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Effect of Motor Skills on Cognitive Development of Children 3-10 Years in Tarka Local Government Area of Benue State

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Abstract

Background: Child development in the early years of life is characterized by constant biological, psychosocial, and emotional changes resulting in acquisition and refinement in the cognitive domain. This study assessed the effects of motor skills on cognitive development of children between 3 to 10 years in Tarka Local Government Area (LGA), Benue State.

Methods: The study employed a cross-sectional survey on a population of 64,934 children in Tarka LGA. A total of 382 participants were recruited through multistage sampling technique. The instruments used for data collection were, the Children's Memory Questionnaire-Revised (CMQ-R), the student's previous academic scores, the ADHD symptom list in the DSM-IV, the Alberta Language and Development Questionnaire (ALDeQ) and the Ages & Stages Questionnaires, Third Edition (ASQ-3). Using mean scores, standard deviation, and simple linear regression, all statistical analysis were performed

Results: The findings revealed that motor skills had effect on language learning of children. The regression analysis revealed no significant effect on language learning [p>.05] while motor skills had significant effect on academic performance; attention; and working memory [p<.05] in children in Tarka LGA.

Conclusion: Motor skills had significant effect on cognitive development of children. The effect varied within language learning and performance. Experts in early childhood should strive to identify children with poorly developed or delayed motor skills following transitions in schools.

Keywords: Motor Skills, Cognitive Development, Children, Language learning, Attention, Working Memory

Introduction

The development of children during the first years of life is characterized by constant biological, psychosocial, and emotional changes that result in significant acquisitions and refinements in the cognitive domain. The child's psychomotor development is an important factor in his or her development, as the environment-organism interaction can induce changes in the child′s motor skills.

In most developing countries, an estimated 99 million primary school-age children are out of school, and only 78% of them complete primary education. Of the 59 million primary school-age children out of school, 32 million, or more than half, live in sub-Saharan Africa. Sub-Saharan Africa also has the highest rate of exclusion, with 19% of primary school-age children deprived of education, followed by North Africa and West Asia (9%) and South Asia (7%) (UNESCO, 2019). Furthermore, children in some developing countries have significantly lower educational attainment than children in developed countries in the same classroom (Faulkner & Cain, 2013). In 12 African countries, surveys of children in Grade 6 (the end of primary school) found that an average of 57% did not achieve minimum reading proficiency (Byamugisha & Ssenabulya, 2015; Chimombo, Kunje, Chimuzu, Mchikoma, 2015).

Cognitive development refers to how children think, explore, and understand things. It involves the development of knowledge, skills, problem-solving abilities and character, helping children think and understand the world around them. Cognitive development is the process of building thinking processes, including memory, problem solving, and decision making, from childhood through adolescence and into adulthood (Schacter, 2019). According to Sellers, Machluf, and Bjorklund (2018), cognitive development is the emergence of a person's ability to know, understand, and consciously express one's understanding in adult language. Cognitive development is how a person perceives, thinks, and makes sense of his or her world through the relationship between genetic factors and learning. Areas of cognitive development include information processing, intelligence, reasoning, language development, and memory.

Motor skills, on the other hand, refer to the ability to control the movement of the body. To perform motor skills, the human brain, muscles, and nervous system must work together. A person′s ability to coordinate movements is determined by the ability to perform the desired function using these motor skills. Motor skills are functions that involve specific movements of the body to perform a certain task. These tasks can include walking, running, or even cycling. To achieve this skill, the body's nervous system, muscles, and brain must work together (Stallings, 2013). The goal of motor skills is to optimize the ability to perform a skill successfully and accurately, while reducing the energy expenditure required to perform the skill. Performance is the act of performing a skill or motor task. Repeated practice of a particular motor skill will result in significant improvements in performance, resulting in motor learning. Motor learning is a relatively permanent change in the ability to perform a skill as a result of repeated practice or experience.

Historically, there have been different views on the relationship between motor skills and cognitive development in children. On the one hand, motor and cognitive skills have been considered to be completely different processes that develop independently and involve different brain regions (van der Fels, te Wierike, Hartman, Elferink-Gemser, Smith & Visscher, 2015). There are several explanations for the possible relationship between motor skills and cognition in children. A second explanation for the relationship between motor skills and cognitive skills is that these skills may have a similar developmental timeline with more rapid development between ages 5 and 10 (Anderson, Anderson, & Northam, 2011). These possible explanations highlight a need to explore how motor skills relate with cognitive skills and whether the link is specific to certain categories of skill.

