Construct and Predictive Validity of Head-Toes-Knee-Shoulder (HTKS) Test as a Measure of Executive Function of Children in Pre-primary O-Classes in Ethiopia

Belay Hagos Hailu*

Received: 8 January 2025; Accepted: December 30 2025

Abstract: *Executive Functions are the cognitive abilities needed to control and regulate one's thoughts, emotions and actions, which are necessary skills for learning, problem solving, coping and adapting with challenges. The purpose of this study was to determine the validity of the HTKS test as a measure of executive function and relate it to academic skills such as emergent mathematics and literacy skills. The research questions were: 1) Is the Head Toes Knee Shoulder (HTKS) Test a reliable and valid measure of executive function? 2) Does executive function predict emergent literacy and mathematics performance of preschool children enrolled in O-class? 3) Do gender, age, regional location account for the contributions of executive functions on emergent literacy and mathematics performance? Cross sectional survey research method was employed and data was collected from 2,515 O-class preschool children (with 50% females) in five regional states of Ethiopia where 98% of the sample were between 5 and 8 years old. Data was collected using the Measure of Early Learning Quality and Outcome (MELQO) with the following sub-tests: emergent mathematics and literacy, executive functions. Reliability and validity of the MELQO tools were established during the pilot phase as well as during the main study and showed sound psychometric characteristics. Data was analyzed using t-test, confirmatory factor analysis and hierarchical multiple linear regression. Results showed that the HTKS test was both reliable and valid measure of executive function. Furthermore, there were no statistically significant difference between boys and girls in emergent literacy, mathematics and in executive function scores. Finally, results revealed that children's executive function significantly predicted performance on emergent literacy and mathematics after controlling the effects of age and regional variations. About 14.3% and 15% of the unique variance on the emergent literacy and mathematics was respectively associated with executive function. In conclusion, executive function skills were found to be good predictors of academic skills and need to be considered in school readiness programs.*

* Associate Professor of Education, Department of Special Needs and Inclusive Education, College of Education and Language Studies, Addis Ababa University.

Background

Investing in early years of human development was found to yield a huge social and economic return at individual and societal levels. For example, some studies show that there is roughly about $ 8.6 gains for society for every 1USD invested in early childhood care and education (Heckman et al., 2010). Investment in early childhood education and development not only improves quality of education but it has also a great potential to break poverty cycle.

Early childhood education programs are set up with the purpose of enhancing children's readiness for the formal schooling. Contents of school readiness programs usually focus on socio-emotional development, fine and gross motor skills, cognitive and language skills and emergent literacy and numeracy skills. Teaching learning in pre-primary education ideally follows play-based active learning methodology where choice of the learner on what to play, do and tell is emphasized. Besides, the facilitator's role is on creating more opportunities for children including more open ended questions for children to reflect on their experiences. There is a need for optimal early intervention as early childhood years are critical for rapid brain, cognitive and language development. The human brain develops most markedly in the first five years of life.

Executive Function

Executive function skills are "the mental processes that enable us to plan, focus attention, remember instructions, and juggle multiple tasks successfully. …the brain needs this skill set to filter distractions, prioritize

tasks, set and achieve goals, and control[1] impulses." Executive Functions are the cognitive abilities needed to control and regulate our thoughts, emotions and actions: behavioral controls, cognitive controls and emotional controls. Executive functions are skills necessary for learning, solving problems, coping and adapting with emerging challenges. Executive functions could be described in terms of response inhibition, cognitive flexibility, working memory, and self-regulation.

Theoretical perspectives on executive function carry the nature vs. nurture controversy, with more emphasis on either biological determinants or environmental influences as points of arguments. The biological bases of executive function show that the prefrontal lobe of the brain could be constrained which limit the executive function of an individual (Fischer & Daley, 2007). Even then, the interaction between biological factors and environmental influences seems to better explain the development and outcomes of executive function (Bernstein & Waber, 2007), where adequate and relevant environmental stimulation can boost executive function and its outcomes, and vice versa.

The first component of executive function is response inhibition. Inhibiting response is stopping an impulsive act or stopping the usual way of thinking and doing in favor of a new demanding situation; or being able to think about the consequences before acting. Although there is some research linking response inhibition and reading comprehension (Altemeier et al., 2008; Borella et al., 2010; Cain, 2006), more work is needed in this area. Perhaps response inhibition is linked with reading comprehension through overriding irrelevant concepts and thereby focusing more precisely on comprehending the passage at hand. In fact, Cain (2006) found that learners with poor comprehension were more

[1] Source: www.developingchild.harvard.edu

likely than those with good comprehension skills to recall items that should have been inhibited. Response inhibition is related to self-regulation skills. Self-regulation includes the management and control of emotional reactions such as reactivity to stimulation, soothing oneself and stabilizing when under pressure, and adjusting one's feelings in time of difficulty.

The second component of executive function is cognitive flexibility or shifting. Cognitive flexibility is the transitioning of thinking about one idea or task to another more important or urgent ones; it could also be shifting thoughts from preferred to non-preferred activity by letting go of a specific interest in favor of a new priority issue. The shift could be behavioral or cognitive shifting. Flexibility is related to reading comprehension during the elementary school years (Cartwright, 2002; Cartwright et al., 2010; Cole' et al., 2014; Gaskins, 2008; Van Der Sluis et al., 2007; Yeniad et al., 2013). For example, Cartwright (2002) found that reading-specific flexibility contributed to reading comprehension even after controlling for age, domain-general shifting performance, decoding skill, and verbal ability. Moreover, Cartwright (2002,) demonstrated that training of reading-specific flexibility skills resulted in gains in reading comprehension. Flexibility is important for reading because it allows readers to make use of multiple features, especially orthographic, phonological, and semantic information that support successful comprehension (Cartwright, 2002; Cole' et al., 2014).

