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Sex and School Differences in Executive Function Performance of Zambian Public Preschoolers

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Abstract Despite a great deal of research on the relations between preschool executive functions (EF) and demographic variables such as age, sex and school variables (classroom organization and teacher behaviours including quality of educational instruction, planning, organization and teacher-learner relationships), not much is known about these associations in Zambian preschoolers. This study was aimed at examining the relations of executive functions to age, sex and school variables in 133 Zambian preschool learners enrolled in urban public preschools aged 5 to 8 years. A between-subjects quasi-experimental research design was utilised. Wilcoxon matched-pairs signed-rank model showed sex and school differences were also observed to be significantly related to executive functions, no significant relationship was found for age. Key implications of the study for pre-primary policy, girl-child education (to discourage child marriage) and preschool teacher professional development in Zambia are discussed.

Keywords: *Zambian preschool learners, executive functions, sex differences, school variables*

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1. Introduction

Sub-Saharan Africa accounts for the largest number of children who drop out of school due to child marriage and other factors [1,2,3] The number of children in sub-saharan Africa who fail to acquire basic reading and mathematics skills continues to remain high [4]. Out of 650 million primary school children, 250 million do not have reading and mathematics skills while one-third of all primary school children who have acquired some reading skills are unable to read a sentence at the end of their primary education [4]. One of the reasons for this poor performance in reading and mathematics is the lack of adequate executive functions (EF) skills [5,6,7]. Executive functions skills are a set of three advanced cognitive skills linked to the brain's prefrontal cortex that enable a child to engage in the following skills; (1) store, update and retrieve information while engaged in other attention-demanding tasks (working memory), (2) withhold inappropriate responses (inhibitory control) and (3) switch attention to different tasks in the environment (cognitive flexibility) [8,9]. These EF skills have been found to predict several child development skills such as reading [10], maths [11], school readiness [12], responsible adult behaviour [13], social skills [14], good parenting quality [15] and non-criminal behaviour [16]. Among many benefits, mastery of executive functions enables children to regulate their actions, thoughts and emotions, solve problems, make meaningful decisions, set goals and work towards goal attainment. Lack of EF skills manifests in maladjusted behaviour and inability to pay attention in class and lack of persistence on the highest pay-off tasks [17].

Factors that influence the development of EF skills include a conducive social-cultural context [18,19], school variables such as positive classroom organization and good teacher behaviours including positive teacher instruction, planning, organization and emotional support [12]. Maturation is another factor that contributes to the development of EF skills in children. Older children can perform better on cognitive tasks than their younger counterparts [20]. EFs develop rapidly during preschool years [21-26]. Sex has also been found to be associated with executive functions. Girls tend to perform better than boys on EF tasks in Western contexts [27-33]. However, the bulk of these investigations mainly focuses on high-income countries than low-income countries. Cognitive developmental milestones in children from low-income backgrounds are threatened by poor health, malnutrition and stunted growth, respiratory infections, malaria, HIV/AIDS [34], child sexual abuse [35,36] and neurocognitive impairments [34,37,38]. Exposure to these cognitive developmental risks has been well documented in Zambia [37,39,40,41,42].

In response to the threatened childhood cognitive development, Zambia has invested in early childhood education (ECE) to enhance early executive function development [40]. Although quality early childhood education (ECE) consists of effective ECE planning and management policies, equal and wide ECE access, adequate supply of self-motivated and qualified teachers, relevant and responsive curriculum and a conducive physical environment for effective teaching and learning, Zambia falls short of these ECE requirements. Less than 15% of children have access to preschool education [43]. While the urban provinces namely Lusaka (36%) and the Copperbelt (30%) account for the largest number of nursery schools' enrollments, the other provinces represent less than 20 % [44] Limited access to early childhood education in Zambia suggests that this level of education is still in its infancy.

