EDUCA Revista Internacional para la calidad educativa
EDUCA International Journal for Educational Quality
ISSN 2792-7660
Publisher: Campus EDUCA SPORTIS. A Coruña. Spain | E-mail: info@plataformaeduca.org | Web: www.revistaeduca.org

Physical Activity and Mathematical Competence in Childhood: A Critical Analysis of Its Predictive Capacity

Actividad física y competencia matemática en la infancia: un análisis crítico de su capacidad predictiva

Rocío Rodríguez-Padín; Víctor Arufe-Giráldez

Research Group Technology Applied to Research in Employment, Equality and Health; University of Cornwall; Faculty of Education. University of A Coruña, Spain

Correspondence email: *rocio.rodriguez.padin@udc.es*

Editorial schedule: *Article received 01/12/2025 Accepted: 15/12/2025 Published: 01/01/2026*

To cite this article use the following reference:
Rodríguez-Padín, R.; Arufe-Giráldez, V. (2026). Physical activity and mathematical competence in childhood: a critical analysis of its predictive capacity. *EDUCATES. International Journal for Educational Quality*, *6*(1) pp. 1-23. https://doi.org/10.55040/arm05z39

Specific contribution of the authors: The authors have participated jointly in all phases of the research.

Funding: There was no funding for this project.

Informed consent for study participants: Informed consents have been requested from participants.

Conflict of interest: The authors do not point out any conflict of interest.

EDUCA Revista Internacional para la calidad educativa
EDUCA International Journal for Educational Quality
ISSN 2792-7660
Publisher: Campus EDUCA SPORTIS. A Coruña. Spain | E-mail: info@plataformaeduca.org | Web: www.revistaeduca.org

Summary
The relationship between physical activity and the development of mathematical competence in childhood has aroused a growing interest in the educational and scientific fields, especially from approaches that highlight the role of movement and embodied cognition in learning processes. However, the available empirical evidence presents heterogeneous results and, in many cases, is supported by simple correlational designs or global indicators of academic performance. The objective of this study is to analyse the predictive capacity of structured and unstructured physical activity on mathematical competence in a sample of Early Childhood Education students, differentiating between informal, formal and total mathematical competence. An ex post facto quantitative design was adopted and multiple linear regression models were used to examine the relationship between the two variables. Mathematical competence was assessed through the Basic Mathematical Competence Test (Topic 3), while physical activity was operationalized based on information provided by families, distinguishing between structured and unstructured contexts. The results show that the proposed regression models have a very limited explanatory capacity, with corrected R^2 values close to zero or negative and lack of statistical significance in the ANOVA test, both in the total sample and in the sex-disaggregated analyses. Likewise, the analyses rule out problems of multicollinearity between the predictor variables, which reinforces the technical soundness of the estimated models. Overall, the findings indicate that physical activity, considered globally and linearly, does not act as a direct predictor of mathematical competence in the sample analyzed. The implications of these results for educational research are discussed, underlining the need to rethink oversimplified explanatory models and to explore approaches that contemplate indirect, mediating or contextual relationships between physical activity and mathematical learning in childhood.

Keywords: Physical activity, mathematical competence, early childhood education, linear regression, mathematical learning, embodied cognition.

Resumen
La relación entre la actividad física y el desarrollo de la competencia matemática en la infancia ha despertado un interés creciente en la investigación educativa y científica, especialmente desde perspectivas que enfatizan el papel del movimiento y la cognición incorporada en los procesos de aprendizaje. Sin embargo, la evidencia empírica disponible sigue siendo heterogénea y, en muchos casos, se basa en diseños correlacionales simples o en indicadores globales del rendimiento académico. El presente estudio tiene como objetivo examinar la capacidad predictiva de la actividad física estructurada y no estructurada sobre la competencia matemática en una muestra de estudiantes de primera infancia, distinguiendo entre competencia informal, formal y matemática general. Se adoptó un diseño cuantitativo ex post facto y se emplearon múltiples modelos de regresión lineal para analizar la relación entre estas variables. La competencia matemática se evaluó utilizando la Prueba de Competencia Matemática Temprana (Tema 3), mientras que la actividad física se operacionalizó en función de la información reportada por los padres, diferenciando entre contextos estructurados y no estructurados. Los resultados indican que los modelos de regresión propuestos muestran un poder explicativo muy limitado, con valores ajustados de R^2 cercanos a cero o negativos y una falta de significación estadística en las pruebas ANOVA, tanto en la muestra total como en

análisis desagregados por sexo. Además, los análisis descartan problemas de multicolinealidad entre las variables predictoras, apoyando así la robustez técnica de los modelos estimados. En general, los hallazgos sugieren que la actividad física, cuando se considera globalmente y mediante modelos lineales, no funciona como predictor directo de la competencia matemática en la muestra analizada. Se discuten las implicaciones de estos resultados para la investigación educativa, destacando la necesidad de reconsiderar modelos explicativos excesivamente simplificados y explorar enfoques que tengan en cuenta las relaciones indirectas, mediadoras o contextuales entre la actividad física y el aprendizaje matemático en la primera infancia.