The third component of executive function is working memory, or short term memory. Working memory is active information available in the short term memory which is ready for use in the present when needed. It requires a sustained attention until completing a task and being persistently mindful. It is also about thinking about one's own thinking

(metacognition) by monitoring one's thoughts, following directions /instructions, initiating planning and organizing tasks. Working memory is positively related to reading (and math) performance during preschool and early elementary school (Bull et al., 2008; Gathercole & Pickering, 2000; Lan et al., 2011; Swanson, 1994; Swanson & Jerman, 2007; Van Der Sluis et al., 2007; Welsh et al., 2010; Willoughby et al., 2012). It is likely that working memory supports reading success by allowing children to hold in mind the multitude of words, concepts, and themes necessary to comprehend texts.

Children are born with the potential to develop executive functions; they are not innate skills per se. The development of executive function skills depends on the interaction between biological maturation and environmental experiences (Blair, 2002; Cicchetti, 2002; Hughes, 2011). In other words, the development of executive function depends on sensitive and responsive caregiving such as the provision of adequate opportunities for children through guided exploration of the social and physical environment, and sustained joint attention, emotional understanding, and problem-solving skills. Delay in executive function development depends on factors related to adverse conditions. For instance, extreme adversity in children's early years, such as maltreatment or severe neglect, traumatic events, increased problems of attention, emotion dysregulation, and language delays (Cicchetti, 2002). Additional examples of factors that contribute to delays in the development of executive function include family poverty, including maternal depression, low levels of social support, stressful life events, and exposure to violence (Scheidecker et al., 2023). The above factors cause the executive regulatory systems to be destabilized by increasing the neuroendocrine and autonomic stress reactivity (Cicchetti, 2002).

Development of executive function skills leads to regulation of emotional reactions, enhancement of mindfulness, flexible cognitive processes, and maladaptive response inhibitions. Success is associated with well-developed executive functions which becomes an alert with proactive mindset. In other words, children with good executive skills do flexibly inhibit, manage and control their behavioral, cognitive and emotional reactions. Executive function is critically important in predicting developmental outcomes such as academic achievement, health behaviors and social adjustments (Cantin et al., 2016; Shoda et al., 1990). Head-Toes-Knee-Shoulder (HTKS) test as a measure of executive function predicts well the academic skills of preschool children (McClelland et al., 2014).

Early intervention by parents and teachers can improve the executive functions of children by allowing more opportunities for children to do a variety of age appropriate real life exercises and problem solving activities through play-based approaches. Scaffolding, supporting and modeling the efforts and engagements of children can enhance the skills development in executive functions. Executive functioning is generally slow to fully develop and emerges in late infancy, goes through marked changes during the ages of 2 through 6, and does not peak until around age 25 (Zelazo, et al., 2014).

The Research Problem

Conceptually executive function is related to one's organized, attentive and adaptive state of mind. There are various tools that measure executive function where Head Toes Knee Shoulder (HTKS) is one of them. However, whether the HTKS test is reliable and valid measure of executive function was not tested in the Ethiopian context. The purpose

of this study, therefore, is to determine the validity of HTKS as a measure of executive function. In light of this, this paper attempts to answer the following research questions:

- Is the Head Toes Knee Shoulder (HTKS) Test a reliable and valid measure of executive function?
- Does executive function predict emergent literacy and mathematics performance of preschool children enrolled in O-class?
- Do gender, age, regional location account for the contributions of executive functions on emergent literacy and mathematics performance?

Significance of the study

Executive function is composed of working memory and cognitive flexibility. Working memory refers to keeping information in short term memory which will be used right away and used to remember instructions and to act accordingly. Children with weak working memory have trouble remembering directions and correctly behaving in line with the active memory. Besides, cognitive flexibility, which sometimes is also called adaptable thinking or flexible thinking, refers to how quickly one adjusts with important changes and flexibly think to differently address the usual way of behaving. Flexible thinking requires quick adaptation to an emerging contextual demand by stopping the usual way of thinking. Inhibitory control includes self-control, self-restraint, management of distractions, and readjusting attention and refocusing to important changes. Both working memory and cognitive flexibility have important implications for learners to pay attention and actively engage in their learning.

Therefore, executive function skills of children, as one of the foundational skills, need to be considered in designing and implementing school readiness programs. This study would contribute to both the practitioners and the policy decision makers in integrating executive function skills as important domains of child development components in the preprimary school curricula. In other words, the preparations of preschool curricula should consider the inclusion and implementation of executive functions using various play based approaches. Play based learning should target the enhancement of executive functions. Besides, this study has identified one of the gaps in executive functions of early childhood education which was not yet addressed in the country. Hence, researchers in the area would consider this study as stepping stone for further study in the area.

Methodology

Design: A cross sectional survey research design was employed to gather the quantitative data.

Sample[2] Size: A multi-stage cluster random sampling technique was employed to select sample schools. A randomly selected O-class children from Addis Ababa and five regional states of Ethiopia (N=2,515; 50% F), between the ages of 5 to 8 years (98%) participated in this study.

[2] Note: Data was collected with the financial support from the World Bank Group on the Early Learning Partnership Program. The author is grateful for financing the study.

