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Executive function and pre-academic skills in preschoolers from South Africa

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Background: While there is now considerable evidence in support of a relationship between executive function (EF) and academic success, these findings almost uniformly derive from Western and high-income countries. Yet, recent findings from low- to middle-income countries have suggested that patterns of EF and academic skills differ in these contexts, but there is little clarity on the extent, direction and nature of their association.

Aim: This study aimed to investigate the contribution of EF to pre-academic skills in a sample of preschool children (N = 124; M_{age} = 50.91 months; 45% female).

Setting: Two preschools were recruited from an urban setting in a community with both formal and informal housing, overcrowding, high levels of crime and violence, and poor service delivery. Three preschools were recruited from rural communities with household plots, a slow rate of infrastructure development, reliance on open fires for cooking, limited access to running water and rudimentary sanitation.

Methods: Pre-academic skills were assessed using the Herbst Early Childhood Development Criteria test, and EF was assessed using the Early Years Toolbox.

Results: Although EF scores appeared high and pre-academic skills were low (in norm comparisons), EF inhibition (ß = 0.23, p = 0.001) and working memory (ß = 0.25, p < 0.001) nevertheless showed strong prediction of pre-academic skills while shifting was not significant.

Conclusion: While EF is an important predictor of pre-academic skills even in this low- and middle-income country context, factors in addition to EF may be equally important targets to foster school readiness in these settings.

Contribution: The current study represents a first step towards an understanding of the current strengths that can be leveraged, and opportunities for additional development, in the service of preparing all children for the demands of school.

Keywords: preschool; school readiness; executive function; early years toolbox; pre-academic skills; low-income.

Introduction

The early years are a time of considerable development in several domains that are foundational to a child's readiness for school and later educational outcomes (Blair 2016). Understanding what contributes to learning in these early years is essential, particularly in understudied low- and middle-income country (LMIC) contexts. Yet, emerging indications suggest that findings from high-income contexts may not uniformly apply to low-income contexts (Howard et al. 2019; Ellis et al. 2020). Furthermore, different contexts within LMICs, such as urban and rural, may also require investigation, as cultural, socioeconomic and societal factors influencing early learning may differ. One such discrepancy pertains to school readiness, as well as its precursors. Executive function (EF) has been highlighted as one such precursor to school readiness with mounting research showing strong associations with both school readiness and later academic achievement (Fitzpatrick et al. 2014; Pellicano et al. 2017). Discrepancies in the influences on pre-academic skills in LMIC contexts would suggest the need for greater nuance in existing models for understanding the contributors to school readiness and would suggest caution in applying current models that have not been evaluated within dissimilar contexts. Considering the strong evidence for EF-promoting interventions for school readiness (Jacob & Parkinson 2015), there is a need to

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investigate the associations between EF and school readiness in underresearched LMIC contexts such as in South Africa.

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 (Lemelin et al. 2007). The exact skills that comprise school readiness remain debated, with some placing emphasis on content-based skills or pre-academic skills (such as knowledge of numbers, letters and vocabulary) (Duncan et al. 2007), while others emphasise a collection of behaviours and cognitive skills that enable children to learn effectively (e.g. self-regulation, EF, social-emotional skills, enthusiasm to learn, ability to sustain attention) (Blair & Raver 2015; Duncan et al. 2018).

Pre-academic knowledge and skills develop rapidly in the preschool years and form the foundation on which more complex skills are built. For example, studies have shown that early literacy and numeracy skills in the preschool years are strong predictors of later reading and mathematics achievement (Duncan et al. 2007). Because of this, pre-academic skills have historically been a predominant focus of early education programmes. Moreover, pre-academic 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 (Sherry & Draper 2013).

Executive function

Executive functions and cognitive control capacities are overlapping but distinct cognitive skills that are considered essential for academic success through their contributions to directing, maintaining and controlling attention and thinking. Executive functions are a set of complex, higher-order skills that help children to hold and work with information in mind (working memory), resist distractions and stay on task (inhibition), and flexibly reorient attention as situations require (shifting or cognitive flexibility) (Miyake & Friedman 2012). International literature has highlighted EF in particular as a key component of cognitive development associated with school readiness and academic achievement (Howard & Vasseleu 2020; Pellicano et al. 2017). Indeed, EFs have been found to be associated with school readiness (Pellicano et al. 2017; Willoughby et al. 2017) and enable learning more broadly, such as acquiring pre-academic literacy and numeracy skills (Clark et al. 2013; Ribner, Willoughby & Blair 2017). In fact, EFs have been shown to be a stronger predictor of academic performance than even IQ (Bull, Espy & Wiebe 2008). For this reason, EFs have drawn substantial interest in research on early learning and interventions (Etokabeka, Van Heerden & Du Preez 2022; Traverso, Viterbori & Usai 2019; Welsh et al. 2020).