Since Piaget's original observations, several studies have reported evidence for relations between motor skills and development in seemingly unrelated domains – such as object perception, face processing, and language skills. For example, object exploration skills have been found to facilitate object segregation abilities in 3-month-old infants (Libertus, & Violi, 2016)). At the same age, early experiences of successful reaching have been found to encourage infants' attention to faces over objects (Libertus & Needham, 2011). Similarly, the onset of independent sitting around 5–7 months has been associated with improved 3-D object completion (Oudgenoeg-Paz et al., 2017) and a temporary disruption in infant's holistic face processing skills (Cashon et al., 2013). Finally, two studies have reported associations between the onset of independent walking and language development in 10- to 14-month-old infants, with walking infants showing larger vocabularies than crawling infants (Walle & Campos, 2014; He et al., 2016). Together, these findings demonstrate that the acquisition of a new motor skill (reaching, sitting, or walking) has consequences for infants' concurrent abilities in the cognitive domain of language learning, academic achievement, attention and working memory.

Studies have also found a relationship between various motor skills and attention in children. The relation between gross motor skills and attention is often explained by an overlap in brain areas that are important for both gross motor skills and attention demands (Diamond, 2010; Leisman, Moustafa & Shafir, 2016). Neural networks including the frontal, parietal and motor cortices are not only underlying executive functions, but are also highly involved in gross motor tasks. In addition, the cerebellum and basal ganglia, crucial for motor skills, are also involved in attention (Diamond, 2010; Bielova, & Konopliasta, 2023). These relations are supported by longitudinal studies showing that better motor skills at baseline are related to better attentional and preparatory processes, which are mainly expressed in the premotor and motor cortex, and the fronto-parietal network, during a working memory task (Ludyga, Mücke, Kamijo, Andrä, Pühse & Gerber, 2020). Regarding a possible relation of motor ability and working memory Lehmann, Quaiser-Pohl and Jansen (2014) showed that balance was positively correlated with different aspects of working memory. Impairments in working memory have been observed in children with developmental coordination disorder. Consistent with this finding, an extracurricular motor coordination activity program improved performance on tasks requiring higher working memory demands in prepubertal children (Kamijo, Pontifex, O'Leary, Scudder, Wu, Castelli, 2011).

Advances in neuroscience have led to significant progress in linking physical activity to brain structure and cognitive development (Donnelly et al., 2016). Physical activity is thought to have a positive effect on cognitive function, in part due to physiological changes in the body. For example, increased levels of brain-derived neurotrophic factor (BDNF) promote learning and preserve cognitive function by enhancing synaptic plasticity and acting as a neuroprotectant, leading to improved neuroelectrical activity and increased cerebral blood flow (Mualem et al., 2018). It has also been suggested that a person's motor skills may influence cognitive development, as motor and cognitive skills share some common underlying processes, such as sequencing, monitoring, and planning (Van Der Veer, Kamphorst, Cantell, Minnaert & Houwen, 2020). Furthermore, both motor and cognitive skills follow similar developmental timelines and may accelerate during childhood. Indeed, the literature consistently reports that increased physical activity at school does not negatively impact academic achievement, but rather may improve academic performance, executive function, and task-related behaviour in children and adolescents (Zeng et al., 2017). Furthermore, recent studies suggest that active children tend to be healthier and have better cognitive abilities than less active children. Although interest in the relationship between motor skills and cognitive function has increased over the past decade, most of the literature on the benefits of motor skills on cognitive function has been featured in studies of teenagers or adults. Unfortunately, there are currently no comprehensive studies that specifically investigate the effectiveness of physical activity on cognitive abilities in early childhood (Timmons et al., 2012).

Early childhood is the most critical period in a person's life for complete and healthy motor and cognitive development (UNICEF, 2017). Advanced motor skills may have beneficial effects on cognitive functions throughout childhood and adolescence. Therefore, it is important to gain a deeper understanding of the potential of motor skills to improve cognitive abilities in young children, which can inform paediatricians and other health professionals on the effectiveness of physical activity as an intervention strategy. There is an urgent need to assess the effect of motor skills on domains of cognitive development in paediatric populations in Tarka LGA of Benue State. Specifically, the study is set to assess the effect of motor skills on;

1. language learning in children 3 – 10 years in Tarka LGA of Benue State.
2. academic achievement in children 3 – 10 years in Tarka LGA of Benue State. (in your abstract, you captured performance)
3. attention in children 3 – 10 years in Tarka LGA of Benue State.
4. working memory in children 3 – 10 years in Tarka LGA of Benue State.

