this research (e.g., the need for different/additional content, effective pedagogical approaches, home learning experiences), these results do suggest that this is not related to insufficient processing and learning (EF) capacity. Indeed, these children appear particularly well-equipped in this regard.

In relation to the associations between aspects of physical and cognitive development, results replicated the often-found associations for EF, attention and, to a lesser extent, self-regulation (with self-regulation associations potentially influenced by the measurement approach). This research also replicated the strong association between EF and school readiness. These cross-sectional (current study) and predictive (previous studies; Hughes, Ensor, Wilson, & Graham, 2010) associations between EF and academic readiness/achievement, has led researchers in HICs to suggest that interventions that improve EF may be a viable means to promote school readiness (Ursache et al., 2012). However, the current findings, which indicate strong cognitive capacities in these contexts, suggest a different approach may be needed to promote school readiness in these settings (e.g. further enriching the early home and pre-school learning environment; placing further emphasis on content for pre-academic skills, such as literacy and numeracy).

Similarly, physical activity interventions have been suggested as a means to promote both cognitive and physical health outcomes in HICs. Yet, results from the current study suggest that this may not be appropriate in LMICs given that children are already engaging in high levels of physical activity (and have a high level of EF). Further, the double-burden of both over- and undernutrition, as illustrated in the current sample and in nationally representative samples (Shisana et al., 2013), highlights the inappropriateness of interventions that merely increase the volume of physical activity in settings where undernutrition is present. Where physical activity *is* used as a vehicle to promote physical and cognitive outcomes, the current results suggest that interventions targeted toward particular types of physical activity (i.e., complex movement sequences such as locomotor skills) may be more effective than general approaches (e.g., increasing the volume of physical activity).

Nevertheless, taken together, the current results suggests that the mechanisms underlying cognitive development are consistent with those found in HIC contexts (e.g., domain-general cognitive capacities that permit attentional resources being directed toward learning, which can be impacted by physical factors). However, the needs of – and thus approaches to support – children in these contexts likely differ.

9.2 Implications and recommendations

9.2.1 The importance of non-WEIRD, LMIC evidence

The evidence emerging from this study suggests additional research is necessary to better understand how LMICs differ from HICs and other Western, educated industrialised, rich and democratic (WEIRD) contexts. Indeed, this has been highlighted in psychology research, with researchers cautioning against the generalisation of findings (Azar, 2010; Kessi & Kiguwa, 2015). For example, Lindsay (1995) wrote: “The challenge is to take account of the gains that we have made in contextualizing human behavior, for example the need to beware of the dangers of generalizing from a Euro-American, white, male experience and perspective, while retaining the scientific rigour which has set psychology apart from many other disciplines” (p. 495). This implies that similar caution should be taken before uniformly applying findings from HICs or WEIRD settings to LMICs, and highlights the need for research in these understudied contexts.

The results from the current study support this assertion. For example, the predictive power of socioeconomic status (SES) on multiple aspects of child development and achievement is widely accepted, so much so that SES is often used as a control variable in studies on child development and achievement. While there is strong evidence indicating this (Hackman, Farah, & Meaney, 2010), much of this evidence is derived from HICs or WEIRD settings. However, results from the current study suggest that effects of SES on cognitive development may not apply uniformly across different contexts. Instead, as suggested in Chapter 4, there may be factors within LMIC settings that might promote or protect cognitive development. Cross-cultural studies have provided some support for this, with children from LMICs showing better performance on tests of cognitive development compared to children from HICs (Gonen et al., 2018; Sabbagh et al., 2006). While some research has begun to investigate the factors that might promote cognitive abilities in LMICs or non-WEIRD settings (Rybanska et al., 2017), more research needs to be done to further explicate and test these assumptions. This is not only important to better understand cognitive development in LMICs, but also because these findings may inform activities and interventions that improve cognitive development in HICs as well (e.g., identify low-cost environments and experiences in LMICs that protect and/or promote EFs).