Palabras clave: actividad física, competencia matemática, educación infantil, regresión lineal, aprendizaje matemático, cognición incorporada.

EDUCA Revista Internacional para la calidad educativa
EDUCA International Journal for Educational Quality
Publisher: Campus EDUCA SPORTIS. A Coruña. Spain | E-mail: info@plataformaeduca.org | Web: www.revistaeduca.org
ISSN 2792-7660

Introduction

In recent decades, interest in understanding the factors that influence the development of mathematical competence in childhood has increased significantly, both from developmental psychology and from the didactics of mathematics and physical education. Traditionally, mathematical learning has been approached from predominantly cognitive and academic approaches; however, a growing body of research has highlighted the close relationship between motor processes, physical activity, and the development of mathematical skills, especially in the early stages of education (Agirre-Basurko et al., 2021; Arias-Otero & Lafuente-Fernández, 2022; Rodríguez-Martín & Buscà-Donet, 2022).

From an interdisciplinary perspective, numerous studies have explored the integration of mathematical content in physical education contexts or through active learning proposals, showing positive effects on mathematical performance, motivation or associated cognitive variables, such as attention or working memory (Cecchini & Carriedo, 2020; Beck et al., 2016; Have et al., 2018; Magistro et al., 2022; Wienecke et al., 2021). These interventions are usually supported by didactic approaches that incorporate body movement as a resource for understanding mathematical concepts, in line with the postulates of embodied cognition (Dackermann et al., 2017; Fischer et al., 2011).

At the same time, research in early childhood education has shown consistent associations between the development of motor skills, both gross and fine, and early mathematical competencies. Correlational and longitudinal studies have shown that fine motor skills, hand-eye coordination, and digital gnosia are significantly related to counting, numerical comparison, and number understanding in preschool ages (Barrocas et al., 2020; Fischer et al., 2020, 2022; Gashaj et al., 2019; Gashaj & Trninic, 2023; Pitchford et al., 2016; Kang et al., 2023). Likewise, recent research has indicated that fundamental motor skills and perceptual-motor competence may show a closer relationship with mathematical performance than with other academic areas, such as language, in early childhood education (Benavides-Pando et al., 2024; Wang et al., 2024; Rodríguez-Guerrero et al., 2023).

Along these lines, various explanatory models have proposed that the relationship between physical activity and mathematical competence would not be direct, but mediated by cognitive variables such as executive functions, working memory, or visuospatial skills (Chou et al., 2022; Syväoja et al., 2021; González-Andrade et al., 2024; Scott et al., 2024). In fact, longitudinal studies and systematic reviews have underlined the complexity of these interactions, noting that the effects of physical activity on mathematical learning may depend on the type of activity, intensity, educational context, and characteristics of the student body (Flores et al., 2023a; Flores et al., 2023b; Sneck et al., 2019; Vetter et al., 2020).

However, despite the growing volume of research, the available empirical evidence presents heterogeneous results. While some studies find positive associations between physical activity, sport or active movement and mathematical performance (Domazet et al., 2016; Suárez-Manzano et al., 2024; Zhang et al., 2024), other studies find no significant relationships or show limited effects when controlling for contextual and cognitive variables (Sember et al., 2022; Dapp & Roebers, 2019; Lubans et al., 2018). This inconsistency is accentuated when multivariate predictive models are used, which highlights the difficulty of explaining mathematical competence based on global indicators of physical activity.

In addition, a relevant part of the literature has focused on structured interventions or specific active learning programs in the classroom (Have et al., 2016; Riley et al., 2015, 2016; Mavilidi & Vazou, 2021; Wang & Chen, 2023), while studies that analyse structured and unstructured physical activity in a differentiated way in natural childhood contexts, such as free play, recess or the family environment, are less frequent. This distinction is especially relevant in early childhood education, where much physical activity occurs outside formal programs and has high interindividual variability (Arufe Giráldez et al., 2021; Amorim et al., 2024).