Material and Methods

Study Design: The research design that was used for this study was cross-sectional survey research design. Survey research design concerns itself with the present and attempts to determine the current status of the phenomena under investigation.

Study Location: The study was undertaken in Tarka LGA of Benue State located in north central Nigeria and lies between longitude $8^0$45′ and $9^0$00′E and latitude $7^0$30′ and $7^0$45′N..

Sample size: A total of 382 participants were selected for the study.

Population: The population of the study comprised all children 0 – 10 years in Tarka LGA. The population of Tarka LGA as at the time of study was estimated to be 210,823 (NPC, 2021). Given that children 0 – 10 years account for 30.8% of this population, the estimated number of children 0 – 10 years in Tarka LGA is 64,934.

Sample and Sampling: a total of 382 were selected. They were recruited using the multistage sampling technique.

Stage 1: In the first stage, Tarka LGA was stratified into 10 council wards.

Stage 2: in the second stage, one primary school was selected from each of the council wards giving a total of 10 schools.

Stage 3: in stage three, Simple random sampling technique was used to select the participants in each of the sampled households.

Instrumentation: The instruments used for data collection were; the Children's Memory Questionnaire-Revised (CMQ-R) which provided indicators of Working Memory, the student′s previous academic scores which provided an indicator of academic achievement, the ADHD symptom list in the DSM-IV which provided three indicators of attention (inattention, hyperactivity and impulsivity), the Alberta Language and Development Questionnaire (ALDeQ) which provided an indicator of infants′ language learning and the

Ages & Stages Questionnaires, Third Edition (ASQ-3) which provided an indicator of child's motor skills.

The Ages and Stages Questionnaire (ASQ) is a parent-completed questionnaire that may be used as a general developmental screening tool. The ASQ was designed and developed by J. Squires and D. Bricker at the University of Oregon and can be completed by parents in 12-18 minutes. The ASQ-3 is a parent reported initial level developmental screening instrument consisting of 21 intervals, each with 30 items in five areas: (i) personal social, (ii) gross motor, (iii) fine motor, (iv) problem solving, and (v) communication for children from 2-66 months. The instrument has a Kaiser-Meyer-Olkin (KMO) measure reliability coefficient of 0.87, Coefficient alpha measuring internal consistency of 0.97, Test-retest reliability results were robust with an intraclass correlation coefficient of 0.94.

The Alberta Language and Development Questionnaire (ALDeQ) was developed by Paradis, Emmerzael, & Sorenson Duncan, (2010). The ALDeQ consists of questions for parents concerning the early and current development of a child's first language. The purpose is to understand whether there may be evidence of delay or difficulties in the first language. The ALDeQ consists of sections on the following topics: Early milestones; Current first language abilities; Behaviour patterns and activity preferences; and Family history. The ALDeQ includes rating scale responses that yield a proportion score between 0 and 4, where higher scores are more consistent with typical development. Administering the ALDeQ takes approximately 30 minutes. The ALDeQ yielded a canonical correlation value in the moderate range, and the model yielded a similar canonical correlation value to the ALDeQ total score model: .973 and .967, respectively. This considers the instrument highly valid for assessing children's language development.

ADHD symptom list in the DSM-IV consists of the 18 items. The first nine items covered inattention symptoms, and the others referred to hyperactivity and impulsivity. For each item, parents selected the answer that best described the frequency of the behavior being rated. The frequency of each type of behaviour or symptom was scored on a four-point Likert scale, ranging from 0 (Not true at all, never, seldom) to 3 (Very much true, very often, very frequent). The instrument has a reliability coefficient of .956. The subscales inattention had a Cronbach Alpha coefficient of 948, hyperactivity had a Cronbach Alpha coefficient of .927 while impulsivity had .934. This makes the instrument highly valid for use in assessing children's attention.

The Children's Memory Questionnaire-Revised (CMQ-R) is a 36-item questionnaire designed to assess parents' perceptions of their children's memory. The CMQ-R primarily presents statements that query everyday memory, such as ''Forgets where he/she has put something.'' The CMQ-R requires parents to assess their child's memory based on five possible options: 1¼ never or almost never happens; 2¼ happens less than once a week; 3¼ happens once or twice in a week; 4¼ happens about once a day; and 5¼ happens more than once a day. The CMQ-R has a strong test–retest reliability (r¼.87, p<.05), and internal consistency (Cronbach's alpha .97).