9.2.2 Uncovering potential for later learning, development and health

The results from this study also revealed the cognitive and physical capacities of South African preschool children.

Learning and development

As mentioned earlier, the strong cognitive abilities of this sample imply a good foundation for learning. Yet, the discrepancy between high cognitive abilities and poor school readiness skills in this sample suggests a missing ingredient, and potentially the need for different approaches to improving school readiness compared to HICs (where these are increasing focus on fostering the domain-general underpinnings of learning, such as EFs; (Ursache et al., 2012). A potential explanation for the disparity between EFs and school readiness in the current sample may be understood by the methods required to improve or develop these skills. While cognitive abilities can be fostered in multiple different ways (e.g. music, rituals, yoga; Alemán et al., 2017; Gothe, Pontifex, Hillman, & McAuley, 2013; Rybanska et al., 2017), academic knowledge and skill are heavily dependent on the content, structure, sequence and quality of educational experience provided (Weiland, Ulvestad, Sachs, & Yoshikawa, 2013). In other words, a child may have the potential to excel academically, but if the knowledge and skills requisite for academic success are not promoted, this potential is unlikely to be realised.

This, along with current state of early childhood development (ECD) in South Africa, suggests the poor quality of early learning environments as an essential but missing ingredient. Even though there has been great progress in ECD provisions in South Africa over the last two decades, with the implementation of a universal reception year (or Grade R; Department of Education, 2001), concerns around the quality of ECD programmes remain (Richter & Samuels, 2018). The barriers and challenges that contribute to this lack quality in South Africa were highlighted by Richter and Samuels (2018, p. 12) as: “low levels of funding; inadequate training, supervision and retention of Grade R teachers; insufficient learner support materials; and inadequate monitoring and quality assurance.” Further, provision of early childhood care and education (ECCE) for children under 5 years-old remains poor, with only 35% of children reported as attending any form of ECCE service (Statistics South Africa, 2015). Even for

children who do attend ECCE services, quality is of concern, particularly in the poorest areas. This is illustrated by findings of a relationship between programme quality and level of deprivation within the surrounding community (Biersteker, Dawes, Hendricks, & Tredoux, 2016). This study also found that, overall, centres lacked provision for stimulation and language, had inadequate space and furnishings (e.g. overcrowded classrooms, no outdoor play area), poor adherence to personal care and hygiene routines, poor adherence to a program structure, poor provision for parents, and poor provision for personal and professional needs of the staff (Biersteker et al., 2016). The study found that 60% of centre managers had completed secondary school and 43% had not received any training in ECCE. Similarly, ECCE teachers (or ECD practitioners), many of whom were volunteers (e.g., grandmothers) from the community, were likely to have low levels of education and minimal ECCE training (Biersteker & Motala, 2008). Together, this suggests that poor quality preschool education may be contributing to these low levels of school readiness, especially for children in low-income LMIC settings.

The South African Government has recognised the need to improve the ECD sector, with the South African National Integrated Early Childhood Development Policy being approved in 2015 (Republic of South Africa, 2015). This policy acknowledged the need for enrolment in and quality of ECD programmes to improve by increasing government support and finances. In light of this, recommendations should be made to government as to the different aspects of ECD provision that should be made a high priority. Researchers have begun to list these recommendations to improve the quality of ECD and ECCE services (Albino & Berry, 2013; Biersteker, 2012; Biersteker et al., 2016; Biersteker & Motala, 2008; Desmond et al., 2019). Among others, these include: increasing financial resources directed at ECD (e.g. increase teacher salaries, provide access to better facilities and educational resources, provide free ECCE services); improve training of current ECD teachers according to a set of standards and improve the status of the profession to include career progression; equip teachers with strategies to deal with overcrowded classrooms and limited resources; and to incorporate interventions to improve the management and administration of ECCE centres. In addition to these recommendations, the results from the current study suggest that emphasis may be better placed on specific pre-academic knowledge and skills (rather than the increasing focus

on domain-general capacities such as EF and self-regulation, or increasing levels of physical activity, as are common in HICs).

