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Relationship between fine/gross motor skills and language and math development in Colombian Caribbean children: A study in Barranquilla

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Abstract

Literature suggests that motor skills are associated with other areas of development or domains, such as language and math, especially at early ages. These results are mainly based on studies developed in medium-to-high sociocultural contexts. Thus, this study was conducted in a medium-to-low-income area. The aim was to know the 4–5 years old children's motor development (both fine and gross motor skills), and its relation to language and mathematical development. A total of 219 Colombian Caribbean children (105 boys and 114 girls) aged 4 and 5 years participated in this study. Results revealed higher motor skills among girls, although differences by gender were not notable. Positive and significant correlations were found between motor skills and language and mathematical skills, although most of the correlations were weak or moderate. Also, it was observed that fine motor skills were less related to language or mathematical development in comparison with gross motor skills, especially among boys. These results suggest that among Colombian Caribbean children gross motor skills could have a higher influence on the development and acquisition of some language and mathematical skills in comparison with fine motor skills.

KEYWORDS
coordination, language development, mathematical development, motor development, preschool children

1 | INTRODUCTION

1.1 | Relations between motor skills and cognitive skills: The case of language and mathematics

It is well known that the first years of life are a critical period for human development in several dimensions (e.g., physical, cognitive, social), which are related to each other. Regarding the physical domain, extant literature demonstrates that motor development not only is relevant for specific motor skills acquisition but also for its close relation with cognition. Thus, 'the importance of motor development goes beyond the attainment of new motor skills' (Houwen et al., 2016, p.19). In this regard, Osorio-Valencia et al. (2017) found that early motor performance may contribute to cognitive abilities development at 5 years, although a systematic review on this topic found insufficient evidence to ensure a correlation between motor and cognitive skills among children aged 4–16 years old (van der Fels et al., 2015).

Despite the mixed results, a large body of research has demonstrated the association between motor and cognitive skills in children (e.g., Chou et al., 2022), which is not surprising if we consider that physical activity plays a predominant role in cognition. According to Piaget's cognitive-developmental theory, motor and cognitive development are strongly related (Roebers et al., 2014). This theory suggests a reciprocal interaction between cognitive and motor development through 'thinking by bodily movement' (Veldman et al., 2019). Piaget argues that children's motor skills give rise to increasing possibilities to explore the environment, which allows the creation of cognitive structures. Thus, by developing motor skills, children form cognitive concepts (e.g., object permanence or tool use), which influence the perception and manipulation of their environment (Roebers et al., 2014).

Also, neuroimaging studies show evidence that physical activity can promote brain activation, improve brain plasticity (Chaddock-Heyman et al., 2013), and modify the frontal cortex, which is responsible for executive functions (Chaddock-Heyman et al., 2021). Therefore, physical activity and motor development might entail cognitive benefits, especially in attentional outcomes such as memory, attention, concentration, so forth (Infantes-Paniagua et al., 2021), which are associated with the skills acquisition and development of other domains where cognition plays an important role (e.g., language and math).

Osorio-Valencia et al. (2017) argue that motor development is the basis of other skills, as it might exert an important influence on the development of reading-writing skills and mathematical calculations. With a large sample of young children, Zhang et al. (2018) found that gross and fine motor skills predicted both language and literacy and mathematics achievement. More specifically, regarding the language domain, Houwen et al. (2016) presented evidence of strong and positive relations between the motor, cognitive and language domains, which is also supported by Campo's (2010) study with Colombian children aged 3–7 years. This relation could be explained because motor development and sensorimotor experiences can help to acquire some linguistic categories, such as verbs or spatial vocabulary (e.g., locative adverbs and prepositions, and verbs indicating movements in a direction) (Andaló et al., 2022).