Statistical analysis: Data collected were analyzed using descriptive statistics of Mean and Standard Deviation to answer the research questions, while inferential statistic of simple linear regression was employed to test the effect of motor skills on cognitive development. The ALDEQ which is rated using a 4-point format of data as 4= Very Much, 3= Sometimes, 2= Rarely, and 1= Never had a mean benchmark calculated thus; $\frac{4+3+2+1}{4} = 2.50$

For the academic performance which was scored according to grades A = 5, B = 4, C = 3, D = 2, and F = 1 had a mean benchmark calculated thus: $\frac{5+4+3+2+1}{5}$ = 3.0

For the ADHD symptom list in the DSM-IV which was rated using a 4-point modified likert type scale of data as 4= Very Much, 3= Sometimes, 2= Rarely, and 1= Never had a mean benchmark calculated thus; $\frac{4+3+2+1}{4}$ = 2.50.

For the CMQ–R which was scored on a likert scale as More than once a day = 5, Once a day = 4, C Once or twice a week = 3, D Less than once a week = 2, and Never = 1 had a mean benchmark calculated thus: $\frac{5+4+3+2+1}{5}$ = 3.0.

Therefore, any item with a mean value of above the respective benchmarks was accepted and vise versa. Linear regression analyses using the Enter method were conducted between motor skills and the domains of cognitive development (language learning, academic performance, attention, and working memory). P-values < .05, were considered significant and null hypotheses were rejected and when P>.05 it was considered Not Significant and null hypotheses accepted. The Statistical Package for Social Sciences (SPSS) was used in coding and analysing the data to avoid any human errors imminent in a manual analysis.

Results

Table 1: Mean Distribution on Domains of Cognitive Development in Children

Item	$\bar{X}$	STD
Motor Skills	2.23	.53
Language Learning	3.04	.92
Academic Performance	4.69	1.31
Attention	3.01	. 91
Working Memory	3.41	1.24

$\bar{X}$ = Mean; STD = Standard Deviation

Children had high means in all domains of cognitive development (Table 1). The mean motor skills score was 2.23 which is higher than the benchmark of 2.0. children also had a mean language learning of 3.04 which is above the cut-off point of 2.50, a mean academic performance score of 4.69 which is above the cut-off point of 3.00, mean attention score of 3.01 which is above the cut-off point of 2.50 and a mean working memory score of 3.41 which is above the cut-off point of 3.00. Since all the domains had mean scores that are greater than their respective benchmarks. This implies that motor skills has an effect on all the domains of cognitive development studied. It had the most effect on academic performance (mean = 4.69). Join the paragraph

To investigate further the effect of motor skills on cognitive development, we used simple linear regression analysis to test for the effect of motor skills on each domain of cognitive development (language learning, academic performance, attention, and working memory).

Table 2: Summary of Linear Regression showing Effect of Motor Skills on Cognitive Development in Children

Variable	Mean	SD	R	R^2	F	β	t	P
Motor Skills	2.23	.530						
Language Learning	3.04	.917	.17	.03	5.47	.17	2.72	.076
Academic Performance	4.69	1.31	.68	.46	334.25	.68	18.28	.00
Attention	3.01	0.91	.79	.63	636.64	.79	25.23	.00
Working Memory	3.41	1.24	.87	.75	1144.70	.87	33.83	.00

R=Correlation Coefficient; R^2=Coefficient of Determination; F=F-Statistic; t=t-Statistic; p=p-Value.

Table 2 presents the summary of linear regression analysis on effect of motor skills on language learning in children 3-10 years. Results available show that motor skills have no significant effect on language learning in children in Tarka LGA [R = .17, R^2 = .03, F = 5.47, t = 2.72, *p =.076* > .05]. This means that motor skills contributes only 3.0% to changes in language learning. On the other hand, motor skills had a significant effect on academic performance [R = .68, R^2 = .46, F = 334.25, t = 18.28, p =.00 < .05], attention [R = .79, R^2 = .63, F = 636.64, t = 25.23, p =.00 < .05], and working memory [R = .87, R^2 = .75, F = 1144.70, t = 33.83, *p* = .00< .05]. This means that motor skills contribute 46.0%, 63.0%, and 75.0% to changes in academic performance, attention and working memory respectively in children. The positive t-values indicate that motor skills have a positive effect on academic performance, attention and working memory.