Despite overwhelming evidence that the first 1000 days are crucial for optimal physical, cognitive, socio-emotional and moral child development, ECE investments in Zambia remain below expectation [39]. Inadequately trained preschool teachers compromise quality early childhood education provision and contribute to poor learning outcomes. The victims of the failed education system in Zambia are the girl child learners in Zambia [45]. The expectations are high with the new Zambian government's efforts to provide support to the education sector through the free education policy and increased teacher recruitment.

Literature has documented many factors associated with young children's executive function development, including gender, age, and academic outcomes [46-51] Defined as possession of biological differences between males and females such as chromosomes (XX or XY), internal and external sex organs (ovaries, testes) and hormonal profiles (of estrogens and androgens), sex has often been found to affect brain development. Sex on the other hand refers to "socially constructed roles and relations, personality traits, attitudes and behaviours and values that are ascribed to the two sexes in a differential manner" ([52], p. 18).

Among the most important variables to consider when examining factors related to executive functions are school variables - classroom organization and teacher behaviours including quality of educational instruction, planning, organization and teacher-learner relationships. Research in Zambia has shown that participation in a non-profit early childhood education programme for 3 to 5 hours per day predicts improved executive functions, and motor and task competence among preschool children [12]. One of the plausible explanations for the significant relationship between the school environment and executive functions is drawn from the pedagogical experience hypothesis that states that teachers who provide proactive rather than reactive instructions to their learners support the development of executive functions [53]. This assertion has been empirically confirmed by cross-cultural research between Chinese and American preschoolers [53].

Age has also been shown to contribute to executive functions in preschool-aged children over and above maternal education and family income in Zambia [40]. This suggests that older children perform better on cognitive tasks than younger children [49,50]. Several other studies among high-income populations confirm age-related differences in executive functions both in children [22,23] and adults [26].

Sex is one of the variables associated with executive functions in children. However, what is problematic in this field is that most of the studies conducted on the sex differences associated with EF among preschool children have been confined to Asia, America and Europe. There is consensus in the Western literature confirming that girls perform better than boys on executive function tasks among preschool children [27,28,29,30]. However, most of this research cannot be generalised to non-Western contexts owing to the varied child-rearing practices specific to each sex in African societies. These varied socialisation practices have resulted in different patterns of social interactions for boys and girls. For instance, girls have been observed to develop smaller and exclusive peer groups (that enhance cognitive development) as compared to boys [31]. Consequently, girls tend to be relationally aggressive while boys are physically aggressive [32]. These social behaviours could contribute to the sex differences in executive functions [54,55].

Although there is substantive evidence on the development of executive functions in early childhood years [53,56], research examining the association between executive functions and demographic factors in Zambia is limited [43]. Furthermore, although, executive functions in preschool-aged children have not been extensively investigated in Sub-Saharan Africa, a huge number of children are living in deprived environments ravaged by HIV/AIDS, Diarrhoea, Malaria and respiratory infections, poverty and cognitive non-stimulation, which threaten optimal cognitive-developmental milestones on these children [39]. The current study focused on investigating the relationship between demographic factors (age, school variables and gender) and executive functions among preschoolers in urban Zambian public schools.

2. Methods

2.1. Participants

Hundred and thirty (133) preschool learners enrolled in public schools aged between 5 to 8 years were recruited from 5 preschools. From each school, a total of 26 learners were randomly selected. The study was approved by the University of Zambia, institutional review board. Consent was first sought from the Chilanga district provincial office (PEO) and then the District Education Secretary issued an approval letter addressed to the school head teachers and teachers in the sampled schools.

Written parental consent for each of the children who participated in the study was obtained. Participants were randomly assigned to three conditions: the intervention, control 1 and 2. The intervention group spent 28 sessions spread over 6 weeks watching rhymes and stories whereas control group 1 played video games, control group 2 engaged in usual free play during the same duration.

As shown by Table 1, there were more female (73) than male (60) participants, the average age of the participants was 6.4 years with a standard deviation (SD) of 0.7.