As children's motor development changes and matures through locomotion (e.g., crawling 'gross motor skill') or fine motor skills (e.g., grasping), new learning can emerge because children have new opportunities to interact with objects and their caregivers as well as to explore their environment (González et al., 2019). For example, a study with very young children observed that fine- and gross-motor coordination skills predicted spatial vocabulary comprehension at 30 months (Andaló et al., 2022). Thus, these authors suggest that motor coordination skills play a role in language acquisition between the second and third years. Also, it seems that the age at which motor skills are achieved could be a notable factor in language development. For example, Longobardi et al. (2014) observed that motor skills at 12 months significantly correlated with language production at 16, 20 and 23 months. Also, the age at which children start to walk independently seems to predict spatial vocabulary at 36 months (Oudgenoeg-Paz et al., 2016). These findings could be understood from the Piagetian constructivism perspective. This theory of learning argues that children are active participants in their learning and create their knowledge through the interaction with the environment and based on the information they already have (Lapegna & Himelfarb, 2002). Thus, through sensorimotor experiences in their environment, they can acquire some vocabulary and linguistic skills based on their previous cognitive structures.

Apart from this relationship between motor development and language skills, previous studies have also demonstrated the association between motor development and mathematical skills. For example, Kim et al. (2017) observed that fine motor coordination contributed to mathematics in children aged 5 and 6 years old. In another study, Reikeras et al. (2015) found that motor skills were significantly related to mathematical skills in toddlers. As these authors state, many children's physical games might stimulate and foster the development of mathematical skills and concepts such as spatiality, classification, counting, or sorting. More recently, Fernández-Méndez et al. (2020) found that spatial and motor skills can be crucial to mathematical skills acquisition in children aged 6 to 8 years. The development of spatial skills can be fostered through movement-based games by working on topological relations (e.g., in front/behind, in/out, on/under), directions (e.g., right/left) and distances (e.g., near/far).

Taking these previous findings into account, motor skills seem to underpin the attainment in language and math, especially fine motor skills (Pitchford et al., 2016). Thus, measures of young children's motor skills may be adequate indicators for the prediction of subsequent development in these domains.

1.2 | Age and gender as potential moderators of relations between motor and cognitive skills

These relationships between motor skills and cognitive development seem to be maintained across life (Ruiz-Pérez, Navia, et al., 2016) or even increase as children become older (e.g., Molfese & Betz, 1984). Children tend to improve their results related to cognitive and academic variables in their adolescence as a consequence of appropriate motor skills development during childhood (Geertsen et al., 2016). In this line, Osorio-Valencia et al. (2017) found that early motor performance seems to contribute to cognitive abilities acquisition some years later. Apart from age, gender also seems an individual factor that could determine to some extent motor development and its association with other learning domains (e.g., maths or language). Results from Osorio-Valencia et al. (2017) reveal that preschool boys had better ability in gross motor, whereas girls obtained higher scores in fine motor skills. Similarly, a study developed with Colombian children (Noguera & García, 2013) observed that girls were better than boys in fine motor skills. However, Pitchford et al. (2016) did not find any gender effect on fine motor tasks in a sample of British children aged 5–6 years. Thus, results are inconsistent, which may be explained by other factors that influence children's development.

1.3 | Importance of considering the cultural context: Current study

Although motor and cognitive development are largely determined by biological or individual factors, the social-cultural context where children are reared is also relevant because of the environmental stimuli. Angulo-Barroso et al. (2011) found that infants in Africa have an advantage in gross motor development and most of the fine-motor tasks in comparison with African American children from the USA. In a previous study, Werner (1972) observed that infants from Western cultures had slower gross motor development, being African infants the most accelerated in their motor development, followed by Latin American and Asian. In the context where this study was developed (Soledad Atlántico, Colombian Caribbean), motor engagement among children is commonly high because they spend time playing in the street. However, due to the low socioeconomic level of families, children are not used to attending sports clubs or other organized physical activities in after-school settings.