Discussion

The findings of the study revealed that motor skills has an effect on language learning in children. However, results of the regression analysis revealed that this effect is not significant [R = .17, R^2 = .03, F = 5.47, t = 2.72, p > .05]. This means that motor skills have no contribution to changes in language learning in children. With these new advances, children begin to develop and refine basic skills that are related (both directly and indirectly) to the development of communication and language. One possible explanation for the lack of a significant relationship in this study is that language learning is more strongly influenced by cognitive and social factors rather than motor development. Language acquisition relies heavily on auditory processing, memory, and exposure to verbal interactions, all of which are primarily cognitive rather than motor-based processes (Snowling & Hulme, 2021). Moreover, research has shown that linguistic input, parental communication styles, and educational environments have a far greater impact on language development than motor coordination (Hoff, 2013). Thus, while motor skills may play an indirect role—such as through gestural communication in infancy (Özçalışkan & Goldin-Meadow, 2010)—they do not appear to be a strong determinant of overall language learning. When compared to other recent studies, the results of this study align with some findings but contradict others. For instance, a large-scale study by Wang et al. (2019) found only a modest association between fine motor skills and early literacy but no significant link between motor coordination and spoken language development. This supports the idea that while motor skills might contribute to writing and reading readiness, they do not directly influence language comprehension or verbal expression. On the other hand, research by Gooch et al. (2014) found a moderate link between motor coordination and phonological processing in children with developmental disorders, suggesting that any observed relationship may be more relevant in children with atypical development rather than the general population. Another key factor to consider is the role of age and developmental stage. Some studies have reported that motor skills have a stronger influence on language development in infancy and toddlerhood than in later childhood (Leonard & Hill, 2014). In younger children, motor activities such as reaching, grasping, and gesturing are often precursors to speech development, but as children grow older, their language skills become more reliant on cognitive and environmental factors rather than physical coordination (Iverson, 2010). This may explain why the current study, which likely included children beyond infancy, found no significant effect of motor skills on language learning. Sociocultural and educational contexts may also influence the findings. In some populations, children engage in more motor-based learning activities, such as play-based or Montessori-style education, where fine motor skills are integrated with early literacy development (Lillard, 2013). In contrast, in environments where language learning is primarily taught through direct instruction and auditory exposure rather than hands-on activities, the link between motor skills and language learning may be weaker. The setting of this study might not have provided enough emphasis on motor-based language learning approaches, which could contribute to the nonsignificant results.

However, motor skills was found to have a significant effect on academic performance in children in Tarka LGA [$R = .68$, $R^2 = .46$, $F = 334.25$, $t = 18.28$, $p < .05$]. The findings indicate a strong and significant relationship between motor skills and academic performance in children in Tarka LGA. Nearly half of the variance in academic performance can be attributed to motor skills. This supports the growing body of research emphasizing the link between motor development and cognitive functions essential for learning. The positive correlation ($R=.68$) signifies that children with better-developed motor skills tend to perform better academically, aligning with the study by Macdonald, Milne, Orr and Pope (2020) who investigated the associations between motor proficiency and academic performance in mathematics and reading in year 1 school children. A significant moderate positive association was found between total motor composite and mathematics composite scores ($r = .466$, $p < .001$). Fine manual control composite scores were significantly associated with both mathematics ($rs = .572$, $p < .001$) and reading ($rs = .476$, $p = .001$) composite scores. One possible explanation for this relationship lies in the role of motor skills in cognitive development. Motor control and cognitive processes share common neural pathways, particularly in the cerebellum and prefrontal cortex, which are responsible for executive functions such as memory, attention, and problem-solving. This neurological overlap explains why children who engage in activities that enhance motor skills also demonstrate improvements in academic-related cognitive abilities. This echoes the finding of Stöckel and Hughes (2016) who found that early childhood interventions focused on motor skill development can significantly enhance literacy and numeracy skills by improving neural efficiency in areas associated with learning. These findings have significant implications for education, health policy, and community development. From an educational perspective, there is a need to integrate structured motor skill development into school curricula, particularly in early childhood education. Movement-based learning approaches, such as incorporating kinesthetic activities into literacy and numeracy instruction, have been shown to enhance academic outcomes by reinforcing neural connections between motor and cognitive functions. Teacher training programs should also emphasize the importance of motor development in learning, equipping educators with strategies to incorporate physical activity into classroom instruction.