Table 1. Demographic characteristics of participants

Variable	Number (%)
Sex	
Male	60 (45.1)
Female	73 (54.9)
School	
1	16 (12.0)
2	18 (13.5)
3	44 (33.1)
4	25 (18.8)
5	30 (22.6)
Age in years [Mean, SD]	6.4 (0.7)

2.2. Measures

The assessments were administered to each child individually in a quiet room at their school by trained researchers. The duration of the tests was about 17-25 min per child. While inhibitory control was assessed by the pencil tap test (PT), processing speed was measured by the Rapid Automatized Naming (RAN) task.

Pencil tap Test (PT). The pencil tap task was used to measure inhibitory control, a core component of executive function, for this test the children were required to tap a pencil on the desk a predetermined number of times in response to the examiner's taps. For instance, when the examiner tapped the desk either once or twice, the child was required to respond by tapping in the opposite order of what the examiner did. The child was required to tap the desk twice (when the examiner tapped once), once (when the examiner tapped twice) and the child was required not to tap the pencil when the examiner tapped it 3 times. The correct number of taps was taken as the outcome score. Learners were tested individually by first giving them 3 practice exercises before the actual test was given. The Pencil tap test is reliable and valid for use among children from low-income families in Zambia [40] and Kenya [57]. Numerous tests of inhibition for preschool children exist such as the go/no-go tasks [58]. For this study, the pencil tap test was used because it is a child-friendly and culturally appropriate test with strong psychometric properties established by prior work in Zambia and Kenya [10,40,57].

Rapid Automatized Naming task (RAN). Processing speed was measured using Rapid Automatized Naming (RAN) task [59]. In this task, children were instructed to name as quickly as possible black images printed on white paper of a tree, duck, chair, pair of scissors and bicycle in a specific order. Children were first asked to identify each of the five stimuli individually to ensure that they were familiar with the objects. A practice trial was administered before the actual test was administered to ensure that the children understood the test rules. The test required the children to name the images from top to bottom and left to right as fast as they could. RAN scores have been associated with reading achievement [60-64]. After naming 50 items in the five lines, the response time was recorded in seconds as the outcome measure. The use of the RAN in the present study was motivated by the test's established ecological validity and scalability [10,43,65].

2.3. Procedure

The study was conducted in the Chilanga district. Five (5) pre-schools from the district participated in the study. The preschools were selected based on a set of criteria. Preschools located within the administrative centre were included in the study for the effective movement of the research team from one school to the other considering the limited school time. The schools that met the inclusion criteria were randomly selected using simple random selection.

Participants for the present study were enrolled in the second week of the third term. Baseline assessments were administered one week before the beginning of the intervention and the same tests were re-administered in the week following the intervention.

In each preschool, three conditions (1 intervention and 2 control conditions) were created where each condition either played games (control 1) or was exposed to rhymes and stories in the local language (intervention) or engaged in usual free play (control 2). Each participant used a mobile device with headphones for maximum engagement with the material. To reduce motor strain, the devices were placed on a desk in front of the participant in an upright position (in landscape orientation) for a uniform participant experience.

The participants in the intervention condition were required to watch a 12-minute video that displayed rhymes and stories during which those in the two control conditions were required to play an action video game or engage in their usual activities outside the classroom.

Baseline. The pre-test was conducted over a period of two weeks. Each participant completed two sessions over a period of two days because the pre-test battery took approximately 45 minutes to complete. Children were assessed using the following executive function tests; the Rapid Automatised Naming test (RAN) and the pencil tap test. The procedure for test administration was standardised for all the learners. The pre-test sessions were conducted in rooms that were free from distractions.

Intervention. Participants in the intervention group spent 28 sessions spread over 6 weeks. The participants were randomly assigned to three conditions namely: intervention (watched rhymes and stories video), control 1 (played an action video game) and control 2 (engaged in free play). The Participants were exposed to 4 sessions per week and each session lasted about 12 minutes. The intervention took place within the school in a separate quiet room.