To our knowledge, most of the research on this topic has been conducted in other different cultural contexts (Ruiz-Pérez, Ruiz-Amengual et al., 2016), especially among the Western population which can bias the results and makes it difficult to have generalized data because of the human differences between the Western and non-Western population (Henrich et al., 2010; Moriguchi, 2022). However, little is known about motor development in rural, isolated and low-income areas, such as the Colombian Caribbean region, where the present study was developed with non-Western preschool children. Also, many works have been aimed at very young children (less than 3 years old) (González et al., 2019), whereas further ages have received less attention in the study of motor development and its association with linguistic and math skills. Thus, it is of interest to analyse if these relations also appear in further ages. Thus, this correlational descriptive study aimed to know the 4–5 years old children's motor development (both fine and gross motor skills), as well as its relation to language and mathematical development (relational aspects). This current study should be understood as a preliminary step in examining these relations in a different cultural context, that is, the research does not intend to analyse the mechanisms or variables that explain the relation between motor and cognitive skills. However, we expect that this first step helps further studies to a deep analyse of these mechanisms in the Colombian Caribbean context.

On the basis of previous literature, it was hypothesized that there would be no gender differences in terms of coordination and motor development (fine and gross motor skills respectively) (Martínez-García, 2021). Also, it was expected that both coordination and motor development would be positively related to language and math development, especially coordination. These hypotheses are established mainly based on the major literature, which is aimed at Western populations. However, although the aim of this study is not to compare the results between Western and non-western populations, authors recognize that results from this study could differ from others conducted with Western children.

2 | METHODS

2.1 | Participants

A total of 219 children aged 4 and 5 years (105 boys and 114 girls; 67.1% aged 5 years) participated in this descriptive and correlational study. All children were recruited through convenience from two public schools located in Soledad Atlántico (Colombian Caribbean region). The socioeconomic level of the families of both schools is medium-low according to the statistics of poverty in this area (United Nations Development Program, 2021). All participants had normal development. Thus, there were no participants with any physical or cognitive impairment.

2.2 | Measures

2.2.1 | Psychomotor development (fine and gross motor skills) and language development

The Psychomotor Development Test (TEPSI) (Haeussler & Marchant, 1980) was used to measure motor development and language skills among children between 2 and 5 years old. This instrument is composed of 52 items or tasks divided into three subtests: coordination, motor development and language.

Haeussler and Marchant demonstrated this instrument is valid and reliable for being used with children aged 2–5 years old. These authors obtained a Pearson's correlation coefficient of 0.92 including all the subtests (0.85 in the coordination subtest, 0.71 in the motor development subtest and 0.84 in the language subtest). Also, this instrument is valid for Colombian preschool children (Plazas, 2018).

The coordination subtest includes 16 items measuring fine motor skills such as drawing, manipulative skills, threading a needle, building towers with cubes and recognizing and copying geometric figures. The language subtest has 24 items that measure language comprehension and expression skills such as naming objects, defining words and verbalizing actions. Finally, the motor development subtest has 12 items and measures gross motor skills to observe the children's ability to control their own bodies (e.g., hopping on one foot, catching a ball and tiptoeing). Each task is scored 0 or 1, depending on whether the child performs it correctly or incorrectly. Thus, the maximum score for each subtest corresponds to the number of items.

2.2.2 | Early numeracy development

Utrecht Early Numeracy Test (ENT) was developed in Holland to measure the early math proficiency level in children aged 4–7 years (Van de Rijt et al., 1999). This test has three versions (A, B and C) of 40 items each. In this work, version A was administered. This instrument has been used and validated in several Latin American countries, as is the case of Chilean preschool children (Cerda et al., 2012) ($\alpha = 0.915$) and Ecuadorian children (Underdal, 2012).

This test has eight components (subtests) with five items each (40 items in total). Each correct answer is scored with 1 and errors with 0. The maximum score that can be obtained is 40. The first four subtests evaluate relational aspects: concepts of comparison, classification, one-to-one correspondence and seriation. The last four subtests assess numerical aspects: use of number words, structured counting, resultative counting and a general understanding of numbers. In this study, only the subtests measuring relational aspects were used for two reasons: (1) because of the age of the participants and curricular requirements, it was considered more appropriate to assess relational aspects; (2) this study is part of a wider project where several mathematical activities based on relational aspects were included in a motor development intervention programme.