We found that motor skills have a significant effect on attention in children in Tarka Local Government Area [$R = .79$, $R^2 = .63$, $F = 636.64$, $t = 25.23$, $p < .05$]. This means that motor skills contribute 63.0% to changes in attention in children. The relationship coefficient ($R=.79R=.79$) shows a tall positive affiliation, meaning that children with better-developed engine aptitudes tend to display more prominent attentional capacity. The coefficient of assurance ($R^2=.63$) suggests that engine abilities clarify 63% of the fluctuation in consideration, underscoring their critical part in cognitive forms related to center and concentration. The F-value ($F=636.64$) and t-value ($t=25.23$) advance affirm that this relationship is factually strong, whereas the p-value (p<.05p<.05) establishes its significance, ruling out the likelihood that the results occurred by chance. This finding is consistent with Best and Miller (2020) which found that motor and cognitive functions share overlapping neuronal networks, particularly in the prefrontal cortex, cerebellum and basal ganglia. Bearing these in mind, Health policies should prioritize physical activity programs that promote both fine and gross motor development as a means to enhance attention regulation. School-based physical education should be designed not only for physical fitness but also for cognitive benefits, ensuring that children engage in activities that improve coordination and executive functioning. Policymakers should advocate for increased access to structured play environments, particularly in underserved areas, to support children's motor and cognitive development. Additionally, parental education programs should emphasize the role of motor activities in attention training, encouraging parents to involve their children in play-based activities that enhance focus and self-regulation.

Motor skills had a significant effect on working memory in children in Tarka Local Government Area [R = .87, R^2 = .75, F = 1144.70, t = 33.83, p < .05]. This means that motor skills contribute 75.0% to changes in working memory in children. Thus, motor coordination was significantly associated with working memory in children. This finding suggests the possibility of specific relationships between working memory and certain aspects of motor coordination. The cerebellum contributes to cognitive processes that rely on internal speech, namely, verbal short-term memory or WM. Consequently, it appears that the cerebellum may play an important role when understanding the relationships found between specific aspects of motor coordination and cognitive areas such as working memory. The correlation coefficient (R=.79) suggests a high positive association, implying that children with better-developed motor skills tend to exhibit superior working memory capacity. The coefficient of determination (R2=.63) shows that motor skills account for 63% of the variance in working memory, suggesting that motor development plays a crucial role in shaping children's cognitive abilities. The F-value (F=636.64) and t-value (t=25.23) confirm that the relationship is statistically significant, Comparing these findings to other recent studies, the strong relationship between motor skills and working memory observed in this study is consistent with global research trends. For example, Ludyga et al. (2020) conducted a meta-analysis on the effects of motor skills on executive function and found that children with higher levels of motor coordination consistently outperformed their peers in working memory tasks. The researchers attributed this to the role of movement-based activities in enhancing neural plasticity and attentional control. Similarly, a study by Schmidt et al. (2017) reported that children who participated in structured physical exercise programs, including coordination and balance training, showed significant improvements in working memory compared to those who engaged in sedentary activities. However, some studies suggest that the relationship between motor skills and working memory may be influenced by additional factors such as age, socioeconomic background, and educational interventions. For instance, Cameron et al. (2016) found that while motor skills predicted working memory performance in younger children, the effect diminished in older children, possibly due to increased reliance on academic skills and cognitive training rather than motor-based learning. These findings have important implications for education, health policy, and child development interventions. Given the strong relationship between motor skills and working memory, schools should incorporate movement-based learning strategies to enhance cognitive development. Activities such as kinesthetic learning, interactive play, and physical education programs can improve both motor proficiency and working memory capacity. Policymakers should advocate for structured motor development programs in early childhood education to support cognitive skills essential for academic success. Additionally, parental awareness campaigns should emphasize the importance of motor activities in enhancing working memory and overall cognitive development.

Conclusion

Motor skills are integral to cognitive and academic development but do not significantly influence all domains equally. The strong links between motor proficiency and academic performance, attention, and working memory suggest that structured physical activity and motor training programs should be prioritized in early childhood education and public health policies. Given the well-documented benefits of physical activity on executive function, Experts in early childhood should strive to identify children with poorly developed or delayed motor skills following transitions in schools.

References

Anderson, V. A., Anderson, P., Northam, E., Jacobs, R. & Catroppa, C. (2011). Development of executive functions through late childhood and adolescence in an Australian sample. *Developmental Neuropsychology, 20*(1), 385-406.