In this context, it is necessary to adopt rigorous analytical approaches that allow a critical examination of the real explanatory capacity of physical activity on mathematical competence, avoiding simplified or excessively optimistic interpretations. The present study is along these lines and aims to analyse the predictive capacity of structured and unstructured physical activity on informal, formal and total mathematical competence in Early Childhood Education students, using multiple linear regression models. From a critical perspective, it is intended to provide empirical evidence that contributes to nuance the prevailing discourses and to move towards more complex and integrative theoretical models of mathematical learning in childhood.

Method

Design

A quantitative study of a non-experimental nature was carried out, with an ex post facto design and a correlational-predictive approach, aimed at analysing the explanatory capacity of structured and unstructured physical activity on mathematical competence in Early Childhood Education using multiple linear regression models. This type of approach has been used in previous research examining the relationship between physical activity, motor skills, executive functions, and mathematical performance, highlighting the complexity of these interactions and the need for multivariate models (Syväoja et al., 2021; González-Andrade et al., 2024; Sember et al., 2022; Scott et al., 2024).

Participants

The sample was composed of 131 children enrolled in the last year of Early Childhood Education. The selection of participants was carried out through convenience sampling, taking into account criteria of accessibility and collaboration of the educational centers. Participation was voluntary and the informed consent of the families or legal guardians was obtained. All participants were in regular schooling at the time of data collection.

Instruments

Mathematical competence

Mathematical competence was assessed using the Basic Mathematical Proficiency Test (TEMA-3) (Ginsburg & Baroody, 2003; Núñez & Lozano, 2007). This instrument allows differentiated scores to be obtained for informal mathematical competence, formal mathematical competence and total mathematical competence, which is especially suitable for the analysis of numerical development in Early Childhood Education. The use of this test is justified by its wide use in research on early mathematical learning and by its sensitivity to detect interindividual differences in basic numerical skills, closely linked to motor and perceptual-motor processes (Barrocas et al., 2020; Fischer et al., 2022; Roesch et al., 2024).

Physical activity

Physical activity was estimated using a questionnaire completed by the families, of their own elaboration, designed with the aim of collecting information on the habitual practice of physical activity in different contexts of daily life. The questionnaire collects information related to contexts of structured and unstructured practice, differentiating between organized activities and situations of free play or spontaneous activity, a distinction used in previous research on physical activity and cognitive and academic development (Domazet et al., 2016; Sember et al., 2022; Zhang et al., 2024).

Operationalization of variables

Variables of mathematical competence

Three dependent variables were defined:

- Informal mathematical competence
- Formal mathematical competence
- Total mathematical competence

All of them derived from the scores obtained in the TEMA-3, according to the criteria established in the instrument's manual (Ginsburg & Baroody, 2003; Núñez & Lozano, 2007).

Physical activity variables

For each physical activity context, unweighted time indicators were calculated, obtained from the product between the number of sessions and the average time per session. Additionally, time-weighted variables were constructed, multiplying the unweighted time by an ordinal indicator of intensity or valence (1 = mild; 2 = moderate; 3 = high; 4 = very high), in order to approximate the perceived intensity of the practice.

Structured physical activity

Structured physical activity was operationalized as the sum of the time (and the weighted time, in complementary analyses) corresponding to physical education, the physical activity programs developed in the school and federated sport.

Unstructured physical activity

Given the variability in the availability of records by indicator (street, recess, home, transport), two families of variables were constructed:

- "Open" unstructured variables: these were obtained by adding the indicators available to each participant, even if some of the planned indicators were missing. This procedure allows cases in which the family provides partial information to be preserved, but it implies that the scores may underestimate the real level of activity when there are omissions.
- "Complete" unstructured variables: these were calculated only when all the indicators predicted for each version were present, reducing bias due to lack of data, but decreasing the effective sample size.

In turn, versions of unstructured physical activity were defined based on the number of indicators combined:

- Unstructured (4 indicators): street + recess + house + transport.
- Unstructured (3 indicators): street + recess + house.
- Unstructured (2 indicators): street + recess.

In this article, and in order to avoid inflating the number of models and favoring parsimony, the main analyses focused on a priority operationalization (unstructured in its broad and structured version), reporting the results according to synthesis criteria recommended in educational and psychological research (Cohen, 1988).

Procedure

The application of TEMA-3 was carried out individually in the school context, following the indications of the manual and under standardized conditions. The physical activity questionnaire was completed by the families in a period close to the evaluation of mathematical competence, with instructions aimed at informing about the usual practices of their children. The confidentiality of the data and the anonymity of the participants were guaranteed at all times.