Current evidence for executive function and school readiness in non-Western, educated, industrialised, rich, democratic contexts

Based on the current evidence, the contribution of EF for pre-academic skills and later academic achievement appears robust. However, these constructs and their associations, and for EFs in particular, remain understudied in LMIC contexts (Haslam et al. 2019; Obradović & Willoughby 2019). Child development research in Majority World countries sometimes referred to as low- and middle-income countries (LMICs) and non-WEIRD (Western, Educated, Industrialised, Rich, Democratic) (Henrich, Heine & Norenzayan 2010) countries is often prefaced upon what is known from Minority World countries (also referred to as high-income or WEIRD countries). This is problematic given evidence that findings from Minority World countries do not unconditionally translate to contexts in Majority World countries. The limited evidence from LMIC settings, which is comprised of two recent studies from sub-Saharan Africa, have shown similar findings to WEIRD settings (Amukune & Józsa 2021; Wolf & McCoy 2019). For example, a longitudinal study in 3826 preschool-age Ghanaian children found a bidirectional, positive relationship between EF and literacy and numeracy skills (Wolf & McCoy 2019). Similarly, a study conducted with 526 Kenyan children in Grade 1 (ranging in age from 6 to 11 years) showed a positive relationship between EF and academic achievement (Amukune & Józsa 2021). While these studies begin to shed a light on the association of EF and academic skills in LMIC, specifically sub-Saharan African settings, more research is needed to further understand the nature and stability of this association across contexts and constructs. As is the case for many LMICs, South Africa has a complex history with many unique challenges that persist today. The legacies of both colonialism and apartheid have contributed to the high levels of inequality and extreme poverty and the continued intergenerational transmission of this poverty. Unlike low-income settings in high-income countries (HICs), families living in poverty in South Africa receive little to no services or assistance from the government. It is important to consider that just as child development may differ between HICs and LMICs, child development may be different in different communities within LMICs. This is particularly important to consider in countries as diverse as South Africa, with 11 official languages, numerous cultures and religions, and different living conditions (e.g. urban and rural).

School readiness and executive function in South Africa

Moreover, this research is vital for South Africa, as education in low-income settings in South Africa has been characterised, on average, by poor academic performance and high dropout rates (Fleisch 2008; Spaull & Kotze 2015). This is in contrast to the typically high levels of academic achievement in children from high-income settings in South Africa, indicating a large and income-dependent achievement gap in educational achievement (Spaull & Kotze 2015). This achievement gap may start before children enter formal schooling, as indicated by studies that report below-average cognitive, early language, literacy and numeracy skills in children from low-income South African settings (Dawes et al. 2020; Draper et al. 2012; Save the Children 2016).

The lack of government support for Early childhood development (ECD) programmes in South Africa is possibly one of the biggest contributors to this achievement gap. Access to ECD programmes in South Africa is limited, fee-based and unequally distributed (eds. Hall et al. 2018). A recent ECD census (South African Government News Agency 2022) revealed that only 34% of children aged 3 years – 5 years are enrolled in ECD programmes, with 62% in urban areas and 38% in rural areas. The census further revealed that only 52% of ECD staff have a relevant qualification, and 61% of ECD centres had more than 10 children's books. The urban and/or rural divide in education has always been evident in South Africa, to the disadvantage of rural areas (Masenya 2021). In terms of access to education, data have shown that children who reside in urban areas are more likely to stay in school longer than those in rural areas (Matthews et al. 2019). This divide begins even earlier with lower population densities in rural areas posing a challenge for ECD service delivery as shown in the ECD census reported earlier (Masenya 2021; Matthews et al. 2019). In addition to education disparities, rural areas face additional challenges including poor living conditions, inadequate water, sanitation and energy to households, all of which have the potential to put children's health and development at risk (Masenya 2021). Low-income urban areas are not without their challenges, with rapid urbanisation resulting in destructive societal, economic and environmental consequences. Many low-income urban areas face high levels of unemployment, poor living conditions, overcrowding, and high levels of crime and violence, all of which have the potential to negatively impact children's development and education. Therefore, consideration of both urban and rural settings is crucial to understanding child development in South Africa.

Research involving EF in typically developing preschool-age children in South Africa remains particularly scarce. One study with preschool children from low-income settings measured EF in order to explore its associations with physical activity (Cook et al. 2019). When combined with a larger South African sample to investigate a socioeconomic status (SES) gradient of EF and a cross-cultural comparison with an HIC sample (Howard et al. 2019), these data showed that although SES gradients of EF existed in the South African context, the South African children were doing as well or better than age-matched children from the HIC Australian sample. This was unanticipated considering the overwhelming evidence from HIC contexts indicating a detrimental effect of poverty on EF (Haft & Hoeft 2017). This, in combination with a modest amount of other EF research in LMICs (Amukune, Józsa & Józsa 2022; Nweze et al. 2020; Obradović & Willoughby 2019; Willoughby et al. 2019; Wolf & McCoy 2019), suggests there may be factors unique to these contexts that protect or even promote the development of EF (Ellis et al. 2020).