Tools of data collection

The Measure of Early Learning Quality and Outcome (MELQO[3]) tools (UNESCO et al., 2017) were used to collect data. Specifically, the child direct assessment tool of the Measure of Development and Early Learning (MODEL) which has the following major components were used to collect data:

- *Emergent Literacy Test (ELT).* ELT has a total of 39 items (α=.933), where, 10 items measured expressive vocabulary; 16 items on letter identification; 5 items on letter sound identification; 3 items on letter sound discrimination; and 5 items on story based listening comprehension.

- *Emergent Mathematics Test (EMT).* EMT has a total of 36 items (α=.892), where, 5 items measured receptive spatial vocabulary; 3 items on counting high; 4 items on producing set of items; 12 items on number identification; 3 items on number comparison; 4 items in simple addition and subtraction; and 5 items measured mental transformation of shapes.

- *The Head–Toes–Knee–Shoulder (HTKS) Test (*α=.953*)*, which has 15 items, which is a valid and reliable measure of executive function (Kenny et al., 2023). In a meta-analysis study of the validity of HTKS test Kenny and others (2023) reported that the HTKS was a valid and reliable measure of executive function in preschool children (p. 2). Previously, the HTKS test was used as

[3] Source: https://www.google.com.et/books/edition/Overview_MELQO/S50zDwAAQBAJ?hl=en&gbpv=1&printsec=frontcover

a valid and reliable measure of executive function (Gonzales et al., 2021; McClelland et al., 2007; Ponitz et al., 2009). In using the HTKS test, the child is oriented how to respond to the questions in the practice sessions where she or he had to respond the opposite as instructed. For instance, when the assessor says 'touch your head' the child is expected to touch her/his toes; similarly, when the assessors says 'touch your toes' the child is expected to touch her/his head. Likewise, when the assessor says 'touch your knee' the child is expected to touch her/his shoulder; similarly, when the child is instructed to touch her/his shoulder, the expected response is to touch the knee. So, it is acting the opposite of what is habitually routine. The accuracy of the child's responses to these unusual instructions depends on how mindful and flexible the child is which demands her/him to self-regulate and inhibit competing responses. The reliability of the HTKS test was calculated using Cronbach alpha and found to be reasonably very high (α=.953). Besides, the confirmatory factor analysis of the HTKS test yielded a two factor solution of short term memory and cognitive flexibility, with sound psychometric properties.

- *Forward and Backward Digit Span Test* (α=.912) was also used as another measure of executive function with the intention of establishing concurrent validity with HTKS test. Ten items were used to measure the digit span test with five items forward digit span and the other five items measuring backward digit span. The correlation coefficient between the total digit span and the HTKS test scores were found to be moderate and positive (r=.447) in this study which is another evidence of the concurrent validity of the HTKS.

*Procedures of data collection***:**

Twenty data collectors were trained for five consecutive days on how to use the MELQO tools and deployed to collect data in five regional states in Ethiopia (Addis Ababa, Amhara, Benshangul-Gumuz, Oromia and Somali). The first two days of the training were focused on sharing a common understanding of the objective of the research and the conceptual understanding of the instrument and the procedures of collecting the data. To further internalize the measuring tools, the third day was scheduled on role play where each of the data collector had to pair up with another assuming the role of an assessor and a child being assessed and this role was reversed with the other trainee. Following the role play on assessing and being assessed there was a reflection session which was important to clarify any confusions and misunderstandings. The fourth day was an assessment practice in preschools in nearby schools of Addis Ababa. Finally, the fifth day was an overall reflection and wrap up day. For those data collectors who didn't practice in local languages in Addis Ababa, they practiced with few children in non-sampled preschool in their study sites before they actually collect the data.

Data was collected using tablets programmed with the tools and the data collector asks a child the questions in the tablet (on one to one basis) and allows the child based on the paper based stimuli prepared (e.g., the stimulus on letter identification or number identification), as needed. The data collector asks the child and she/he responds to the questions based on the stimulus provided to him/her. Then, the data collector enters the response of the child as correct or incorrect on the tablet.

Methods of data analysis:

SPSS software was used to analyze the data. In addition to the basic descriptive statistics, higher level inferential statistics were also employed. CFA, t-test, ANOVA, Hierarchical Multiple Regression were used to establish statistical association. Confirmatory Factor Analysis (CFA) was used to establish the construct validity of the HTKS test as a measure of executive function.

Results

Characteristics of sampled children

A total of 2,515 children enrolled in 90 “O-class” preschools in five regional states of Ethiopia were assessed. That is, 208 children from 10 preschools in Addis Ababa (8.3%), 556 from 17 preschools in Amhara (22.1%), 266 children from 8 preschools in Benshangul-Gumuz (10.6%), 700 children from 33 preschools in Oromia (27.8%), 640 children from 18 preschools in Hadiya, Wolayta and Sidama, the former SNNP region (25.4%), and 145 children from 4 preschools in Somali (5.8%) participated in this assessment. About 98% of these children were within 5 and 8 years of age. In the sampled five regional states, there were seven mother tongue languages of instruction: Amharic, Berta, Afan Oromo, Hadiysa, Wolaytatu, Sidamu Afu, and Af Somali.

About equal proportion (50%) of males and females participated in this assessment. There was no statistically significant difference among the regional states in the proportion of males and females (X^2=5.63, df=5, p>.05). Besides, about 98% of the children sampled in this study were between ages 5 and 8 years.

Regarding the first research question on whether the Head Toes Knee Shoulder (HTKS) Test was a reliable and valid measure of executive function two types of reliabilities (internal consistency and composite reliability) and two measures of validity (convergent and discriminant validity) were calculated. The internal consistency measure, which was largely used for exploratory factor analysis, was found to be Cronbach's Alpha (α) of 0.953 (for 15 HTKS items) with valid cases of 2,515. Besides, the composite reliability, which was used largely for confirmatory factor analysis, showed that the two factors of HTKS test had a reasonably high reliability indexes; that is, 0.849 for Working Memory (WM) and 0.892 for Cognitive Flexibility (CF). In other words, if executive function is measured using the HTKS test repeatedly the chances are very high that similar results occur. Hence, the findings of this study confirmed that the HTKS test was a reliable measure of executive function.