Data analysis

Statistical analyses were performed using the IBM SPSS Statistics program (Mallery & George, 2005). First, descriptive statistics of the dependent variables were calculated. Subsequently, multiple linear regression models were estimated for each dimension of mathematical competence (informal, formal and total), using structured and unstructured physical activity as predictor variables. The corrected R^2 and the global significance of the model were reported by the ANOVA test, taking into account the explanatory capacity of each model (Cohen, 1988). To rule out multicollinearity problems, tolerance and variance inflation factor (IVF) values were examined. Likewise, sex-separated analyses were carried out in order to explore possible differential patterns, as has been pointed out in previous research (Syväoja et al., 2021; Scott et al., 2024; Suárez-Manzano et al., 2024).

Ethical considerations

The research was carried out following the specific recommendations for educational research, which underline the need to guarantee respect, voluntariness, confidentiality and protection of participants, especially when it comes to children (Paz Maldonado, 2018; Sañudo, 2006). Before the start of data collection, families and schools were informed about the objectives, procedures and purpose of the study, obtaining written informed consent from the parents or legal guardians of the students, as well as the authorisation of the teachers and schools involved. Participation was voluntary and did not entail any type of compensation or academic consequences for the participants.

The information collected was treated confidentially and anonymously, assigning numerical codes to each participant to prevent their identification. The data was used exclusively for research purposes and stored in accordance with current data protection regulations. At all times, the right of families to withdraw their consent and to request the deletion of the data was respected, thus guaranteeing the principles of autonomy, non-maleficence and ethical responsibility that govern educational research (Paz Maldonado, 2018; Sañudo, 2006).

Results

Descriptive statistics of mathematical competence

Table 1 presents the descriptive statistics corresponding to the dimensions of mathematical competence evaluated by THEME-3. The sample analyzed (N = 131) showed a mean score of 25.49 (SD = 9.61) in informal mathematical competence and 5.13 (SD = 3.36) in formal mathematical competence. The average score in total mathematical competence was 30.62 (SD = 12.09), reflecting a high interindividual variability in the mathematical performance of students in the last year of Early Childhood Education.

Variable	N	Media	DT
Informal mathematical competence	131	25,49	9,61
Formal mathematical competence	131	5,13	3,36
Total mathematical competence	131	30,62	12,09

Table 1. Descriptive characteristics of the sample in terms of mathematical competence

Note. Mathematical competence was assessed using the Basic Mathematical Proficiency Test (Topic 3). The total score corresponds to the sum of the informal and formal dimensions.

Linear regression models in the total sample

In order to analyze the predictive capacity of physical activity on mathematical competence, multiple linear regression models were estimated using structured physical activity and unstructured physical activity as predictor variables, and informal, formal and total mathematical competence as dependent variables.

As shown in Table 2, none of the proposed models reached statistical significance in the ANOVA test. The corrected R^2 values were very low and, in some cases, negative, indicating that the models do not improve the prediction against a null model. Specifically, the model for informal mathematical competence presented a corrected R^2 of −.003 ($F = 0.77$; $p = .463$), while the models corresponding to formal and total mathematical competence showed corrected R^2 values of −.004, with equally non-significant levels of significance ($p > .45$).

Dependent variable	Predictors	Corrected R²	F	p
Informal mathematical competence	Structured AF + Unstructured AF	−.003	0.77	.463
Formal mathematical competence	Structured AF + Unstructured AF	−.004	0.76	.469
Total mathematical competence	Structured AF + Unstructured AF	−.004	0.75	.474

Table 2. Results of linear regression models for mathematical competence in the total sample

Note. PA = physical activity. None of the models reached statistical significance. Negative corrected R^2 values indicate that the models do not improve prediction against a null model.

These results indicate that, in the total sample, structured and unstructured physical activity, considered together, do not present relevant explanatory capacity on the different dimensions of mathematical competence analyzed.

Linear regression models according to sex

In order to explore possible differences in the patterns of relationship between physical activity and mathematical competence, separate regression analyses were performed for boys and girls. The results are presented in Table 3.

Children

Dependent variable	Predictors	Corrected R²	F	p
Informal mathematical competence	Structured AF + Unstructured AF	.063	3.09	.053
Formal mathematical competence	Structured AF + Unstructured AF	−.027	0.18	.837
Total mathematical competence	Structured AF + Unstructured AF	.064	3.13	.051

Girls

Dependent variable	Predictors	Corrected R²	F	p
Informal mathematical competence	Structured AF + Unstructured AF	−.006	0.80	.453
Formal mathematical competence	Structured AF + Unstructured AF	.003	1.09	.344
Total mathematical competence	Structured AF + Unstructured AF	.000	0.99	.378

Table 3. Linear regression models of mathematical competence as a function of physical activity according to sex

EDUCA Revista Internacional para la calidad educativa
EDUCA International Journal for Educational Quality
Publisher: Campus EDUCA SPORTIS. A Coruña. Spain | E-mail: info@plataformaeduca.org | Web: www.revistaeduca.org
educa
ISSN 2792-7660

Note. P values close to .05 are considered statistical trends and are not interpreted as significant effects.