Current study

This was the first study to assess associations of EF with pre-academic skills in young South African children. It was important to include both urban and rural settings and look at the potential differences in these settings in order to guide future work and to better understand children's cognitive and educational development in context to avoid merely adopting findings, recommendations and interventions that are derived from highly dissimilar HIC contexts. This study aimed to describe EF and pre-academic skills in a sample of South African preschool children from urban and rural low-income settings, and to answer two research questions: (1) whether EF and pre-academic skills would differ between children from urban and rural settings; and (2) whether there would be an association between EF and pre-academic skills that would extend the evidence for this relationship to this understudied, LMIC context.

Methods

Study sites

Data were collected from urban and rural low-income settings in South Africa so as to reflect some of the diversity of low-income South African settings (but did intend to be nationally representative). The particular sites and preschools were chosen based on existing connections with the research team and therefore constituted a sample of convenience. Given varied historical (e.g. apprehension to disclose), financial literacy and inconsistent income factors that can often constrain accurate collection of individual-level sociodemographic data in these communities, SES for the community was used. A further indication of community SES for these communities is the poverty index applied to government-funded schools; in both of these communities, schools are classified in the lowest three quintiles of this index. Both settings had a number of challenges that are inherent to low-income areas in South Africa, including high unemployment (27.7% of the population are unemployed; Statistics South Africa 2017) and poor educational outcomes (50% of students drop out before final year of school; Spaull 2015).

The urban low-income setting included two preschools, in a community with both formal and informal housing, resulting in a population density of 6357.29 per km^2 (Statistics South Africa 2011). 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). Service delivery is poor, with common issues including overcrowding, high levels of crime and violence (Biersteker 2010). Both preschools in the urban setting were small, based in a residential house, with limited classroom space and almost no outdoor space or outdoor play equipment, which is typical of preschools and early childhood development centres in urban low-income settings in South Africa. Some educational resources were observed in the preschools (books, stationery), but children did not have their own table and desk; one of the preschools did not have any tables and children did activities on the floor. Children typically came to school on public transport with many children spending a full 8-h day at the school. The age range for the participants from the urban setting was 35 months – 73 months.

Three preschools from the low-income rural setting were recruited. The population density is substantially lower than in the urban setting, at 610 per km², although extreme poverty is similarly pervasive. The language of Xitsonga is being spoken by 94.7% of the population (Statistics South Africa 2011). The district has a slow rate of infrastructure development, very few tarred roads, and typical living conditions include household plots with a small area that supports 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 toilet (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 and make use of pit toilets. Very limited educational resources were observed, most of which were poor quality (old and possibly broken), and included books, stationery and toys. Children typically spent most of their day playing outdoors. Children came to and from the preschool by walking with their caregiver or older sibling or using public transport. The age range for the rural setting was 38–57 months. These participants were slightly younger compared to the urban group due to the age at which they started their reception year (Grade R). While all children in South Africa should start Grade R in the year they turn 6 years old, children in the rural setting were said to start earlier because Grade R is free, whereas parents have to pay preschool fees.

Participants and recruitment

All parents and caregivers of eligible children in the recruited preschools were invited to an information meeting at the school, during which both written and verbal information about the study were provided. 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.

Among the 188 eligible children, parental consent was received for 137 children (72.9% consent rate). Children who expressed unwillingness to participate were excluded before testing (n = 7). A further six participants were excluded from the analyses due to missing data, resulting in a sample of 124 with complete data (89% of consented children). Missing data were due to participant absenteeism on testing days. This final sample subjected to analysis was comprised of 62 children from urban preschools (M_{age} = 52.82 months, 45% female) and 62 children from rural preschools (M_{age} = 49 months, 58% female).

Measures

Pre-academic skills

The Herbst Early Childhood Development Criteria test (ECDC; Herbst & Huysamen 2000) was used to assess pre-academic skills. It was developed and validated specifically for the South African context, to assess the cognitive, fine motor and gross motor development skills that underlie school readiness in 3- to 6-year-old children. The test is child-centred and culturally and contextually relevant for use in South African settings. The ECDC has three sections: cognitive school readiness risk areas, fine motor coordination and gross motor skills. For this study, only the cognitive subsection was administered given its focus on the pre-academic skills that underlie school readiness (Herbst & Huysamen 2000). This section shows good test-retest reliability (r = 0.93) and concurrent validity with the Gesell Preschool Test (Ilg & Ames 1972).

The cognitive subsection includes 10 subscales that assess the following areas of cognitive development: (1) incomplete man: body part awareness; (2) visual-motor integration (VMI); (3) block building: visual discrimination, fine motor coordination, spatial concepts; (4) stick figures: spatial concepts and VMI; (5) direction similarities: three- and two-dimensional perception of direction and similarities; (6) form concept: three- and two-dimensional form test; (7) colour concept; (8) number counting: numerical and counting concepts; (9) picture puzzles: puzzle building and (10) picture perception: visual discrimination.