These findings notwithstanding, further research is needed to evaluate whether these high levels of cognitive ability (EF, self-regulation, attention) can facilitate more effective learning and school readiness under the right conditions (e.g., high quality early learning experiences). Although the current study was not set out to test this, results did reveal a positive association between EF and school readiness, suggesting that high EF skills could contribute to children's school readiness. An example of how EF and other cognitive abilities can be leveraged to improve school readiness can be seen in the Tools of the Mind curriculum (Bodrova & Leong, 2007). This curriculum places specific emphasis on activities and teaching styles that promote EF, as it is considered the primary mechanism behind academic achievement and social-emotional development (Blair & Raver, 2014).

Implementing a programme as comprehensive as Tools of the Mind on a large scale would be difficult in low-income settings in South Africa, as it would require intensive teacher training and access to specific curricula and resources that are not readily available in these settings. Further, where that curriculum focuses on fostering EF by embedding it within curricular and academic activities (e.g., literacy, numeracy), there is the potential for transforming this to leverage EFs to foster academic content. For example, Tools of the Mind teaches foundational academic skills such as literacy and numeracy, using intentional fantasy play that requires EF and self-regulatory skills. Using (instead of fostering) children's already strong EF capacities in these contexts may provide interesting chances to inject play with essential pre-academic skills (e.g., in running a shop, being able to understand and match digits, numbers and quantities to reconcile stock and payments). Other components that could be leveraged are: varying classroom organisation to promote learning and interactions in small groups; training and supporting teachers to embed foundational academic skills in simple games and activities that children are already playing (e.g., hop scotch to teach basic numeracy skills, the learning of which would be supported by already-high levels of memory, being able to take turns, and encouragement of peers).

Another feasible approach in these settings might be to capitalise on the already high quantity of physical activity of children in these settings, by using physical activity as a vehicle to improve pre-academic skills. This could be achieved by introducing structured physical activity in place of unstructured, free play that currently makes up the majority of time spent in physical activity in these contexts (Tomaz, 2018). Like the hop-scotch example above, teachers could be encouraged to facilitate more structured physical activities that can promote foundational academic skills, and potentially also domain-general learning capacities. Examples of how physical activity can be used as a vehicle to promote learning can be seen in the literature. For example, the integration of gross motor movements into a mathematics class for preadolescent children resulted in greater improvement of mathematics ability compared to the integration of fine motor movements (Beck et al., 2016). Similarly, a study with preschool children found that integrating task-relevant physical activity in the classroom had beneficial effects on children's numeracy skills (Mavilidi, Okely, Chandler, Louise Domazet, & Paas, 2018). However, this type of approach may only be appropriate in settings where physical activity levels can be safely increased, such as in the case of normal weight, overweight or obese children.

Health

Research has shown that children who are more active in early childhood are more likely to remain active throughout childhood and into adulthood (Telama, 2009). Similarly, good gross motor proficiency in the preschool years has been associated with increased levels of physical activity and sports participation later on (Barnett, Lai, et al., 2016; Robinson et al., 2015). Both of these contribute to better health outcomes later in life, such as healthy body weight, lower risk of cardiometabolic diseases (e.g., diabetes, hypertension; Carson et al., 2017; Ekelund et al., 2012; Hills, King, & Armstrong, 2007; Skrede et al., 2017). Therefore, high levels of physical activity and good gross motor proficiency found in this study, and previous studies in similar settings, suggests that as these children develop they are, on average, likely to maintain this healthy body weight and have a lower risk of developing cardiometabolic diseases. Although there is not longitudinal evidence to determine whether these health behaviours track into later childhood, adolescence and adulthood, current evidence in South Africa suggests that it may not be so simple. South Africa has a high prevalence of overweight and obesity in children (Shisana et al., 2013) and adults (Statistics South Africa, 2017), as well as high levels of

cardiometabolic diseases (e.g. hypertension; Berry et al., 2017; Ntuli, Maimela, Alberts, Choma, & Dikotope, 2015 and diabetes; Stokes et al., 2017).