Post assessment. The participants were assessed a week after the intervention. Each participant was assessed using the Rapid Automatised Naming test (RAN) and the pencil tap test to measure executive function after exposure to the intervention.

3. Results

The goal of the present study was to examine the relations between demographic variables (school, age and gender) and executive functions in urban preschool children. The study findings will be presented as follows. First, the participant's sex and age will be present, and then the associations between executive functions and school climate and sex will be presented. Second, using the Wilcoxon matched-pairs signed-rank model, the unique contributions of the three intervention conditions (control, games and stories) to the executive function performance as measured by the two tests (Pencil tap test and Rapid Automated Naming test) will be provided and finally, the relationship between age and executive function will be shown.

3.1. Association between Executive Function (RAN) and School Variables

As shown by Table 2, There was no significant difference in the overall Rapid Automatised Naming test score between the pretest and posttest scores (p = 0.13). When the median scores were stratified by the school, the results from schools 1 and 3 showed a significantly higher difference between the pretest and posttest median scores, (p = 0.02) and 3 (p = 0.03) respectively, while other schools showed no difference. However, there was no significant difference in test scores when the results were stratified by sex.

3.2. Sex Differences in Executive Functions

Table 3 shows that there was a significant improvement in the overall executive functions as measured by the pencil tap test when the pretest and the post-test scores were compared. Similarly, there was a difference in executive function between the pretest and post-test among children in School 1 (p = 0.02) but not in the other schools. Also, the males performed better than the females on the pencil tap test (p = 0.01).

3.3. Effect of the Intervention on Executive Function Performance

As shown by Figure 1 and Figure 2, Wilcoxon matched-pairs signed-rank test was used to investigate the unique contributions of the three intervention conditions (control, games and videos) to the executive function performance as measured by the two tests (Rapid Automated Naming test and Pencil tap test respectively). This set of predictors was not significantly associated with the change in EF scores on both the pencil tap and the Rapid Automatised Naming test, control (p = 0.09, 0.06) played games (p = 0.47, 0.53), and told stories (p = 0.89, 0.31).

Table 2. Association between demographic variables and RAN* scores

Variable	Number of participants	Executive function (EF) score [Median, (IQR)]		p-value*
		RAN pre-test	RAN post-test	
Overall	133	103 (86, 139)	102 (80, 127)	0.13
School				
1	16	**106 (94, 128)**	**92.5 (78, 117.5)**	**0.02**
2	18	93 (76, 126)	107 (80, 124)	0.44
3	44	**110 (86, 157)**	**100.5 (76, 126)**	**0.03**
4	25	102 (81, 129)	104 (93, 125)	0.76
5	30	100 (86, 127)	100 (79, 140)	0.58
Sex				
Male	60	107 (89.5, 139.5)	104.5 (83.5, 129)	0.39
Female	73	101 (83, 136)	98 (79, 120)	0.19

Note. * Wilcoxon matched-pairs signed-ranks test, EF = Executive Function, RAN= Rapid Automatised Naming test.

Table 3. Association between sex and pencil tap scores*

Variable	Number of participants	Executive function score [Median, (IQR)]		p-value*
		Pencil Tap pre-test	Pencil Tap post-test	
Overall	133	23 (12, 31)	26 (15, 33)	**0.03**
School				
1	16	22 (12.5, 30.5)	32 (27, 37)	**0.02**
2	18	26.5 (13, 32)	24.5 (13, 30)	0.48
3	44	27.5 (11.5, 37.5)	30 (18, 36)	0.12
4	25	23 (14, 30)	25 (12, 29)	0.60
5	30	25 (9, 25)	18.5 (10, 26)	0.44
Sex				
Male	60	21.5 (11.5, 30)	26 (15,33)	**0.01**
Female	73	23 (12, 32)	26 (15, 33)	0.43

Note. * Wilcoxon matched-pairs signed-ranks test, Pencil tap = executive function test.