The subscale scores add up to a possible total of 79, with each subscale ranging between 6 and 12 possible points. These subscales were indexed by a total raw score – that is, the sum of points scored on each subscale, such that a higher score indicated better performance – and a percentile rank that is based on norms for South African children that compare performance against the child’s age, population group and educational status (whether the child attends preschool or not). A total score for the cognitive section was also indexed by a raw score (sum of points scored on each subscale) and a z-score that classifies the score into descriptive categories for performance including very low, low, normal, high and very high. Only the total raw score was used in the analyses testing relationships with EF, while the percentile ranks and z-scores were employed to compare performance to South African norms.

Executive function

Executive function was assessed using iPad-based direct assessments from the Early Years Toolbox (EYT; Howard & Melhuish 2017). Measures assessing the three core components of EF were selected, namely, Go/No-Go (inhibition), Card Sorting (shifting) and Mr Ant (working memory). The EYT was chosen as it minimises literacy and numeracy demands often found in EF measures, something that was particularly pertinent in these settings given the evidence for poor literacy and numeracy skills in South African children (Mohangi et al. 2016). The design of EYT also leverages the affordances of technology but does not advantage children with technological expertise (i.e. children interact with the iPad as they would with a piece of paper; Howard & Melhuish 2017). This is possible as responses required are intuitive and were designed to mirror those of noncomputerised versions of these tasks (Howard & Melhuish 2017; Howard & Okely 2015). Stimuli embedded in the tasks have been found to be engaging, age-appropriate and familiar to the children in these settings. Furthermore, previous studies have shown that the EYT is suitable for use in South African settings (Cook et al. 2019).

The EYT tasks included integrated audio instructions translated into local languages to ensure the consistent sequencing and timing of tasks. Comprehension of instructions was determined during the practice rounds in each task. If it was clear that the participant lacked comprehension of any aspects of the task, the fieldworker provided further explanations in the participant's home language before moving on to the test trials, after which no further scaffolding was given.

The *Go/No-Go* task 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 this pre-potent response whenever a no-go trial is presented. Initial practice includes instructions and 20 practice trials to allow familiarisation with the task. The task then follows with 75 test stimuli, divided into three 1-min test blocks separated by a short break and repetition of instructions. Inhibition was indexed by an impulse control score that represents the product of the Go and No-Go proportional accuracy, thereby representing the strength of the pre-potent response in relation to their ability to overcome this response. The scores range from 0 to 1.

The *Card Sorting* task requires children to sort stimuli according to a changing sorting rule. The first phase (pre-switch phase) requires participants to sort stimuli (i.e. blue rabbits, red boats) by colour. After six trials, children are informed that the sorting rule has changed (post-switch phase) and they must now sort the stimuli according to shape. The third phase (border phase) is reached if the participant sorts at least five stimuli correctly during both the pre- and post-switch phases. In the border phase, stimuli are either presented with or without a black border; if there is a black border, stimuli must be sorted according to colour, or if there is no black border, stimuli are to be sorted by shape. The first and third conditions begin with a demonstration and two practice trials, in which incorrect sorting is corrected and sorting rules are repeated. For all trials, the current sorting rule is reiterated prior to presentation of the stimulus to be sorted. Shifting was indexed by the number of correct sorts that occurred after the pre-switch phase and ranges from 0 to 12.

The *Mr Ant* task asks participants 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 5 s and then an image of Mr Ant without stickers on which children indicate where the stickers were by tapping the relevant spatial locations on Mr Ant. The number of stickers corresponds to the task level (i.e. working memory demand), which is increased sequentially after three trials at each level. The task begins with instructions and two practice trials. Performance continues until the completion of level eight or, in the case of young children, failure on all three trials of the same level. Working memory is indexed by a point score that awards one 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 a child completes only one trial correctly, a third of a point for each correct trial thereafter. The scores range from 0 to 8.

Procedure

Data collection was conducted by a trained researcher with the assistance of a trained, local fieldworker from each setting who could communicate in participants' home language. Testing was conducted in August 2016 for the urban site and in March 2017 for the rural site. Data were collected over the course of one month at each site, with the ECDC and EYT done on separate days. The tasks were carried out in the same fixed order at each site: Herbst ECDC test (± 30 min per child); and then on another day, the three EF tasks in the EYT administered in a single session in the order Go/No-Go, Card Sorting and then Mr Ant (± 20 min per child for all three tasks). If participants showed signs of fatigue during the EYT tasks, a 15-min break was given before resuming. All testing took place at the children's preschools during school hours (± 08:30–16:30 for the urban preschools and 08:00–15:00 for the rural preschools). For both the ECDC test and the EYT, participants were tested individually in a quiet area of the preschool. This investigation formed part of a larger study in which researchers collected data on the variables included in this analysis, as well as objectively measured physical activity and gross motor skills (Cook et al. 2019).