Best, J. R., & Miller, P. H. (2020). A developmental perspective on executive function: A framework for cognitive development. *Psychological Bulletin*, *136*(1), 139-163.

Bielova, O., Konopliasta, S. (2023). Description of kinesthetic and kinetic motor praxis in older preschool children with logopathology. *Pedagogy of Physical Culture and Sports, 27*(5), 386-95.

Byamugisha, A. & Ssenabulya, F. (2015). *The SACMEQ II Project in Uganda: A Study of the Conditions of Schooling and the Quality of Education*. Harare: SACMEQ

Cameron, C. E., Brock, L. L., Murrah, W. M., Bell, L. H., Worzalla, S. L., Grissmer, D., & Morrison, F. J. (2016). Fine motor skills and executive function both contribute to kindergarten achievement. *Child Development, 83*(4), 1229-1244.

Cashon, C. H., Ha, O-R., Allen, C. L. & Barna, A. C. (2013). A U-Shaped Relation between Sitting Ability and Upright Face Processing in Infants. *Child Development, 84*(3), 802–809.

Chimombo, J., Kunje, D., Chimuzu, T. & Mchikoma, C. (2015). The SACMEQ II project in Malawi: A study of the conditions of schooling and the quality of education. *SACMEQ Policy Research Report*, IIEP.

Diamond, A. (2010). The evidence base for improving school outcomes by addressing the whole child and by addressing skills and attitudes, not just content. *Early Education and Development, 21*(5), 780–793.

Donnelly, J. E., Hillman, C. H., Castelli, D., Etnier, J. L., Lee, S., Tomporowski, P., Lambourne, K., & Szabo-Reed, A. N. (2016). Physical activity, fitness, cognitive function, and academic achievement in children: A systematic review. *Medicine and Science in Sports and Exercise, 48*(6), 1197–1222.

Faulkner, V. & Cain, C. (2013). Improving the mathematical content knowledge of general and special educators evaluating a professional development module that focuses on number sense. Teacher education and special education. *The Journal of the Teacher Education Division of the Council for Exceptional Children*, *36*, 115-131.

Fernandes, V. R., Ribeiro, M. L., Melo, T., de Tarso Maciel-Pinheiro, P., Guimarães, T. T., Araújo, N. B., Ribeiro, S., & Deslandes, A. C. (2016). Motor Coordination Correlates with Academic Achievement and Cognitive Function in Children. *Frontiers in psychology, 7,* 318.

Gooch, D., Hulme, C., Nash, H. M., & Snowling, M. J. (2014). The development of executive function and language skills in the early school years. *Journal of Child Psychology and Psychiatry*, *55*(2), 180-187.

Hoff, E. (2013). Language development. Cengage Learning.

He, K., Zhang, X., Ren, S., & Sun, J. (2016). Deep residual learning for image recognition. Proceedings of the *IEEE Conference on Computer Vision and Pattern Recognition* (pp. 770-778).