Table 1.

Characteristics of sampled preschool children by gender and region

Regions[4]	N Schools[5]	Gender, %		
		Male	Female	Total

[4] Five regional states and one city administration, seven mother tongue languages, where SNNP had three local languages (Sidamu Afu, Wolaitatu, Hadiyisa) and Addis Ababa and Amhara had the same language, Amharic.

[5] List of schools (with preschools) included in this study:
Addis Ababa (Felegeberhan Primary School; Dj. Wendirad; Felegeyrdanos Full Cycle Primary School; Walia Primary School; Sibeste Negasi; Kara Kore; Repi; Kotebe 1 Cycle School; Meri Hidase; Yeka Taffo); **Amhara** (Angot Kutir 2 Full Cycle Primary School; Mantogera Full Cycle Primary School; Yediro Full Cycle Primary School; Taria Primary Schools; Yito; Guguftu; Kebedem Primery School; Enetemen

		N Children			
Addis Ababa	10	208	43.8%	56.3%	8.3%
Amhara	17	556	52.9%	47.1%	22.1%
Benishangul Gumuz	8	266	47.7%	52.3%	10.6%
Oromia	33	700	50.1%	49.9%	27.8%
Former SNNP (Hadiya, Wolayta, Sidama)	18	640	49.8%	50.2%	25.4%
Somali	4	145	49.7%	50.3%	5.8%
Total, N (%)	90	2515	49.9%	50.1%	100%

Primery School; Gelesha; Tebasit; Borebor; Tik; Yetnora; Wudmen Fcps; Beklo Manekiya Fcps; Wurgessa Fcps; Girana Fcps);
Benshangul_Gumuz (Famatsore Primary School; Hoha Number 8; Addis Alem Primary School; Hoha No.4; Homosha Pimary School; Asossa Primary; Benishangul; Selam Ber);
Oromia (Gasala Primary School; Maankulaa; Asela Piraymari Scool; Silingoo Lamlam; Dibandiba; Tafi Abo; Biiqqaa Sad_1ffaa; Koka Negawo; Adulaalaa Qocee; Bate Bora; Baatee Tiifuu; Dhankaaka Lakk.2; Dheertuu; Erar; Ude Denkaka Primary School No.One; Bochesa Primery School; Muketuri No.1 Primary School; Bowa Primary School; Fiche Kutir 1 Primary School; Muketuri No. 2 (Wuchale); Wayu Chancho (Adaa Berga));
The former SNNP (East Fonko; Ondelemo; Magara; Woto; Homecho Chewa; Gangawa; Dongora Kabado; Ruffo Chancho; Dila Afrara; Morocho Shondolo; Boditi Primery School; Belesa; Ambecho Gode; Wasedo Primery School; Gudicho Priemery School
Dolla; Wushu Wocha Dekeya Primery School; Kodo Priemery School);
Somali (Ahmed Guray Elementary And Junior School; Haroraysa Primary & Junior School; Farax Magool; Will-Waal P. School)

To conduct confirmatory factor analysis the first step is to conduct an exploratory factor analysis. Accordingly, a principal components analysis with varimax rotation was run and results showed that the 15 items HTKS tool yielded a two factor solution: Working Memory and Cognitive Flexibility, where six and nine items loaded in the factors respectively.

Following the exploratory factor analysis of the HTKS test, which yielded two factor solution, the second step was to do the confirmatory factor analysis using SPSS AMOS software and determine the latent variables. Accordingly, the nine indicator items loaded on the latent variable, which was named as cognitive flexibility after careful observation of the properties of the indicators items. Likewise, the six indicator items loaded on the other latent variable, working memory. Whereas working memory is related to paying attention and keeping information in memory until it is used, cognitive flexibility is beyond paying attention to controlling competing responses and shifting thinking towards accurate responding even if the instructions for doing so are out of the usual ways of responding.

To determine the validity of a scale, especially for confirming the concurrent, convergent and discriminant validity of a measuring scale some criteria must be met (Bagozzi & Yi, 1988, p. 82; Fornell & Larcker, 1981, p.46). Accordingly, the validity of the scale on the HTKS could be evaluated using the following three criteria. First, to determine the concurrent validity of HTKS as a measure of executive function, a bivariate correlation with another measure of executive function, in this case the measure on digit span (both forward and backward digit span test) must be greater than 0.35. Based on this criteria, the correlations between Forward and Backward Digit Span (FBDS) and Head Toes Keens Shoulder (HTKS) Tests was found to be 0.477, which confirmed the concurrent validity of the HTKS test.

Table 2.