Ethical considerations

Ethical approval for the project Physical Activity, Gross Motor Skills, EF and School Readiness in Preschool Children from Low-income Rural and Urban Settings 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 given by the Mpumalanga Provincial Department of Health Research Committee. This study adheres to the guidelines explained in the Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects. Parents provided written informed consent for each participant.

Ethical clearance to conduct this study was obtained from the University of the Witwatersrand, Human Research Ethics Committee (No. Ref: M160534) and the University of Cape Town Human Research Ethics Committee (Ref: 053/2015).

Statistical analysis

Data were explored using IBM SPSS Statistics version 26 (IBM Corp, Armonk, NY). Shapiro-Wilk tests for normality were conducted and all variables did not significantly deviate from normality; therefore, parametric tests were used. Only participants with complete data were included in the analyses. To answer the first research question, T-tests and chi-square tests were used to evaluate differences in EF (inhibition, shifting, working memory) and pre-academic skills (percentiles of individual ECDC subscales and descriptive categories) between urban and rural settings. Bivariate correlations among the EF (inhibition, shifting, working memory) and pre-academic skills (ECDC subscales raw scores, ECDC total raw score) were explored using Pearson correlations. To answer the second research question, multiple linear regression analyses were conducted to determine whether EF, including inhibition, shifting and working memory, was associated with the total ECDC raw score (pre-academic skills), while controlling for age, sex and setting. Hierarchical linear regression was used with the demographic variables (age, sex, setting) in the first block and the three EF task scores (inhibition, shifting, working memory) in the second block. The data reported here overlap partially with data reported by Cook et al. (2019) and Howard et al. (2019). Those analyses focused, respectively, on physical activity and school readiness in this sample of preschoolers (Cook et al. 2019) and the direct comparison of EF scores in South African preschoolers and Australian preschoolers of varying SES (Howard et al. 2019).

Results

Descriptive statistics

Table 1 shows the means and standard deviations for the individual EF task scores and the means and standard deviations as well as the percentile ranks for the pre-academic skills (ECDC) raw scores. Percentile ranks give an indication of the performance in a subscale according to age and preschool experience. Table 2 shows the z-scores, or the proportion of children per ECDC descriptive category. These categories are based on South African normative data and reveal just less than half (47%) of children were

TABLE 1: Descriptive statistics for total, urban and rural samples.

Child variables	Total (N = 124)	Urban (n = 62)	Rural (n = 62)	p
Age (in months)	50.91 ± 8.38	52.82 ± 10.53	49.0 ± 4.8	0.010*
ECDC total	26.34 ± 13.62	32.4 ± 14.93	20.27 ± 8.74	< 0.001*
Incomplete man				
Raw	3.15 ± 2.26	3.9 ± 2.46	2.4 ± 1.75	-
Percentile	51.08	60.45	41.86	0.003*
VMI				
Raw	2.41 ± 1.85	3 ± 1.89	1.82 ± 1.61	-
Percentile	48.95	55.56	42.45	0.034*
Block building				
Raw	2.85 ± 1.59	3.24 ± 1.76	2.47 ± 1.3	-
Percentile	44.51	51.9	37.23	0.021*
Stick figures				
Raw	2.51 ± 1.74	3.11 ± 1.54	1.9 ± 1.41	-
Percentile	48.88	54.45	43.4	0.061
Direction similarities				
Raw	4.28 ± 2.48	4.77 ± 2.69	3.79 ± 2.17	-
Percentile	57.96	57.98	57.95	0.996
Form concept				
Raw	2.46 ± 1.40	3.11 ± 1.54	1.81 ± 0.85	-
Percentile	43.16	56.8	29.73	< 0.001*
Colour concept				
Raw	1.53 ± 1.57	2.23 ± 1.94	0.84 ± 0.49	-
Percentile	64.34	67.7	61.03	0.225
Number counting				
Raw	2.42 ± 2.29	3.69 ± 2.13	1.15 ± 1.65	-
Percentile	39.46	58.26	20.95	< 0.001*
Picture puzzles				
Raw	0.66 ± 0.20	1.26 ± 0.97	0.69 ± 0.69	-
Percentile	64.47	66.86	62.12	0.324
Picture perception				
Raw	3.53 ± 1.47	3.09 ± 1.57	3.16 ± 0.28	-
Percentile	80.44	80.92	79.98	0.859
Inhibition	0.66 ± 0.20	0.69 ± 0.22	0.63 ± 0.17	0.092
Shifting	5.73 ± 3.09	6.42 ± 3.07	5.03 ± 0.17	0.012*
Working memory	1.67 ± 0.82	2.01 ± 0.82	1.30 ± 0.70	< 0.001*

Note: Means are presented as mean ± standard deviation. Percentile ranks are included below M ± SD for the ECDC subscales.