Iverson, J. M. (2010). Developing language in a developing body: The relationship between motor development and language development. *Journal of Child Language*, *37*(2), 229-261.
Kamijo, K., Pontifex, M. B., O'Leary, K. C., Scudder, M. R., Wu, C. T., Castelli, D. M., & Hillman, C. H. (2011). The effects of an afterschool physical activity program on working memory in preadolescent children. *Developmental Science, 14*(5), 1046–1058.
Lehmann, J., Quaiser-Pohl, C., & Jansen, P. (2014). Correlation of motor skill, mental rotation, and working memory in 3- to 6-year-old children. *European Journal of Developmental Psychology, 11*(5), 560–573.
Leisman, G., Moustafa, A. A., & Shafir, T. (2016). Thinking, Walking, Talking: Integratory Motor and Cognitive Behaviour. *Frontiers in Public Health, 4*(94). https://doi.org/10.3389/fpubh.2016.00094
Leonard, H. C., & Hill, E. L. (2014). Review: The impact of motor development on typical and atypical social cognition and language: A systematic review. *Child and Adolescent Mental Health, 19*(3), 163-170.
Libertus, K., & Needham, A. (2011). Reaching experience increases face preference in 3-month-old infants. *Developmental Science*, *14*(6), 1355–1364.
Libertus, K., & Violi, D. A. (2016). Sit to Talk: Relation between Motor Skills and Language Development in Infancy. *Frontiers in Psychology, 7*, 475. https://doi.org/10.3389/fpsyg.2016.00475
Lillard, A. S. (2013). *Montessori: The science behind the genius*. Oxford University Press.
Ludyga, S., Mücke, M., Kamijo, K., Andrä, C., Pühse, U., Gerber, M., & Herrmann, C. (2020). The Role of Motor Competences in Predicting Working Memory Maintenance and Preparatory Processing. *Child Development*, *91*(3), 799–813.
Macdonald, K., Milne, N., Orr, R., & Pope, R. (2020). Associations between motor proficiency and academic performance in mathematics and reading in year 1 school children: a cross-sectional study. *BMC Pediatrics, 20*(1), 69. https://doi.org/10.1186/s12887-020-1967-8
Mualem, R., Leisman, G., Zbedat, Y., Ganem, S., Mualem, O., Amaria, M., Kozle, A., Khayat-Moughrabi, S., & Ornai, A. (2018). The effect of movement on cognitive performance. *Frontiers in Public Health, 6,* 23-34. DOI: 10.3389/fpubh.2018.00100
Oudgenoeg-Paz, O., Mulder, H., Jongmans, M. J., van der Ham, J. M., & Van der Stigchel, S. (2017). The link between motor and cognitive development in children born preterm and/or with low birth weight: A review of current evidence. *Neuroscience & Biobehavioral Reviews, 80*, 382-393.
Özçalışkan, S., & Goldin-Meadow, S. (2010). Sex differences in language first appear in gesture. *Developmental Science*, *13*(5), 752-760.
Rigoli, D., Piek, J. P., Kane, R., & Oosterlaan, J. (2012). An examination of the relationship between motor coordination and executive functions in adolescents. *Developmental Medicine and Child Neurology, 54*(11), 1025–1031.
Schacter, D. L. (2019). Implicit memory, constructive memory, and imagining the future: A career perspective. *Perspectives on Psychological Science, 14*(2), 256–272.
Schmidt, M., Egger, F., Conzelmann, A., & Dahmann, R. (2017). Cognitive functions and physical activity in elementary school children: A randomized controlled trial. *Journal of Sport and Exercise Psychology*, *39*(5), 377-387.
Sellers, P. D. II, Machluf, K., & Bjorklund, D. F. (2018). The development of evolutionarily adaptive individual differences: Children as active participants in their current and future survival. In V. Zeigler-Hill & T. K. Shackelford (Eds.), Th*e SAGE handbook of personality and individual differences: Origins of personality and individual differences* (pp. 203–217).
Snowling, M. J., & Hulme, C. (2021). *Reading development and dyslexia*. Wiley Blackwell.
Stöckel, T., & Hughes, C. M. (2016). The relation between motor skill development and cognitive abilities in children. *Human Movement Science*, *49*, 344-351. Sage Reference.
Tseng, M. H., Henderson, A., Chow, S. M., & Yao, G. (2014). Relationship between motor proficiency, attention, impulse, and activity in children with ADHD. *Developmental Medicine & Child Neurology, 46*(6), 381–388.
UNESCO (2019). *Out-of-school children, adolescents and youth: Global status and trends*. Fact Sheet no. 56. UNESCO Institute for Statistics.

UNICEF, Early childhood development, 2017, https://www.unicef.org/dprk/ecd.pdf.

Van Der Fels, I. M. J., Te Wierike, S. C. M., Hartman, E., Elferink-Gemser, M. T., Smith, J. & Visscher, C. (2015). The relationship between motor skills and cognitive skills in 4–16 year old typically developing children: A systematic review. *Journal of Science and Medicine in Sport*, *18*(6), 697–703.

van der Veer G., Kamphorst E., Cantell M., Minnaert A. & Houwen S. (2020). Task-specific and latent relationships between motor skills and executive functions in preschool children. *Frontiers in Psychology, 11*. DOI=10.3389/fpsyg.2020.02208.

Walle, E. A., & Campos, J. J. (2014). Infant language development is related to the acquisition of walking. *Developmental Psychology, 50*(2), 336–348.

Wang, T., Lekhal, R., Aarø, L. E., & Schjølberg, S. (2019). Co-occurring development of motor, language, and social skills from infancy to childhood: A longitudinal study. *Child Development*, *90*(4), 823-838.

Zeng, N., Ayyub, M., Sun, H., Wen, X., Xiang, P. & Gao, Z. (2017). Effects of physical activity on motor skills and cognitive development in early childhood: A systematic review. *BioMed Research International,* 2760716. https://doi.org/10.1155/2017/2760716.