In the group of children, the models corresponding to informal and total mathematical competence showed moderately higher corrected R^2 values than those observed in the total sample (corrected $R^2 = .063$ and .064, respectively). However, none of these models reached the threshold of statistical significance, although values close to significance were observed ($p = .053$ for informal mathematical competence and $p = .051$ for total mathematical competence). The model related to formal mathematical competence did not show explanatory capacity (corrected $R^2 = -.027$; $p = .837$).

In the group of girls, none of the estimated models was significant. The corrected R^2 values were close to zero or negative, and the ANOVA tests did not indicate an improvement in prediction compared to the null model in any of the dimensions of mathematical competence considered ($p > .34$).

Overall, sex-disaggregated analyses do not show a statistically significant predictive relationship between structured or unstructured physical activity and mathematical competence, although inconclusive trends are observed in the group of children that need to be interpreted with caution.

Collinnearity analysis of predictor variables

In order to rule out possible problems of multicollinearity between the independent variables included in the models, the tolerance and variance inflation factor (IVF) values were examined. As shown in Table 4, both predictor variables had high tolerance values (.992) and variance inflation factors close to unity (IVF = 1.01), indicating an absence of collinearity between structured and unstructured physical activity.

Predictor variable	Tolerance	IVF
Structured physical activity	.992	1.01
Unstructured physical activity	.992	1.01

Table 4. Indicators of collinearity of predictor variables in regression models

Note. The values indicate the absence of multicollinearity between the predictor variables.

These results confirm that the limited explanatory capacity of the models cannot be attributed to overlaps between the predictor variables, but rather reflects the lack of a direct linear relationship between the physical activity indicators considered and mathematical competence in the sample analyzed.

Discussion

The main objective of this study was to analyze the predictive capacity of structured and unstructured physical activity on mathematics, informal, formal and total competence in students in the last year of Early Childhood Education, using multiple linear regression models. The results obtained indicate that, in the sample analyzed, physical activity considered globally and linearly does not act as a direct predictor of mathematical competence, which is reflected in very low or negative values of corrected R^2 and in the absence of statistical significance of the estimated models.

These findings are part of a line of results that questions the existence of simple and direct relationships between general levels of physical activity and mathematical performance, especially when multivariate models that simultaneously control different types of practice are used (Sember et al., 2022; Lubans et al., 2018; Dapp & Roebers, 2019). In this sense, the results of this study reinforce the idea that mathematical competence in childhood is a complex construct, difficult to explain from aggregate indicators of physical activity, and that it requires more integrative theoretical and analytical models.

A possible explanation for the absence of direct predictive effects lies in the fact that much of the literature that has reported positive associations between physical activity and mathematical learning is based on specific interventions, explicitly designed to integrate mathematical content and body movement in structured educational contexts (Beck et al., 2016; Cecchini & Carriedo, 2020; Have et al., 2018; Magistro et al., 2022; Wienecke et al., 2021). In these studies, physical activity does not act as a mere context of practice, but as an intentional didactic resource, carefully aligned with mathematical learning objectives. On the contrary, the present work analyzes habitual physical activity in everyday contexts, both structured and unstructured, which may contribute to explain the lack of predictive capacity observed.

Likewise, the results obtained are consistent with research suggesting that the relationship between physical activity and mathematical competence could be mediated by intermediate cognitive variables, such as executive functions, working memory, or visuospatial skills, rather than operating directly (Syväoja et al., 2021; Chou et al., 2022; González-Andrade et al., 2024; Scott et al., 2024). From this perspective, physical activity could favor the development of general cognitive processes that, in turn, are related to mathematical learning, which would make the use of direct regression models between physical activity and mathematical competence insufficient to capture the complexity of the phenomenon.

In early childhood education, this complexity is accentuated by the central role of specific motor skills, especially fine motor skills, hand-eye coordination, and digital gnosia, which have shown more consistent associations with early numeracy competencies than global levels of physical activity (Barrocas et al., 2020; Fischer et al., 2020, 2022; Gashaj et al., 2019; Gashaj & Trninic, 2023; Pitchford et al., 2016; Kang et al., 2023). In fact, several systematic reviews and empirical studies have indicated that specific motor skills, rather than the total amount of physical activity, constitute a relevant predictor of mathematical development at an early age (Flores et al., 2023a; Flores et al., 2023b; Rodríguez-Guerrero et al., 2023; Wang et al., 2024).