Principal Components Analysis of the HTKS test

Rotated Component Matrix		
HTKS Test Items	Factors	
	Cognitive Flexibility	Working Memory
Item 13. Touch your knees	.843	
Item 14. Touch your Shoulder	.834	
Item 12. Touch your knees	.828	
Item 15. Touch your toes	.826	
Item 11. Touch your head	.799	
Item 10. Touch your Shoulder	.782	
Item 9. Touch your toes	.741	
Item 8. Touch your knees	.685	
Item 7. Touch your toes	.622	
Item 2. Touch your toes		.849
Item 1. Touch your head		.826
Item 4. Touch your head		.807
Item 3. Touch your toes		.806
Item 5. Touch your toes		.791
Item 6. Touch your head		.558

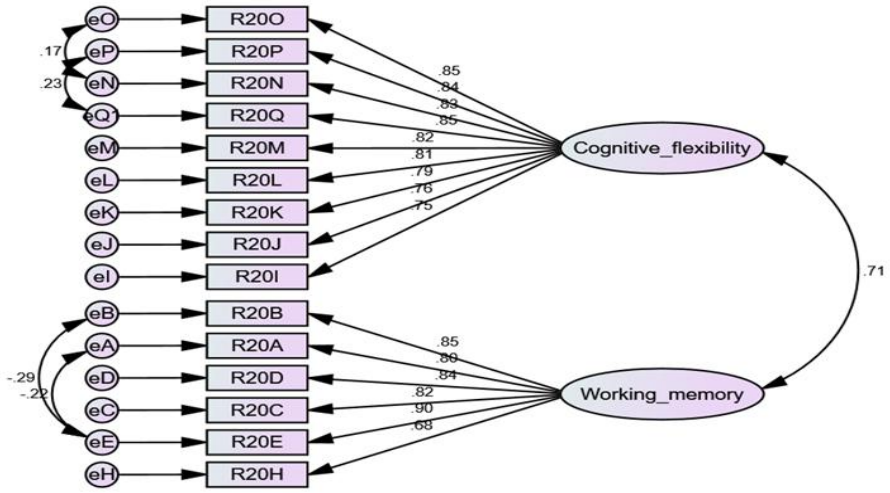

Figure 1. Confirmatory factor analysis of executive function as measured by HTKS Test with standardized factor loadings of two latent variables

Table 3.

The Average Variance Extracted (AVE) for Working Memory (WM) and for Cognitive Flexibility (CF)

Factors	Sum of square of loadings ($\Sigma\lambda^2$)	Number of indicators (n)	AVE $[(\Sigma\lambda^2)/n]$	Square root of AVE	Correlation (r) between latent variables (WM & CF)
Cognitive Flexibility (CF)	5.429	9	0.603	0.777	0.71
Working Memory (WM)	3.641	6	0.607	0.779	

Second, to establish the convergent validity of the HTKS test the average variance extracted (AVE) must be greater than 0.50. In this study, the AVE for Working Memory (WM) and for Cognitive Flexibility (ICF) were 0.607 and 0.603 respectively, confirming convergent validity of the HTKS test. Third, to determine the discriminant validity of the HTKS test, the square root of the AVE must be greater than the correlations between the latent variables, in this case, the working memory and the cognitive flexibility. The square root of the AVE for the working memory (WM) was found to be 0.779 and the square root of the AVE for Cognitive Flexibility (ICF) was 0.777. These indexes were higher than the bivariate correlations between the latent variables, WM & ICF, which was 0.71. This result confirmed the discriminant validity of the HTKS test. Since the three criteria were met, one could say that the HTKS test is a valid measure of executive function.

Table 4.
Inter-correlations among components of two measures of executive function (Digit Span and HTKS tests)

Two Measures of Executive Function	1	2	3	4	5
I. Digit Span Test					
1. Forward Digit Span	1				
2. Backward Digit Span	.354**	1			
3. FBDS Total	.855**	.791**	1		
II. HTKS Test					
4. Working Memory	.410**	.314**	.437**	1	
5. Cognitive Flexibility	.364**	.378**	.441**	.707**	1
6. HTKS Total Score	.414**	.383**	.477**	.888**	.956**

Correlations (N=2,451), **p<.001

Results on gender differences

The other research question was on whether there was a gender difference in emergent literacy and mathematics and executive function test scores. The result of this study showed that there was no statistically significant differences between boys and girls on age, emergent literacy test scores, emergent mathematics test scores, and scores on executive functions, as measured by Head Toes Knee Shoulder (HTKS) and Backward & Forward Digit Span (FBDS) tests.

Table 5.

Gender differences in age, emergent literacy and emergent mathematics, and executive functions (HTKS and FBDS)

Variables	Child Gender	Independent Samples T-test					
		N	Mean	SD	t	Df	p
Age in years(98%: 5-8)	M	951	6.82	.73	-0.89	1938	
	F	989	6.85	.66			ns
Emergent literacy score (Max 39)	M	1254	11.60	5.15	-1.89	2513	
	F	1261	12.00	5.37			ns
Emergent mathematics score (Max 36)	M	1254	21.33	9.13	-1.89	2513	
	F	1261	21.23	9.13			ns
HTKS Total Score (Max 30)	M	1254	17.46	10.45	-0.75	2513	
	F	1261	17.76	10.17			ns
F&B Digit Span (Max 10)	M	1251	3.29	1.834	-1.27	2503	
	F	1254	3.39	1.822			ns

ns = statistically not significant (p>.05)

To find out whether scores on executive function predict performances on emergent literacy and mathematics test score after controlling the effects of age, gender, and regional locations. As the correlation between gender and all other variables are not statistically significant, gender was removed from the analysis. The independent variable was the executive function as measured by the HTKS tests, the dependent variables were emergent literacy and mathematics tests scores, and the confounding variables were age, gender and regional locations.

Table 6.