Therefore, the current evidence suggests a need for strategies focused on sustaining these positive early health behaviours. Strategies proposed to sustain levels of early physical activity (Tonge, Jones, & Okely, 2016) and gross motor proficiency (Barnett, Lai, et al., 2016) from HICs include providing children with access to safe and supervised spaces to be active, safe play equipment (indoor and outdoor), physically active parents/caregivers, and instructors to facilitate structured physical activity and teach accurate motor skills. Yet, these strategies are not always possible in low-income settings in South Africa as there is limited access to play equipment, sports grounds and sports equipment. Additionally, the high levels of crime and violence in many low-income settings limits access to playgrounds or sports fields even more as they are unsafe for young children. Further, as illustrated by the cognitive results of this study, it should not be presumed that effects will unconditionally transfer from HIC studies to LMIC contexts.

On the other hand, school settings can provide an opportunity for children and adolescents to be active in a safe, structured space and to learn about the different aspects of living a healthy lifestyle (physical activity, diet, hygiene, etc.) For example, in the South African school curriculum the subjects '*Life Skills*' (grade R to 6) and '*Life Orientation*' (Grade 7-12) cover aspects of a healthy life, including physical activity and eating habits (Department of Basic Education Republic of South Africa, 2011). According to the curriculum, these subjects incorporate physical education lessons in which children are meant to be exposed to different skills and sports, and taught the importance of physical activity for their health. However, the hours dedicated to physical education are currently minimal, and actually decrease over the school years (e.g. 60 hours per year in the earlier grades, dropping to 28 hours per year in grade 12). Moreover, physical education in South African schools has been deprioritised, a trend that has been seen across the globe (Pühse & Gerber, 2005). Reconciling the current results with evidence of the likely health trajectories of these children suggests that this is the reverse direction to what is needed.

Barriers to the implementation of physical education across high- and low-income settings in South Africa include insufficient training for teachers on physical education, the low priority of the subject and limited time allocated to it (subjects considered higher priority would take its place when necessary), a shortage of equipment and facilities (e.g. sports grounds, sports equipment), and practical issues such as large, overcrowded classrooms and culturally diverse learners (Du Toit, Van der Merwe, & Rossouw, 2007). Following suggestions from Du Toit and colleagues (2007), efforts should be made to provide appropriate training for teachers regarding physical and health education, including practical didactics of conducting physical and health education lessons. Practical training should also include equipping teachers with the skills to be able to determine and accommodate the needs of children from different backgrounds and cultures in the same class, and be able to improvise and devise strategies to work with limited space and equipment when conducting these lessons. To support this, recommendations should be made to policy-makers to increase the priority of physical and health education in Life Skills and Life Orientation subjects and increase the financial support of these subjects, to facilitate teacher training and provision of facilities and equipment.

9.3 Strengths and limitations

The methodology followed in the current study presents both strengths and limitations. A strength of the research is that it was conducted in both urban and a rural settings, providing insight into unique and potentially divergent contexts. However, given that South Africa is comprised of many types of low-income environments, results cannot be generalised to all low-income settings. Additionally, both urban and rural groups consisted of a convenience sample, further limiting generalisability of the findings to South African preschool children more widely. The sample size was influenced by logistical factors such as time, funding and contextual constraints. For example, in the rural setting, preschools (where data collection was taking place) were forced to close over four testing days due to protests in the village that affected the safety of the children. Furthermore, regarding the study design, the cross-sectional design presented some limitations as it precluded any analysis of directions of effects and did not control for stable individual differences.

Furthermore, this study was limited by the lack of specific SES indicators, as the settings in South Africa were classified as low-income at a community level, rather than at a household level. Household-level SES indicators could have given more insight into the levels and aspects of poverty that might have a particular effect on cognitive development in each setting (either detrimental or protective), and should be included in future studies.