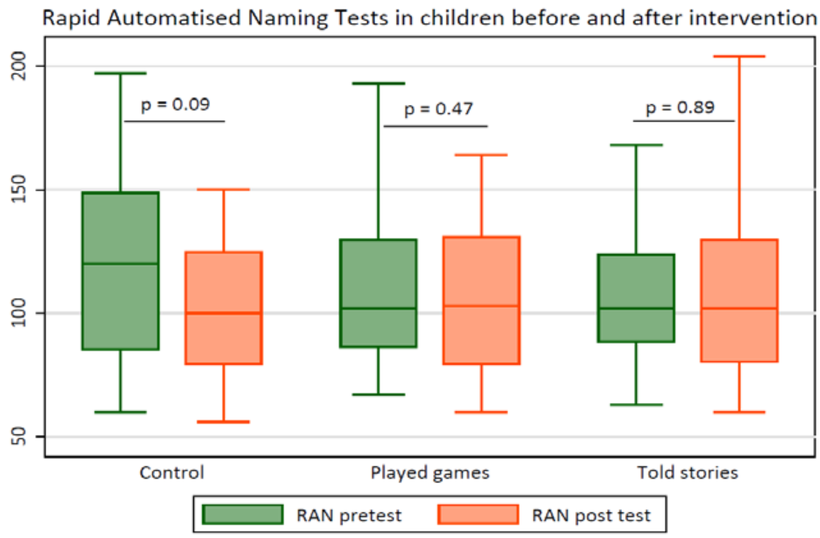

Figure 1. Rapid automated naming test by intervention condition

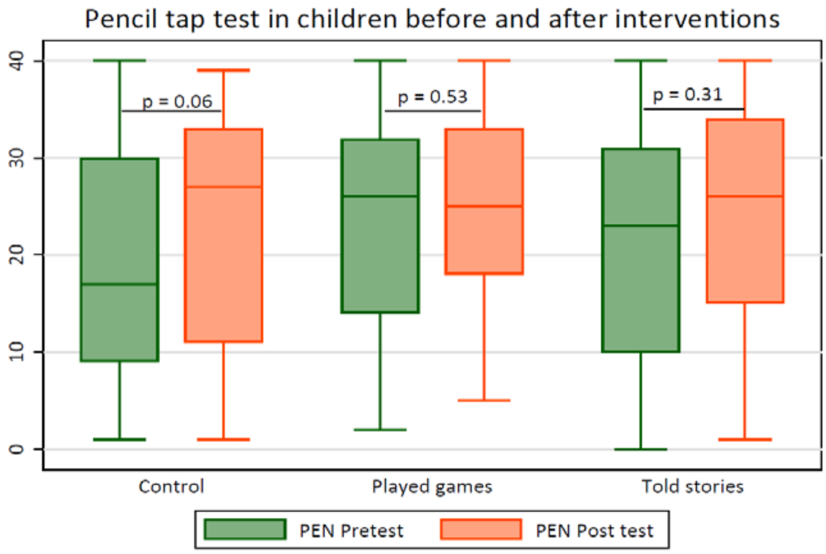

Figure 2. Pencil tap test by intervention condition

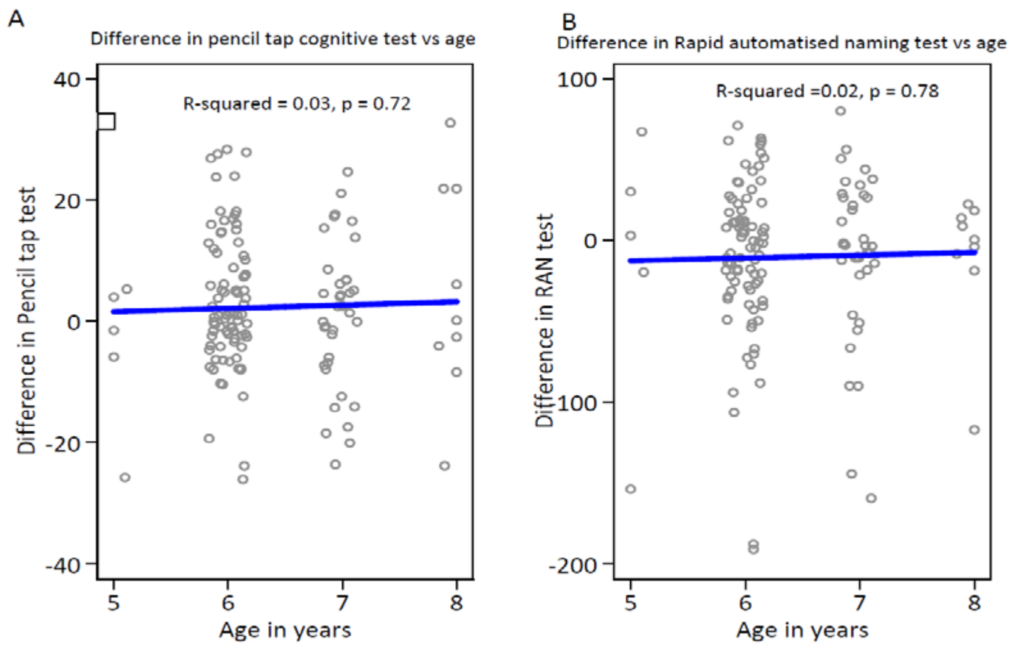

Figure 3. Age differences in Pencil tap and RAN composite EF scores

3.4. Age-related Differences in Executive Functions

There was no correlation between age and either the pencil tap (R^2 = 0.03, p = 0.72, see panel A) or the RAN (R^2 = 0.02, p = 0.78, see panel B) executive function scores as shown by Figure 3.

4. Discussion

The current study examined the relations of demographic variables (age, sex and school climate) to preschool executive functions as measured by validated direct local child assessments to gain an in-depth understanding of how Zambian public preschools nurture the development of childhood executive functions. This study provided two main findings. First, while sex and school variables were associated with executive functions, age was not related to executive functions assessed in this study. Second, passive videos that the participants viewed did not predict preschool executive functions.

4.1. Age and Executive Functions

The present study found that age was not related to preschool executive functions. Contrary to this finding, Loher & Roebers [66] showed that executive function components such as sustained attention continuously improved with age from 5 to at least 8 years. These findings have also been confirmed by several other studies [67,68,69]. It is crucial to conduct more executive function studies that consist of a wide range of age groups. There is wide consensus in the literature that age-dependent differences in executive functions among preschool children are attributed to brain maturation and development.

4.2. Sex and Executive Functions

In the current study, boys demonstrated higher executive function scores than girls partly due to specific Zambian cultural beliefs and practices and conditions that adversely affect the girl's cognitive development. With this understanding, there is no doubt that gender roles, which are constructed by society, would be related to executive functions in children. This finding is contrary to literature which reports that girls outperform boys on executive function tasks [27,70,71]. The low performance in executive function among girls may reflect the sex differences in the risk for neurocognitive impairments in Zambia [72], The sex differences in neurocognitive development could be attributed to adverse experiences such as girl child sexual abuse, abductions, menstruation, child marriages and limited educational opportunities for girls in Zambia.

The most apparent weakness with most of the studies that have found gender-related differences in executive functions in preschool children, however, is that their samples are drawn from high-income contexts where girl children are spared from child developmental risks, which are common in low-income countries like Zambia where girl children might be subjected to child abuse, limited educational opportunities and demanding sibling care which negatively affects cognitive development [39]. Lack of infrastructure for early education, inadequate teaching-learning materials, lack of trained personnel, poor funding to the education sector; poor community involvement among others makes the survival of girls difficult [65]. It may be helpful to broaden the scope of Western-based studies to include non-western child populations that have inadequate quality access to education. The aim of this study attempted to address this observed deficit in Western-based research.