2.3 | Procedure

First, the study was explained to school principals. Once their approval was obtained, children's parents and caregivers were informed about the aims and method of the study in a face-to-face meeting. Due to the early age of participants, children's caregivers' approval was asked through a consent form, whereas children gave their verbal assent to participate in this study.

The main researcher of this study along with a school psychologist and two specialized teachers administered in Spanish the instruments to all participants in an individual way. Some of these data were collected in person, whereas others were collected virtually due to the COVID-19 pandemic. More specifically, TEPSI was administered 100% virtually, whereas ENT was administered face-to-face to 43% of participants, and virtually to 57% of them. Data collection lasted 60 min in total (about 40 min to administer the TEPSI and 20 min for the ENT). Both tests were administered in separate sessions. To promote the children's motivation, instruments and tasks were introduced and explained like a game and a confident and safe environment was created prior to data collection.

Approval for this study was granted by the Research Ethics Committee of a public educational institution of Soledad Atlántico [ref: 001].

2.4 | Data analysis

To analyse the data, SPSS IBM 28.0 was used. Descriptive results (mean scores and standard deviations) were obtained to know the participants' motor skills. A group statistical analysis was conducted, as well as a correlational analysis between studied variables through Pearson's Bivariate correlation test.

3 | RESULTS

Table 1 shows the mean scores obtained in TEPSI and ENT subtests. According to TEPSI standards, descriptive results reveal that children have high levels of coordination (fine motor skills) and motor development (gross motor skills). Out of 16 points in coordination, children obtained 12.45 ± 2.77 points on average, whereas in motor development they scored 9.19 ± 2.01 out of 12. Regarding language, children scored 20.46 ± 3.03 out of 24 points. Finally, the global mean punctuation of mathematical skills was 15.56 ± 3.8 out of 20. More specifically, children obtained around 3 points out of 5 in the four numerical variables (comparison, classification, seriation and correspondence) Table 1 reveals. With regard to gender, it is observed that results in language, coordination and motor development are similar in both genders, although girls obtain slightly higher scores in all domains.

As shown in Table 2, all Pearson correlations between variables of TEPSI and ENT tests are significant and positive, although most of them are weak-to-moderate (ranging from 0.166 to 0.484). A positive and significant correlation is observed between coordination and the following variables: comparison ($r = 0.238$; $p = 0.000$), classification ($r = 0.185$; $p = 0.006$), seriation ($r = 0.166$; $p = 0.014$) and correspondence ($r = 0.320$; $p = 0.000$). Language is positively and significantly related to comparison ($r = 0.333$; $p = 0.000$), classification ($r = 0.332$; $p = 0.000$), seriation ($r = 0.375$; $p = 0.000$) and correspondence ($r = 0.399$; $p = 0.000$). Also, we found a relation between language and coordination ($r = 0.379$; $p = 0.000$) and motor development ($r = 0.484$; $p = 0.000$). Finally, motor development also has a positive and significant relation with comparison ($r = 0.343$; $p = 0.000$), classification ($r = 0.359$; $p = 0.000$), seriation ($r = 0.303$; $p = 0.000$) and correspondence ($r = 0.453$; $p = 0.000$). In general, motor development is higher correlated to language and ENT variables, whereas coordination has weaker correlation scores with the rest of variables.

Regarding gender, Table 3 reveals that coordination has a positive and significant relation with comparison ($r = 0.338$; $p = 0.000$), classification ($r = 0.234$; $p = 0.000$) and correspondence ($r = 0.237$; $p = 0.000$) in females, whereas in males the coordination only has a significant relation with correspondence ($r = 0.388$; $p = 0.000$). Also, language and motor development are positively related to comparison, classification, seriation and correspondence both in males and females. The correlations between language and variables of motor development and coordination

TABLE 1 Mean (SD) of TEPSI and ENT variables according to all participants and stratified by gender.