ECDC, early childhood development criteria test; VMI, visual-motor integration.

*, $p \leq 0.05$.

classified as below average (average indicated as 'normal' in the ECDC), suggesting poor pre-academic skills in this sample. Both urban and rural groups appeared to show relatively strong EF abilities, when contrasted with established Australian preliminary norms (Howard & Melhuish 2017). Specifically, one-sample T-tests indicated that inhibition scores were significantly higher than the Australian norm in all age groups except the 3–3.5-year-old group. For shifting, the current sample had significantly higher scores across all age groups except for the 5.6–5.11-year-old group. However, working memory only showed significantly higher scores for the 5–5.5-year-old group. See supplementary table for full comparison.

Research question 1: Urban and rural differences

T-tests revealed significant differences between the urban and rural samples. Children in the urban group (M_{age} = 52.82) were significantly older than children from the rural group (M_{age} = 49.0), and thus age was controlled in subsequent analyses. Furthermore, children from the urban group had significantly better performance on EF tasks shifting ($p = 0.012$) and working memory ($p < 0.001$), with no significant differences between inhibition scores. For the ECDC subscales, *T*-tests were conducted on the percentile ranks as they took age into account. Urban children still had significantly higher scores on most of the ECDC subscales (incomplete man, VMI, block building, forms, number counting) with some of the biggest discrepancies seen in form concepts (percentile rank urban = 56.8, rural = 29.73, $p < 0.001$) and number concepts (percentile rank urban = 58.26, rural = 20.95, $p < 0.001$). The proportion of children in each ECDC descriptive category was significantly different between the settings (X^2 (6) = 23.93, $p = 0.001$), with a higher proportion of rural children (61%) falling into categories that were below average compared to urban children (33%).

Research question 2: Associations between executive function and pre-academic skills

Table 3 presents the results from the hierarchical linear regression analysis that was used to assess the relative association of EF (individual EF indices) with pre-academic skills (ECDC total raw score), while controlling for age, sex and setting (see Table 4 for bivariate correlations). Results indicated that child age (ß = 0.64, $p < 0.001$) and setting (ß = −0.31, $p < 0.001$) were significant predictors of pre-academic skills, such that children who were older outperformed younger children and children who were from the urban ($M_{\text{ECDC score}} = 32.4$) setting outperformed children from the rural setting ($M_{\text{ECDC score}} = 20.27$). These control variables accounted for a high 59% of the variance in pre-academic skills ($F(3) = 58.63$, $p < 0.001$).

TABLE 2: Early childhood development criteria descriptive categories based on achievement in comparison to norm group.

ECDC descriptive category (% of sample)	Total ($N = 124$)	Urban ($n = 62$)	Rural ($n = 62$)
Very low	31.8	15.7	47.7
Low	15.5	17.2	13.8
Normal	34.9	35.9	33.8
High	8.5	14.1	3.1
Very high	9.3	17.2	1.5

ECDC, early childhood development criteria test.

The EF indices accounted for an additional 12% (71% total) of the variance in pre-academic skills ($F(6) = 47.91$, $p < 0.001$). More specifically, two of the three EF indices significantly predicted pre-academic skills, working memory (ß = 0.25, $p < 0.001$) and inhibition (ß = 0.23, $p < 0.001$), whereas shifting did not (ß = 0.11, $p = 0.055$).

Discussion

The current study sought to examine the associations of EF (as individual EF scores) with pre-academic skills in an urban and rural low-income sample of South African preschoolers. Even though EF scores appeared high and pre-academic skills were low (in norm comparisons), EFs nevertheless showed strong prediction of pre-academic skills. This study also highlighted the differences between urban and rural settings, such that children growing up in rural settings have mastered fewer pre-academic skills and may be at higher risk of not being ready for school and for poor academic achievement. These results contribute to the small, but growing evidence for strong or on par EF abilities in African samples (Lamm et al. 2018; Nweze et al. 2020; Wolf & McCoy 2019) and reinforce the importance of EF for the acquisition of pre-academic skills reported in previous research from HICs (Pellicano et al. 2017; Ribner et al. 2017) and LMIC settings (Amukune & Józsa 2021; Wolf & McCoy 2019).

Regarding the associations between EF and pre-academic skills, the direction and degree of the relationship between school readiness and EF measured by the EYT is similar to studies from Australia that used the EYT (Howard & Vasseleu 2020). The current study extends this finding to an understudied LMIC context, adding to a study that reported moderate to strong correlations for EF with numeracy and literacy scores in children from a low-income setting in Ghana (Wolf & McCoy 2019). Mechanisms for this association have been proposed; that is, with higher EF abilities, children are better able to pay attention and ignore distractions, remain on task, and hold and work with information in mind (Duncan et al. 2007; Wolf & McCoy 2019). All of these are likely to have direct benefit to the on-task behaviours and cognitive engagement necessary for learning and acquisition of pre-academic skills.