A strength of the study is that it is one of the first to assess executive function objectively (and first to use the Early Years Toolbox) with South African preschool children, thereby providing preliminary viability and validity evidence to support their appropriateness in these contexts. Indeed, the data derived from EYT did not appear to be plagued by issues that are often found with many other measures (e.g., floor effects, low correlations between tasks). At the same time, it was able to address pragmatic limitations that were a particular concern with young children in LMICs (e.g., lack of electricity, lack of access to wi-fi in field, mobility, low costs, not introducing effects of technological expertise, literacy and numeracy demands minimised; Howard & Melhuish, 2017). However, the absence of South African EYT norms for this sample is a limitation of the study, and therefore no conclusions can be made about the participants' relative and contextual performances on these measures. Similarly, as this is the first study to assess selective attention and self-regulation using these measures with preschool children in South Africa, there are no South African norms. Nevertheless, the results provide evidence for the appropriateness of these assessment tools and the feasibility of using these tools in LMIC early years settings.

The use of the TGMD-2 to measure GMS and accelerometers to measure physical activity also contribute to the strength of the study. They are widely used measures, enabling comparison between countries. Specifically, the wide use of TGMD-2 was advantageous to compare with the evidence showing, for example, that process orientated measures of gross motor skills (e.g., how the ball is thrown) are more strongly related to EFs than outcome-orientated measures (e.g., how far the ball was thrown; Wassenberg et al., 2016). Additionally, the TGMD-2 assesses performance in two subtests: locomotor and object control. This allowed insight into specific relationships of these two subtests of GMS with cognitive development. However, there are no established South African norms for the TGMD-2 and, as a result, United States norms had to be used for norm comparison and classification (Ulrich, 2000).

While this limits contextual interpretation, it provides opportunity for comparison with studies in HICs (Scotland; Johnstone, Hughes, Janssen, & Reilly, 2017, Italy; Cristina, Panebianco, Polman, & Stagni, 2017, Australia; Barnett, Salmon, & Hesketh, 2016, Singapore; Mukherjee, Ching, Jamie, & Fong, 2017, Japan; Aye et al., 2018) and LMICs (Myanmar; Aye, Oo, Khin, Kuramoto-Ahuja, & Maruyama, 2017, Brazil; Valentini, Rudisill, Bandeira, & Hastie, 2018), all of which have deemed the United States norms (Ulrich, 2000) as valid and reliable for use in each diverse context.

Accelerometers are currently considered to be the preferred method to assess free-living physical activity in preschool children (Butte, Ekelund, & Westerterp, 2012). Furthermore, the children participating in this study demonstrated excellent compliance with wearing the accelerometers, contributing to the quality of the physical activity data. However, because the context of physical activity (types, cognitive demands, etc.) may influence whether or how physical activity relates to EF (Adele Diamond, 2015), the current study is limited in that it was only able to consider amounts and intensities of physical activity undertaken by the participants. As such, higher levels of certain types of physical activity may show differential associations with components of cognitive development, rather than simply physical activity per se.

The omission of fine motor skills (FMS) as a predictor is also a limitation, considering evidence linking FMS to school readiness and cognitive achievement (Pagani & Messier, 2012). Yet GMS were privileged over FMS based on their associations with physical activity, and a previous study in South Africa showing school readiness can be improved through a GMS intervention (Draper et al., 2012). Including a separate FMS would have increased participant burden and study demands, and thus limit the sample size further due to time constraints and available resources. Additionally, verbal ability was not measured in the current study, and considering the wide age-range, may have limited the ability to interpret components of cognition. However, in South Africa there are many issues surrounding a valid and reliable tool to measure verbal ability given that there are 11 official languages and very few children in the current study sites were able to speak English at this age. Therefore, including a measure of verbal ability would present additional challenges and limitations to findings and interpretations.