Intercorrelations among variables

Variables	N	1	2	3	4	5	6	7	8	9
1. Gender**	2515	1								
2. Age	2465	.02	1							
3.Emergent literacy	2515	.04	.265*	1						
4. Emergent mathematics	2515	.01	.261*	.700*	1					
5. Forward Digit Span (FDS)	2504	.03	.109*	.439*	.556*	1				
6. Backward Digit Span (BDS)	2309	.01	.177*	.482*	.443*	.348*	1			
7. Digit Span (FDS+BDS)	2505	.03	.166*	.555*	.611*	.848*	.795*	1		
8. Working Memory (WM)	2515	.02	.092*	.471*	.479*	.395*	.302*	.421*	1	
9. Cognitive Flexibility (CF)	2515	.01	.127*	.472*	.461*	.351*	.370*	.430*	.705*	1
10. HTKS Total (WM+CF)	2515	.02	.123*	.509*	.504*	.397*	.371*	.460*	.881*	.957*

* significant, p<.01

**ns, non-significant, p>.05

A hierarchical multiple linear regression was run to predict emergent literacy test scores of children based on executive function scores, after controlling for age and regional locations. A significant regression equation was found (F(7, 1932)) = 208.92, p<.001, with an adjusted R^2 of .431 and a unique contribution of executive function, or R^2 Change, of 0.143. Children's executive function significantly predicted performance on emergent literacy test scores after controlling the effects of age and regional variations. In other words, about 14.3% of the unique variance in executive function is associated with performance on the emergent literacy test.

Table 7.

Contribution of executive function to emergent literacy and mathematics scores

Results of regression analysis on emergent literacy and mathematics test scores

Variables	DV: Emergent literacy scores		
Predictors	B	R^2	ΔR^2
Step 1. Control[a] variables		.287***	
Step 2. Executive Functions	.211***	.431***	.143***
	DV: Emergent mathematics scores		
Predictors	B	R^2	ΔR^2
Step 1. Control[b] variables		.216***	
Step 2. Executive Functions	.374***	.366***	.15***

N= 2515

[a,b]Control variables: Age and regional location (Addis Ababa, Amhara, Benshangul_G, Oromia, SNNP, and Somali)

***p<.001; DV = Dependent Variable

Similarly, the contribution of executive function to emergent mathematics was analyzed. A hierarchical multiple linear regression analysis was run to estimate the prediction of executive function on emergent mathematics tests scores after controlling the effects of age and regional locations. A significant regression equation was found ($F(7, 1932)) = 159.6$, $p<.001$, with an adjusted R^2 of .366, and a unique contribution of executive function, or R^2 Change of 0.15, to emergent mathematics. The result of the hierarchical regression analysis showed that children's executive function significantly predicted performance on emergent mathematics test scores after controlling the effects of age and regional variations. In other words, about 15% of the unique variance in executive function is associated with performance on the emergent mathematics test scores.

Discussion

High quality of early learning environment in general and better quality of interactions in preschool settings contribute to children's overall development (Bernstein & Waber, 2007; Blair, 2002). Early interventions especially provision of age appropriate play based activities during preschool years can enhance the development of children's executive function. Academic skills such as emergent literacy and mathematics skills are highly influenced by other cognitive skills such as executive functions (Chan & Scalise, 2022; Kenny et al., 2023; McClelland et al., 2007). One of the key findings of this study revealed that children's skills in executive function positively predicts their performance in emergent literacy and mathematics skills. These findings are in line with other studies conducted in preschoolers in other countries (Cantin et al., 2016; Kahl et al., 2021, 2021; Kenny et al., 2023; Lan et al., 2011; Ponitz et al.,

2009; Schmitt et al., 2017; Welsh et al., 2010; Yeniad et al., 2013). One of the possible reasons why executive function skills have positive contributions to academic skills such as the emergent literacy and mathematics skills is that attention, concentration, mindfulness and active shifting of thinking are essences embedded within executive function (McClelland et al., 2014; Ribner, 2020), which are relevant to academic skills. On the contrary, other studies showed that executive function scores of preschoolers were correlated with mathematics but not with literacy (Ernst et al., 2022) although some studies showed that a specific component of executive function, such as inhibitory control, was reported to be related with literacy (Traverso et al., 2022). One explanation for the lack of association between executive function and literacy score might be due to the differences in measurement of literacy where the study by Ernst et al. (2022) used Woodson Johnson Letter-Word Identification scores to measure literacy while this study MELQO to measure literacy with more subtests.

Executive function has been measured using various tools one of which is the Head-Toes-Knee-Shoulder (HTKS) Test. The validity and reliability of such measure of executive function was established (Da Silva et al., 2024; McClelland et al., 2014). This study also revealed that the HTKS test is a valid and reliable measure of executive function in the Ethiopian context. The confirmatory factor analysis revealed two latent variables: working memory and cognitive flexibility. This result is in line with other studies that yielded a two factor solution of the executive function as measured by the HTKS test (Gonzales et al., 2021). Although the findings of this study confirmed that the HTKS measure had two latent variables on working memory and cognitive flexibility, the finding of this study didn't reveal the third factor on inhibitory control. One of the arguments could be that inhibitory control wouldn't be an independent and a standalone factor as it was embedded within the cognitive

flexibility factor and hence the two factor solution in this study seems to be more plausible.

The findings of this study revealed that there was no statistically significant difference between boys and girls not only in executive functions scores but also in emergent literacy and mathematics sub-test scores. These results were in line with similar studies in Brazilian children (Da Silva et al., 2024). One of the possible explanations why boys and girls didn't differ in their scores on executive function might be because of the deployment of more female teachers. About 95% of the preschool teachers in these study areas were females and girls might be encouraged to actively engage in the preschool activities as much as boys.