TABLE 3: Summary details of multiple linear regression analyses predicting early childhood development criteria score.

Regression models	Predictors	ß	*t*	*p*	*F*	*df*	*p*	R^2
Model 1a	-	-	-	-	58.63	3	< 0.001	0.59
	Setting (rural = 1)	−0.31	−5.12	< 0.001*	-	-	-	-
	Sex (male = 1)	−0.07	−1.13	−0.26	-	-	-	-
	Age	0.64	10.72	< 0.001*	-	-	-	-
Model 1b	-	-	-	-	47.91	6	< 0.001	0.71
	Setting (rural = 1)	−0.21	−3.87	< 0.001*	-	-	-	-
	Sex (male = 1)	−0.07	−1.41	0.16	-	-	-	-
	Age	0.34	5.08	< 0.001*	-	-	-	-
	Inhibition	0.23	3.48	0.001*	-	-	-	-
	Shifting	0.11	1.94	0.055	-	-	-	-
	Working memory	0.25	3.75	< 0.001*	-	-	-	-

*, $p \leq 0.05$.

TABLE 4: Correlation matrix.

Child variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Pre-academic skills	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Incomplete man	0.79*	1	-	-	-	-	-	-	-	-	-	-	-	-
VMI	0.82*	0.61*	1	-	-	-	-	-	-	-	-	-	-	-
Block building	0.79*	0.56*	0.58*	1	-	-	-	-	-	-	-	-	-	-
Stick figures	0.76*	0.60*	0.65*	0.64*	1	-	-	-	-	-	-	-	-	-
Direction similarities	0.73*	0.45*	0.53*	0.58*	0.49*	1	-	-	-	-	-	-	-	-
Form concept	0.78*	0.56*	0.62*	0.54*	0.56*	0.52*	1	-	-	-	-	-	-	-
Colour concept	0.75*	0.56*	0.58*	0.58*	0.49*	0.45*	0.63*	1	-	-	-	-	-	-
Number counting	0.75*	0.50*	0.56*	0.49*	0.44*	0.48*	0.65*	0.62*	1	-	-	-	-	-
Picture puzzles	0.70*	0.52*	0.55*	0.52*	0.56*	0.41*	0.52*	0.50*	0.45*	1	-	-	-	-
Picture perception	0.74*	0.58*	0.58*	0.58*	0.50*	0.54*	0.53*	0.43*	0.48*	0.56*	1	-	-	-
Inhibition	0.64*	0.52*	0.50*	0.46*	0.46*	0.49*	0.56*	0.49*	0.48*	0.39*	0.55*	1	-	-
Shifting	0.48*	0.31*	0.47*	0.32*	0.44*	0.40*	0.42*	0.34*	0.34*	0.33*	0.32*	0.31*	1	-
Working memory	0.67*	0.53*	0.57*	0.53*	0.52*	0.46*	0.48*	0.47*	0.55*	0.55*	0.51*	0.52*	0.40*	1

VMI, visual-motor integration.
*, $p \leq 0.05$.

In looking at associations with individual EF tasks, both inhibition and working memory were uniquely associated with pre-academic skills, whereas shifting was not (showing some discrimination between EFs and their associations with pre-academic skills). This finding is similar to that of Amukune et al. (2022), who used a teacher rating scale to assess EF in Kenyan Grade 1 (6–11 years). Their confirmatory factor analysis revealed a two-factor solution, inhibition and working memory, and both of these factors were associated with academic achievement (Amukune & Józsa 2021). 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, this discrepancy may be due more to issues in data distribution than meaningful separation of these functions.

The finding of average or below-average pre-academic skills is in line with local (Spaull & Kotze 2015) literature showing poorer school achievement in low-income contexts. Notably, age and setting accounted for the more of the variance in pre-academic skills than EF. While age may be accounting for a large portion of this variance, the contextual differences in the settings may be just as important as predictors of pre-academic skills and require further investigation. Therefore, while the current results support EF as clearly associated with pre-academic skills, within this low-income LMIC context, it is likely that there were a range of other factors that are also contributing to lower pre-academic skills, such as preschool attendance, access to educational resources, teacher qualifications and/or stimulation at home (Richter & Samuels 2018). While EFs may be important ingredients to facilitate learning, they alone are insufficient to foster pre-academic skills in the absence of the requisite content and a supportive context. Academic knowledge and skills are also highly dependent on content, structure, sequence and quality of educational experiences provided (Weiland et al. 2013). This suggests that, at least in these contexts, EFs may be an important facilitator of learning, but perhaps should not be considered as a sole or priority target for interventions aiming to promote school readiness.