	All participants	Girls	Boys
Coordination (TEPSI)	12.45 (2.77)	12.56 (2.75)	12.32 (2.8)
Language (TEPSI)	20.46 (3.03)	20.64 (3.01)	20.27 (3.06)
Motor development (TEPSI)	9.19 (2.01)	9.31 (2.05)	9.04 (1.97)
Comparison (UTRECHT)	3.49 (1.12)	3.58 (1.05)	3.4 (1.19)
Classification (UTRECHT)	3.47 (1.15)	3.55 (1.15)	3.38 (1.15)
Seriation (UTRECHT)	3.43 (1.11)	3.47 (1.17)	3.38 (1.06)
Correspondence (UTRECHT)	3.32 (1.12)	3.51 (0.96)	3.1 (1.24)

Note: $N = 219$, $n_{boys} = 105$, $n_{girls} = 114$.
Abbreviations: ENT, Early Numeracy Test; TEPSI, The Psychomotor Development Test.

TABLE 2 Pearson correlations between TEPSI and ENT variables in all participants.

	Coordination	Language	Motor development	Comparison	Classification	Seriation	Correspondence
Coordination	1	0.379**	0.454**	0.238**	0.185**	0.166**	0.320**
Language	0.379**	1	0.484**	0.333**	0.332**	0.375**	0.399**
Motor development	0.454**	0.484**	1	0.343**	0.359**	0.303**	0.453**

Note: Coordination (fine motor skills) and motor development (gross motor skills).
Abbreviations: ENT, Early Numeracy Test; TEPSI, The Psychomotor Development Test.
***p* < 0.001.

TABLE 3 Pearson correlations between TEPSI and ENT variables.

	Coordination	Language	Motor development	Comparison	Classification	Seriation	Correspondence
Coordination	1	0.372**	0.471**	0.338**	0.234**	0.176	0.237**
Language	0.372**	1	0.507**	0.335**	0.358**	0.362**	0.467**
Motor development	0.471**	0.507**	1	0.421**	0.413**	0.261**	0.499**
Coordination	1	0.384**	0.433**	0.140	0.129	0.152	0.388**
Language	0.384**	1	0.454**	326**	0.298**	0.398**	0.340**
Motor development	0.433**	0.454**	1	0.261**	0.293**	0.353**	0.415**

Note: Results by gender. Girls above; Boys below. Coordination (fine motor skills) and motor development (gross motor skills).
Abbreviations: ENT, Early Numeracy Test; TEPSI, The Psychomotor Development Test.
***p* < 0.001.

were similar in both genders, although girls revealed a slightly higher correlation between language and motor development ($r = 0.507$; $p = 0.000$) in comparison with males ($r = 0.454$; $p = 0.000$).

4 | DISCUSSION

This study aimed to analyse the 4–5 years old children's motor development, through fine and gross motor skills, and its relation to language and mathematical skills. Results of this study echo that there are no significant differences in motor development according to gender, which is consistent with our expectations and in line with previous studies (Coetzee & Du Plessis, 2013; Martínez-García, 2021; Singh et al., 2010). Thus, it seems that differences by gender are not especially noticeable at early ages (Lingam et al., 2009) as generally there are no important physical differences among genders and many motor skills have a generalized improvement in both girls and boys (Yanci et al., 2014). Contrary to this result, some studies have found differences by gender in young children, as girls seem to have better fine motor skills, whereas males outscored females in gross motor tasks (Morley et al., 2015; Osorio-Valencia et al., 2017). Some authors have claimed that these differences by gender could be explained by environmental, sociocultural or genetic factors (Gabbard et al., 2012; Marta et al., 2012; Wrotniak et al., 2006).