In relation to the sex-disaggregated analyses, although no statistically significant models were identified, inconclusive trends were observed in the group of boys for informal and total mathematical competence. This pattern, although it does not allow firm conclusions to be drawn, is consistent with studies that have described differentiated trajectories in the relationship between physical activity, motor skills, and cognitive variables according to sex, especially in early stages of development (Syväoja et al., 2021; Scott et al., 2024; Suárez-Manzano et al., 2024). However, these trends should be interpreted with caution and do not justify predictive inferences in the absence of global significance of the models.

From the methodological point of view, it is relevant to emphasize that the absence of effects cannot be attributed to technical problems of the models used. The collinearity analyses showed high tolerance values and variance inflation factors close to unity, which rules out overlaps between the predictor variables. Consequently, the results reflect a real explanatory limitation of the proposed models and not a statistical deficiency, which reinforces the need to critically review oversimplified approaches in the study of the relationship between physical activity and mathematical learning.

Finally, it should be considered that physical activity was assessed using a questionnaire of their own elaboration completed by the families, without formal psychometric validation.

Although this procedure is common in exploratory studies and allows relevant contextual information to be collected (Arufe Giráldez et al., 2021; Amorim et al., 2024), inevitably introduces a margin of error and variability that can attenuate the detection of statistical relationships. However, this limitation does not invalidate the results obtained, but rather underlines the convenience of interpreting the findings from a prudent perspective and of promoting future studies that incorporate more precise and multi-method measures of physical activity.

Overall, the results of this study provide empirical evidence that invites us to nuance the discourses that attribute to physical activity a direct predictive effect on mathematical competence, especially in early childhood education. Far from questioning the educational relevance of movement, these findings suggest the need to move towards theoretical and didactic models that explicitly integrate motor activity with specific cognitive and mathematical processes, overcoming linear and generalist approaches.

Conclusions

The objective of this study was to analyze the predictive capacity of structured and unstructured physical activity on informal, formal and total mathematical competence in students in the last year of Early Childhood Education. Based on multiple linear regression models, the results obtained consistently show that physical activity, considered globally and linearly, does not act as a direct predictor of mathematical competence in the sample analyzed.

The estimated models had a very limited explanatory capacity, with corrected R^2 values close to zero or negative and no statistical significance, both in the total sample and in the sex-disaggregated analyses. Likewise, collinearity analyses confirmed that the lack of effects cannot be attributed to overlaps between the predictor variables, which reinforces the technical soundness of the results and underlines that the absence of a predictive relationship reflects a real explanatory limitation of the models used.

These findings contribute to nuance part of the literature that has suggested positive relationships between physical activity and mathematical learning, especially when these relationships are inferred from global indicators of physical practice. In this sense, the results support the idea that mathematical competence in early childhood education is a complex construct, difficult to explain through simplified models based only on the amount or general context of physical activity.

From an educational perspective, the conclusions of the study do not question the relevance of physical activity in childhood, but invite us to reconsider the way in which its relationship with mathematical learning is conceptualized. The evidence obtained suggests that the benefits of movement on mathematical development could depend on the intentional integration of content, the specificity of the motor skills involved or the mediation of cognitive processes such as executive functions, rather than on physical practice understood as an isolated predictor factor.

Finally, the study highlights the need to move towards research approaches that contemplate more complex explanatory models, incorporating mediating variables and methodological designs that allow capturing the dynamic and contextual nature of mathematical learning in childhood. In this framework, future research should combine accurate measures of physical activity and motor competence with detailed assessments of underlying cognitive processes, as well as explore the impact of integrated didactic proposals that explicitly link body movement with mathematical learning.

Limitations and prospects

The present study must be interpreted taking into account a series of methodological limitations that, far from invalidating the results obtained, contribute to adequately contextualize them and to guide future lines of research.

First, the measurement of physical activity was carried out through a self-developed questionnaire completed by the families, which does not have a formal psychometric validation process. Although this type of instrument is common in exploratory studies and allows access to contextual information that is difficult to obtain by other means, its use implies a possible bias of information derived from the subjective perception of families, as well as limited precision in the estimation of the time and intensity of physical activity. This circumstance may have contributed to attenuating the detection of statistical relationships between physical activity and mathematical competence.