Conclusions

One of the research questions of this study was whether the Head-Toes-Kee_Shoulder (HTKS) test was valid and reliable measure in the Ethiopian context. The results of confirmatory factor analysis revealed that the HTKS test is both reliable and valid measure of executive function with two latent variables: working memory and cognitive flexibility. Besides, executive function as measured by the HTKS test was a good predictor of academic skills of preschool children. Executive function is a good predictor of emergent literacy and emergent mathematics test scores in O-classes even when the effect of age and regional variations are held constant. Finally, boys and girls did not significantly differ on emergent literacy, emergent mathematics and executive function scores.

Implications

What are the implications of the contributions of executive function? The findings of this study showed that executive function predicts the performance of children on emergent literacy and emergent mathematics. One of the implications could be considering executive function related activities in the curriculum of early childhood education (ECE) and tailoring play based learning activities to promote executive functions. Besides, to develop the skills on executive function skills of preschool children, key stakeholders such as policy decision makers, education leaders, educators, teachers and even parents are required to enhance the active learning pedagogical approaches in preschools. Designing early intervention by integrating executive functions might yield better developmental, behavioral and social outcomes. Furthermore, enhancing executive function has implications for enhancing inclusive quality education.

References

Altemeier, L. E., Abbott, R. D., & Berninger, V. W. (2008). Executive functions for reading and writing in typical literacy development and dyslexia. *Journal of Clinical and Experimental Neuropsychology*, *30*(5), 588–606. https://doi.org/10.1080/13803390701562818

Bagozzi, R. P., & Yi, Y. (n.d.). *On the evaluation of structural equation models*.

Bernstein, J. H., & Waber, D. P. (2007). Executive capacities from a developmental perspective. *Executive Function in Education: From Theory to Practice*, 39–54.

Blair, C. (2002). School readiness: Integrating cognition and emotion in a neurobiological conceptualization of children's functioning at school entry. *American Psychologist*, *57*(2), 111.

Borella, E., Carretti, B., & Pelegrina, S. (2010). The Specific Role of Inhibition in Reading Comprehension in Good and Poor Comprehenders. *Journal of Learning Disabilities*, *43*(6), 541–552. https://doi.org/10.1177/0022219410371676

Bull, R., Espy, K. A., & Wiebe, S. A. (2008). Short-Term Memory, Working Memory, and Executive Functioning in Preschoolers: Longitudinal Predictors of Mathematical Achievement at Age 7 Years. *Developmental Neuropsychology*, *33*(3), 205–228. https://doi.org/10.1080/87565640801982312

Cain, K. (2006). Individual differences in children's memory and reading comprehension: An investigation of semantic and inhibitory deficits. *Memory*, *14*(5), 553–569. https://doi.org/10.1080/09658210600624481

Cantin, R. H., Gnaedinger, E. K., Gallaway, K. C., Hesson-McInnis, M. S., & Hund, A. M. (2016). Executive functioning predicts reading, mathematics, and theory of mind during the elementary years. *Journal of Experimental Child Psychology*, *146*, 66–78. https://doi.org/10.1016/j.jecp.2016.01.014

Cartwright, K. B. (2002). Cognitive development and reading: The relation of reading-specific multiple classification skill to reading comprehension in elementary school children. *Journal of Educational Psychology*, *94*(1), 56–63. https://doi.org/10.1037/0022-0663.94.1.56

Cartwright, K. B., Marshall, T. R., Dandy, K. L., & Isaac, M. C. (2010). The Development of Graphophonological-Semantic Cognitive Flexibility and Its Contribution to Reading Comprehension in Beginning Readers. *Journal of Cognition and Development*, *11*(1), 61–85. https://doi.org/10.1080/15248370903453584

Chan, J. Y.-C., & Scalise, N. R. (2022). Numeracy skills mediate the relation between executive function and mathematics achievement in early childhood. *Cognitive Development*, *62*, 101154. https://doi.org/10.1016/j.cogdev.2022.101154

Cicchetti, D. (2002). The impact of social experience on neurobiological systems: Illustration from a constructivist view of child maltreatment. *Cognitive Development*, *17*(3–4), 1407–1428.

Cole', P., Duncan, L. G., & Blaye, A. (2014). Cognitive flexibility predicts early reading skills. *Frontiers in Psychology*, *5*. https://doi.org/10.3389/fpsyg.2014.00565

Da Silva, M. A. C., Mota, J. G., Lemos, N. B. A. G., Martins, C. M. D. L., & Bandeira, P. F. R. (2024). Evidence of validity of the Head-Toes-Knees-Shoulders Revised (HTKS-R) for Brazilian children. *Child Neuropsychology*, 1–12. https://doi.org/10.1080/09297049.2024.2424330

Ernst, J. R., Grenell, A., & Carlson, S. M. (2022). Associations between executive function and early math and literacy skills in preschool children. *International Journal of Educational Research Open*, *3*, 100201. https://doi.org/10.1016/j.ijedro.2022.100201

Fischer, K. W., & Daley, S. G. (2007). Connecting cognitive science and neuroscience to education. *Executive Function in Education: From Theory to Practice*, 237–160.

Fornell, C., & Larcker, D. F. (n.d.). *Evaluating Structural Equation Models with Unobservable Variables and Measurement Error*.

Gaskins, I. W. (2008). Developing cognitive flexibility in word reading among beginning and struggling readers. *Literacy Processes: Cognitive Flexibility in Learning and Teaching*, 90–113.