The finding that children from the urban setting outperformed children from the rural setting highlights the fact that even within the same LMIC, low-income settings and the needs of each setting can differ. Although the current study did not set out to identify those factors that may be contributing to poorer performance among the rural children, factors such as limited access to essential services (Biersteker 2012) and high-quality preschools or early learning provision (Richter & Samuels 2018) have been suggested in previous research. In low-income settings in South Africa, early childhood education for children under the age of 5 years remains largely unsupported and unregulated, with most early education centres being run by community-based organisations or low-trained volunteers from the community as was the case in the preschools from the current study (Sherry & Draper 2013).

Findings from this study further challenge the SES, EF association derived from studies in HIC contexts. In the current study, participants (both urban and rural) showed strong EFs despite their low-income context; this is in contrast to the more commonly found SES-EF gradient (Ursache & Noble 2016). Even though children from the rural setting demonstrated weaker pre-academic skills compared to the urban setting, they still showed strong EF abilities compared to Australian norms, as did the children from the urban setting. While it is possible that the strong EF abilities captured in these settings might be an indication of other skills beyond cognitive control, such as obedience or compliance, children still need to have sufficient EF capacity to achieve in the tasks (i.e. compliance in isolation would be insufficient to achieve a high working memory score). These strong EF abilities in the low-income urban and rural children have been speculated elsewhere to derive from the unique characteristics and social-cultural contexts of the settings (Cook et al. 2019; Howard et al. 2019). For example, South Africa is rich in diversity, with 11 official languages and numerous ethnicities. Responsibility, multilingualism, rituals and routines, and collectivist cultures are all factors that have been considered as EF-promotive (Li, Vazsonyi & Dou 2018; Rybanska et al. 2017) and thus are plausible mechanisms driving the strong EF abilities in these settings.

Strengths and limitations

A strength of this research is that it was conducted in both urban and rural settings, reflecting some of the diversity of South African low-income contexts. However, it is limited in that it could not capture the full and vast range of diversity in low-income settings in South Africa. Furthermore, the cross-sectional design precluded analyses of directions of effects. While the sample size, sample diversity and study design do limit the generalisability of results, studies such as this are necessary precursors to identify likely fruitful targets in larger and better-powered studies in these settings, where research is lacking. It is also important to note that these settings are extremely complex, and there may be many factors not measured in the current study that play a role in child development and specifically the development of EF and pre-academic skills and the relationship between them. Future studies should aim to include factors such as practitioner qualifications and resources in the preschool, caregiver education, and the home learning environment.

A strength of the study is that it is one of the first to examine associations between EF and pre-academic skills with South African preschool children. These EF findings contribute further evidence in favour of the viability and validity (e.g. concurrent validity with a school readiness measure) of the EYT in these contexts. As has been previously reported (Cook et al. 2019), data derived from EYT did not appear to be plagued by issues that are often found with many other measures when used in these contexts (e.g. floor effects, low correlation between tasks). At the same time, EYT is able to address pragmatic limitations that are a particular concern with young children in LMICs (e.g. lack of electricity, lack of access to Wi-Fi in field, mobility, cost, effects of technological expertise, artefacts from literacy and numeracy demands; Howard & Melhuish 2017). The absence of South African EYT norms for this sample is a limitation, and therefore conclusions cannot be drawn about the relative performance of this sample relative to the South African population and other subgroups. This is an area for further development. However, as LMIC countries often do not have a set of local norms for assessments, initial studies looking at comparisons with norms from HICs create a starting point in describing the performance of the sample and highlight the need for more research to develop normative data.

Conclusion

The results from this study contribute to the mounting evidence showing association between EFs with pre-academic skills, with the current study extending this to South African contexts. South Africa is a country often considered synonymous with poverty, inequality, crime and violence, and a failing education system. The current data give a more positive view of South African preschool children, showing strong EF and thus potential for learning. 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 transferring intervention strategies from HICs (e.g. EF programmes to boost school readiness), but rather requires solutions that recognise and address the unique contexts and considerations of these communities. The current study represents a first step towards an understanding of the current strengths that can be leveraged, and opportunities for additional development, in the service of preparing all children for the demands of school.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

C.J.C. collected the data, carried out the analyses, drafted the manuscript, reviewed and revised the manuscript. C.D. conceptualised and designed the study, acquired the funding, supervised data collection, drafted the manuscript and critically reviewed the manuscript for important intellectual content; R.T., K.K. and S.N. contributed to the study design, recruitment and data collection, provided strategic research oversight and reviewed the manuscript. G.S. acquired the funding, conceptualised and designed the study, drafted the manuscript, reviewed and revised the manuscript. S.H. conceptualised and designed the study, drafted the manuscript, reviewed and revised the manuscript, and designed data collection instruments. All the authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

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Data availability

The data that support the findings of this study are available from the corresponding author, C.J.C., upon reasonable request.

Disclaimer

The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of any affiliated agency of the authors.

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