Secondly, the cross-sectional design of the study prevents establishing causal or directional relationships between the variables analyzed. The use of linear regression models allows us to explore predictive associations, but it does not capture the dynamic and evolutionary nature of mathematical and motor development in childhood. Future research should incorporate longitudinal designs that allow for the analysis of developmental trajectories and examine how changes in physical activity, motor competence and cognitive processes are related to the evolution of mathematical competence over time.

The study also focused on global indicators of structured and unstructured physical activity, which may be insufficient to capture the influence of specific motor skills or certain qualitative characteristics of physical practice. The literature suggests that skills such as fine motor skills, hand-eye coordination, or digital gnosia are more consistent with early numeracy than the total amount of physical activity. In this sense, future work should integrate direct and standardized measures of motor competence and perceptual-motor skills, as well as evaluate their possible mediating role in the relationship between physical activity and mathematical learning.

Another relevant limitation refers to the sample size and the use of convenience sampling, which may limit the generalization of the results. Although the sample size is comparable to that of other studies in early childhood education, subsequent research with larger and more diverse samples would make it possible to contrast the stability of the results and to analyse in greater depth possible differential effects depending on sex, sociocultural context or the characteristics of the educational centre.

Finally, from the educational point of view, the prospective of the study suggests that the promotion of physical activity in childhood should be conceived not only as a health objective, but also as an opportunity to design integrated didactic proposals, in which movement is explicitly linked to the mathematical processes that are to be developed. Evaluating the impact of this type of approach through rigorous designs and validated assessment tools represents a challenge and, at the same time, a priority line of research to better understand the complex relationship between movement and mathematical learning in early childhood education.

Bibliographic references

Agirre Basurko, E., Zuazagoitia Rey-Baltar, A., & Carden Castanos, S. (2021). *Mathematics hand in hand with Physical Education in Elementary School. Guiniguada, 30,* 176–192.

Amorim, N., Marques, A., & Santos, S. (2024). Beyond the classroom: Investigating the relationship between psychomotor development and academic achievement in 4–12-year-olds. *Children, 11*(8), 973. https://doi.org/10.3390/children11080973

Arias Otero, M., & Lafuente Fernández, J. C. (2022). *Analysis of the work of mathematical contents from the area of Physical Education in Primary Education.* Retos-Nuevas Tendencias en Educación Física Deporte y Recreación, (45), 224–232.

Arufe Giráldez, V., Pena García, A., & Navarro Patón, R. (2021). Effects of Physical Education programs on the motor, cognitive, social, emotional and health development of children from 0 to 6 years old. A systematic review. *Sportis. Scientific Journal of School Sport, Physical Education and Psychomotricity,* 7(3), 448–480. https://doi.org/10.17979/sportis.2021.7.3.8661

Barrocas, R., Roesch, S., Gawrilow, C., & Moeller, K. (2020). Putting a Finger on Numerical Development - Reviewing the Contributions of Kindergarten Finger Gnosis and Fine Motor Skills to Numerical Abilities. *Frontiers in psychology*, *11*, 1012. https://doi.org/10.3389/fpsyg.2020.01012

Beck, M. M., Lind, R. R., Geertsen, S. S., Ritz, C., Lundbye-Jensen, J., & Wienecke, J. (2016). Motor-enriched learning activities can improve mathematical performance in preadolescent children. *Frontiers in Human Neuroscience, 10*, 645. https://doi.org/10.3389/fnhum.2016.00645

Benavides-Pando, E. V., Jiménez-Lira, C., Paz García, D. S., Susperreguy, M. I., Palma-Gardea, L. C., & Mondaca-Fernández, F. (2024). Early symbolic numeracy and gross, fine, and perceptual-motor skills in Mexican preschool children. *Challenges: New Trends in Physical Education, Sports, and Recreation, 51*, 1452–1462. https://dialnet.unirioja.es/descarga/articulo/9212785.pdf

Cecchini, J. A., & Carriedo, A. (2020). Effects of an interdisciplinary approach integrating mathematics and physical education on mathematical learning and physical activity levels. *Journal of Teaching in Physical Education, 39*(1), 121–125. https://doi.org/10.1123/jtpe.2018-0274

Chou, Y., Hu, B. Y., Winsler, A., Wu, H., Greenburg, J., & Kong, Z. (2022). Chinese preschool children's physical fitness, motor competence, executive functioning, and receptive language, math, and science performance in Kindergarten. *Children and Youth Services Review, 136*, 106397. https://doi.org/10.1016/j.childyouth.2022.106397