Regarding the relationship of motor skills with other cognitive domains, the results of this study echo that, in general, motor skills are positively and significantly associated with language and several mathematical skills, which support previous findings (e.g., Houwen et al., 2016). These results are consistent with our hypothesis, although coordination, which refers to fine motor skills, had weaker or no correlations with some language and mathematical skills such as comparison, classification and seriation. This finding is discrepant from those of Carlson et al. (2013), Haapala (2013) and Pitchford et al. (2016), who found that fine motor skills are more linked to academic achievement in comparison with gross motor skills. However, results of other research suggest that gross motor skills could also be a good predictor of subsequent language development, as Libertus and Violi (2016) observed in their study about the onset of independent sitting and its relation to language acquisition. The weaker association between fine motor skills and other learning domains obtained in the current study was lower among boys, which could be because boys commonly obtain higher scores in gross motor tasks (e.g., Morley et al., 2015; Osorio-Valencia et al., 2017).

This association between gross motor skills and maths and language acquisition could be explained by the cultural context of the participants. Children that took part in this study are from Barranquilla where it seems that gross motor skills are more encouraged by the context where they live, as they usually have many green areas and facilities for engaging in sports (e.g., soccer, volleyball, basketball) in the school. In this line, a study developed with children aged 3–7 years old from the same location (Barranquilla) found that they had a better development of gross motor skills than fine motor skills. In fact, almost 20% of children revealed unexpected scores in gross motor skills, as they were higher than the normal patterns at these ages (Campo, 2011).

The novelty of this study is the sample, as it was developed with young Colombian Caribbean children, that seems to be an understudied population on this research topic. Despite the strength of this work, these findings must be considered in light of some limitations. For example, questionnaires were administered virtually to some participants. Another limitation is related to results, as most of the correlations were weak or moderate. Thus, considerable caution should be taken in the interpretation of these results. Also, our results should be understood considering the context of the participants as their motor engagement is normally high because they spend time playing in the street. However, due to the low socioeconomic level of families, children are not used to attending sports clubs or other organized physical activities in after-school settings. In the school, children have one lesson of dance per week and one lesson to develop motor skills.

It would be valuable to further explore the mechanisms that explain the relation between motor and cognitive skills, as well as the sociodemographic variables that can moderate motor skills in children, such as type of birth, ethnicity, number of siblings, parents' qualification, daily physical activity, so forth. These variables can entail more stimuli or access to several opportunities to improve motor skills. According to the review of Iivonen and Sääkslahti (2014), there are four categories of factors that influence preschoolers' fundamental motor skills: individual characteristics, education-related variables, social environment and physical environment. Thus, all factors included in these categories are worth being considered when it comes to analysing motor development.

5 | CONCLUSIONS

Motor development in childhood can be considered a transversal axis for the adequate development of other dimensions of the child, such as language and math skills. Through this study, we observed that gross motor skills are moderately related to language and mathematical development, whereas fine motor skills (coordination) are weakly correlated to language and mathematical development, especially in boys. Thus, in this sample of Caribbean children, it seems that fine motor skills could be less important for the development of these areas of cognitive development in comparison with gross motor skills.

The findings of this study provide some implications for education policy and practice. It seems relevant that educators and policymakers place emphasis on children's physical activity and motor skills, as they could contribute to obtaining higher benefits in academic achievement and the development of other areas. Therefore, there is a possibility of promoting cognitive skills through movement. Also, it would be valuable to develop interdisciplinary programmes or methods that explicitly work several contents through movement. For example, active breaks could be a good strategy to encourage physical activity and motor development while language and math skills are worked through body movement, as some existent active breaks programmes propose (e.g., Take10).

AUTHOR CONTRIBUTIONS

Pedro Gil-Madrona: Conceptualization; investigation; methodology; supervision; visualization. **Yulmis Isabel Rodríguez-Guerrero:** Investigation; methodology; project administration; resources; supervision; writing – review and editing. **María Pilar León:** Investigation; methodology; writing – original draft; writing – review and editing. **Adrián Eduardo Vásquez-Cruz:** Data curation; formal analysis; software; supervision.

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DATA AVAILABILITY STATEMENT

Data available on request due to privacy/ethical restrictions.

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