9.4 Future research directions

This study highlighted multiple areas for future research. Firstly, future research should aim to address some of the limitations of the current study. For example, future studies should focus on the context of physical activity, and the effects of certain types of physical activity on cognitive development, rather than simply measuring habitual/ free living physical activity. Studies should also consider including a measure of fine motor skills when investigating associations with school readiness and its underlying capacities. This could potentially provide a more complete picture of physical and cognitive development in preschool children in these settings.

Given that the statistics, interpretation and generalisability of the findings in the current study were limited by sample size and diversity, future research should aim to study larger, more diverse samples. For example, future studies could consider a variety of urban and rural settings across different geographical locations in South Africa. This is important given the diversity in South Africa and that context, needs and challenges differ not only between urban and rural contexts, but within different urban and rural settings as well.

Larger samples should also include children from a range of income settings in South Africa, and include comprehensive measures of community and individual SES to determine whether and how different aspects of SES might relate to cognitive development. As mentioned, SES is a complex construct and the SES gradient of EF (and related abilities) may not uniformly apply to all settings. Therefore, future research should aim to identify the conditions that may impact, either positively or negatively, on early development. While factors associated with low SES, such as poor quality education and limited access to resources, has shown a negative effect on children's cognitive development and academic achievement, other factors such as the effect of stressful life events (e.g. violence, loss of a family member, conflict, etc.; Blair & Raver, 2016) also warrants investigation in these settings.

Larger samples would also provide an opportunity to develop normative scores on measures that do not yet have benchmarks for South Africa, such as the Early Years Toolbox, the visual search task and the TGMD-2. A handful of studies have successfully adapted Western

measures of cognitive development to be contextually appropriate for their relative settings (Holding et al., 2018; Nampijja et al., 2010; Selvam et al., 2018; Willoughby et al., 2019); however, only one has developed local norms (Selvam et al., 2018). Future research should aim to develop local normative data, rather than relying on norms from HICs / WEIRD settings to contextualise and interpret findings. Considering the measures used to assess cognitive ability (EYT and visual search task) were found to be appropriate for these settings, particular efforts should be made to develop local norms for these measures.

The results from this study also revealed the need for longitudinal research to determine the consistency, direction and underlying mechanisms of the relationships between physical and cognitive development in these novel settings, before interventions based on evidence from HICs or WEIRD settings are unconditionally adopted. Specifically, longitudinal research would be necessary to more conclusively determine associations between EF, self-regulation and school readiness in the early years, through the transition to school and across the student's academic journey. This would permit evaluation of whether preschool cognitive abilities are a primary contributor to school readiness and achievement in these settings, or if there are other more salient factors involved. Similarly, longitudinal studies can provide more rigorous evidence for the consistency, direction and mechanisms underpinning relationships between cognitive development, physical activity and GMS, and also the relationship between physical activity, GMS and adiposity. Neuroimaging techniques, such as electroencephalogram and functional near-infrared spectroscopy, could also be incorporated into longitudinal studies to gain brain-based mechanistic insights into cognitive development (resources permitting).

9.5 Conclusion

South Africa is a country often considered synonymous with poverty, inequality, crime and violence, a failing education system, and political corruptness. The current study presents a more positive view of South Africa, and South African preschool children, showing a range of strengths amongst children in these settings. That is, these children are not only meeting, but exceeding guidelines for physical activity, have good gross motor proficiency (some showing GMS far more advanced than expected at their age) and excellent cognitive capacities (even

outpacing children from high SES settings in HICs). However, if these children are to realise this potential, these opportunities need to be supported, leveraged and maintained in, and beyond, the preschool years. This is unlikely to involve simply transporting intervention strategies from HICs (e.g., boosting school readiness via EF intervention, increasing physical activity), but rather requires solutions that recognise and address unique contexts and considerations of these communities. If this can be achieved, South Africa's children could be set on a strong trajectory of health and educational achievement, moving South Africa toward a reputation synonymous with academic excellence, health and equality (as a start).

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APPENDICES