Gathercole, S. E., & Pickering, S. J. (2000). Working memory deficits in children with low achievements in the national curriculum at 7 years of age. *British Journal of Educational Psychology*, *70*(2), 177–194. https://doi.org/10.1348/000709900158047

Gonzales, C. R., Bowles, R., Geldhof, G. J., Cameron, C. E., Tracy, A., & McClelland, M. M. (2021). The Head-Toes-Knees-Shoulders Revised (HTKS-R): Development and psychometric properties of a revision to reduce floor effects. *Early Childhood Research Quarterly*, *56*, 320–332. https://doi.org/10.1016/j.ecresq.2021.03.008

Heckman, J. J., Moon, S. H., Pinto, R., Savelyev, P. A., & Yavitz, A. (2010). The rate of return to the HighScope Perry Preschool Program. *Journal of Public Economics*, *94*(1–2), 114–128. https://doi.org/10.1016/j.jpubeco.2009.11.001

Hughes, C. (2011). Changes and challenges in 20 years of research into the development of executive functions. *Infant and Child Development*, *20*(3), 251–271. https://doi.org/10.1002/icd.736

Kahl, T., Grob, A., Segerer, R., & Möhring, W. (2021). Executive Functions and Visual-Spatial Skills Predict Mathematical Achievement: Asymmetrical Associations Across Age. *Psychological Research*, *85*(1), 36–46. https://doi.org/10.1007/s00426-019-01249-4

Kenny, S. A., Cameron, C. E., Karing, J. T., Ahmadi, A., Braithwaite, P. N., & McClelland, M. M. (2023). A meta-analysis of the validity of the Head-Toes-Knees-Shoulders task in predicting young children's academic performance. *Frontiers in Psychology*, *14*, 1124235. https://doi.org/10.3389/fpsyg.2023.1124235

Lan, X., Legare, C. H., Ponitz, C. C., Li, S., & Morrison, F. J. (2011). Investigating the links between the subcomponents of executive function and academic achievement: A cross-cultural analysis of

Chinese and American preschoolers. *Journal of Experimental Child Psychology*, *108*(3), 677–692.

McClelland, M. M., Cameron, C. E., Duncan, R., Bowles, R. P., Acock, A. C., Miao, A., & Pratt, M. E. (2014). Predictors of early growth in academic achievement: The head-toes-knees-shoulders task. *Frontiers in Psychology*, *5*. https://doi.org/10.3389/fpsyg.2014.00599

McClelland, M. M., Cameron, C. E., Wanless, S. B., Murray, A., Saracho, O., & Spodek, B. (2007). Executive function, behavioral self-regulation, and social-emotional competence. *Contemporary Perspectives on Social Learning in Early Childhood Education*, *1*, 113–137.

Ponitz, C. C., McClelland, M. M., Matthews, J. S., & Morrison, F. J. (2009). A structured observation of behavioral self-regulation and its contribution to kindergarten outcomes. *Developmental Psychology*, *45*(3), 605–619. https://doi.org/10.1037/a0015365

Ribner, A. D. (2020). Executive function facilitates learning from math instruction in kindergarten: Evidence from the ECLS-K. *Learning and Instruction*, *65*, 101251. https://doi.org/10.1016/j.learninstruc.2019.101251

Scheidecker, G., Chaudhary, N., Keller, H., Mezzenzana, F., & Lancy, D. F. (2023). “Poor brain development” in the global South? Challenging the science of early childhood interventions. *Ethos*, *51*(1), 3–26. https://doi.org/10.1111/etho.12379

Schmitt, S. A., Geldhof, G. J., Purpura, D. J., Duncan, R., & McClelland, M. M. (2017). Examining the relations between executive function, math, and literacy during the transition to kindergarten: A multi-analytic approach. *Journal of Educational Psychology*, *109*(8), 1120–1140. https://doi.org/10.1037/edu0000193

Shoda, Y., Mischel, W., & Peake, P. K. (1990). Predicting adolescent cognitive and self-regulatory competencies from preschool delay of gratification: Identifying diagnostic conditions. *Developmental Psychology*, *26*(6), 978.

Swanson, H. L. (1994). Short-Term Memory and Working Memory: Do Both Contribute to Our Understanding of Academic Achievement in Children and Adults with Learning Disabilities? *Journal of Learning Disabilities*, *27*(1), 34–50. https://doi.org/10.1177/002221949402700107

Swanson, H. L., & Jerman, O. (2007). The influence of working memory on reading growth in subgroups of children with reading disabilities. *Journal of Experimental Child Psychology*, *96*(4), 249–283.

Traverso, L., Viterbori, P., Gandolfi, E., Zanobini, M., & Usai, M. C. (2022). The contribution of inhibitory control to early literacy skills in 4- to 5-year-old children. *Early Childhood Research Quarterly*, *59*, 265–286. https://doi.org/10.1016/j.ecresq.2021.11.010

UNESCO, UNICEF, Bank, W., & Education, B. I. (USA) C. for U. (2017). *Overview: MELQO: Measuring Early Learning Quality and Outcomes*. UNESCO Publishing.

Van Der Sluis, S., De Jong, P. F., & Van Der Leij, A. (2007). Executive functioning in children, and its relations with reasoning, reading, and arithmetic. *Intelligence*, *35*(5), 427–449. https://doi.org/10.1016/j.intell.2006.09.001

Welsh, J. A., Nix, R. L., Blair, C., Bierman, K. L., & Nelson, K. E. (2010). The development of cognitive skills and gains in academic school readiness for children from low-income families. *Journal of Educational Psychology*, *102*(1), 43.

Willoughby, M. T., Blair, C. B., Wirth, R. J., & Greenberg, M. (2012). The measurement of executive function at age 5: Psychometric properties and relationship to academic achievement. *Psychological Assessment*, *24*(1), 226.

Yeniad, N., Malda, M., Mesman, J., Van IJzendoorn, M. H., & Pieper, S. (2013). Shifting ability predicts math and reading performance in children: A meta-analytical study. *Learning and Individual Differences*, *23*, 1–9.