4.3. School Variables and Executive Functions

This study found that school participation had a significant influence on executive functions. Several prior studies substantiate the current study findings that school variables including teacher practices, teacher-child engagement, classroom climate and organization affect executive function outcomes such as inhibitory control [73], language development, mathematics and emotional development [74]. However, the opposite is also true that teacher-child conflict is detrimental to cognitive development, especially adversely affecting key executive function processes including inhibitory control [75].

High-quality teacher-learner relationships such as positive emotional tone, teacher-approving behaviour and quality of instruction contribute to improved preschoolers' cognitive self-regulation [76].

One of the limitations of these studies is that they do not specify how these school outcomes were measured, such a finding is limited only to the setting investigated and cannot be easily generalised to other contexts. The association between school variables and executive functions confirms Vygotsky's theory emphasizing the role of significant knowledgeable others including teachers in stimulating child cognitive development [77]. The current study proposes interventions that encourage positive teacher-learner interactions, planning and organization, classroom management, and the opportunity for learners to work freely and creatively to enhance executive functions [78].

This study was conducted to determine the associations that exist between social-demographic factors such as school, age and gender. What is clear from this study is that sex and school variables were associated with executive functions and passive videos were not effective in preschool executive functions. This study is relevant for many reasons which include the following. First, the teachers' cognitive expectations of the preschool learners and teacher beliefs contribute to the executive functions of the learner. Second, school rules which constitute the context-specific regulation and expected classroom behaviour, all affect executive functions [76]. Girl child education needs to be prioritized if sex equality in access to basic social services is to be attained in Zambia.

5. Conclusion

Taken together, the contribution of this work in child neuropsychology validates the combined effect of both biological and environmental factors on executive function development in low-income preschoolers. Thus, emphasizing the biopsychosocial approach to studying cognitive development in learners. Four key implications emerge from the present study. First, the findings provide evidence that supports the Vygotskian socio-cultural theory in that the school environment contributes to improved executive functions by highlighting the need for implementation of teacher professional development programmes ineffective classroom practices and other proven preschool executive function interventions in Zambian public preschools. The associations between school variables such as classroom climate and teacher behaviours suggest that more needs to be done. For instance, the provision of quality early childhood education needs to be strengthened by motivated and qualified teachers, adequate teaching and play facilities in the preschools and teacher emotional support which have been found to predict school achievement and problem-solving in preschool-aged children.

Second, arising from the poor executive function performance on the part of girls, more effort should be directed towards girl child education for the increased provision of educational and enrichment opportunities to girls who are usually deprived of the basic cognitive stimulation experiences due to their higher risk of child sexual abuse, early marriages and poor access to education and health services [39]. Girl child education intervention programmes predict enrolment and retention in Zambia [45]. Third, effective parenting interventions need to be implemented in Zambia to promote holistic healthy child growth that fully supports brain maturation and development [79,80]. Additionally, the Zambian government's efforts to implement the recent Early Childhood Education (ECE) National Policy and Policy Implementation Plan, increased investment in publicly funded ECE, development of an ECE curriculum and establishment of an ECE directorate deserve support from all ECE stakeholders in Zambia. Finally, if there is a significant relationship between school variables and executive functions, the provision of high-quality preschools in low-income settings including rural areas in Zambia needs to be prioritised [43].

More progressive future research efforts should focus on the relations between parent-child engagements and executive functions in preschool learners attending private preschools which are largely unsupervised by the Ministry of General Education in Zambia. Second, research in this area needs to examine executive function interventions that are both scalable and cost-effective for low-income families in rural settings. Finally, cognitive training of executive function skills in public preschools needs to be prioritized and fully supported.

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