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Dackermann, T., Fischer, U., Nuerk, H. C., Moeller, K., & Wood, G. (2017). Applying embodied cognition: From useful interventions and their theoretical underpinnings to practical applications. *ZDM – Mathematics Education, 49*(4), 545–557. https://doi.org/10.1007/s11858-017-0850-z

Dapp, L. C., & Roebers, C. M. (2019). The mediating role of self-concept between sports-related physical activity and mathematical achievement in fourth graders. *International Journal of Environmental Research and Public Health, 16*(15), 2658. https://doi.org/10.3390/ijerph16152658

Domazet, S. L., Tarp, J., Huang, T., Gejl, A. K., Andersen, L. B., Frøberg, K., & Bugge, A. (2016). Associations of physical activity, sports participation and active commuting on mathematic performance and inhibitory control in adolescents. *PLOS ONE, 11*(1), e0146319. https://doi.org/10.1371/journal.pone.0146319

Fischer, U., Moeller, K., Bientzle, M., Cress, U., & Nuerk, H. C. (2011). Sensori-motor spatial training of number magnitude representation. *Psychonomic bulletin & review*, *18*(1), 177–183. https://doi.org/10.3758/s13423-010-0031-3

Fischer, U., Suggate, S. P., & Stoeger, H. (2020). The implicit contribution of fine motor skills to mathematical insight in early childhood. *Frontiers in Psychology, 11*, 1143. https://doi.org/10.3389/fpsyg.2020.01143

Fischer, U., Suggate, S. P., & Stoeger, H. (2022). Fine motor skills and finger gnosia contribute to preschool children's numerical competencies. *Acta psychologica*, *226*, 103576. https://doi.org/10.1016/j.actpsy.2022.103576

Flores, P., Coelho, E., Mourão-Carvalhal, M. I., & Forte, P. (2023a). Association between motor and math skills in preschool children with typical development: Systematic review. *Frontiers in Psychology, 14*, 1105391. https://doi.org/10.3389/fpsyg.2023.1105391

Flores, P., Coelho, E., Mourão-Carvalhal, I., & Forte, P. (2023b). Relationships between Math Skills, Motor Skills, Physical Activity, and Obesity in Typically Developing Preschool

Children. *Behavioral sciences (Basel, Switzerland)*, *13*(12), 1000. https://doi.org/10.3390/bs13121000

Gashaj, V., Oberer, N., Mast, F. W., & Roebers, C. M. (2019). The relation between executive functions, fine motor skills, and basic numerical skills and their relevance for later mathematics achievement. *Early Education and Development, 30*(7), 913–926. https://doi.org/10.1080/10409289.2018.1539556

Gashaj, V., & Trninic, D. (2023). Adding up fine motor skills: Developmental relations between manual dexterity and numerical abilities. *Acta psychologica*, *241*, 104087. https://doi.org/10.1016/j.actpsy.2023.104087

Ginsburg, H. P., & Baroody, A. J. (2003). TOPIC-3: *Basic mathematical competence test. TEA Ediciones.*

González-Andrade, A., Tubío, J., Álvarez-Bardón, A., & Santiago-Ramajo, S. (2024). Relationship between executive functions, mathematical skills and fitness/physical activity in elementary school children: A systematic review. *Electronic Journal of Research in Educational Psychology,* *22*(62), 469–504. https://doi.org/10.25115/ejrep.v22i63.9216

Have, M., Nielsen, J. H., Gejl, A. K., Thomsen Ernst, M., Fredens, K., Støckel, J. T., Wedderkopp, N., Domazet, S. L., Gudex, C., Grøntved, A., & Kristensen, P. L. (2016). Rationale and design of a randomized controlled trial examining the effect of classroom-based physical activity on math achievement. *BMC Public Health, 16*(1). https://10.1186/s12889-016-2971-7

Have, M., Nielsen, J. H., Ernst, M. T., Gejl, A. K., Fredens, K., Grøntved, A., & Kristensen, P. L. (2018). Classroom-based physical activity improves children's math achievement – A randomized controlled trial. *PLOS ONE, 13*(12), e0208787. https://doi.org/10.1371/journal.pone.0208787

Kang, D., Wen, M., & Zhang, Y. (2023). The relationship between fine motor skills and mathematical ability in children: A meta-analysis[J]. *Advances in Psychological Science, 31*(8), 1443-1459. https://doi.org/10.3724/SP.J.1042.2023.01443

Lubans, D. R., Beauchamp, M. R., Diallo, T. M. O., Peralta, L. R., Bennie, A., White, R. L., Owen, K., & Lonsdale, C. (2018). School physical activity intervention effect on adolescents' performance in mathematics. *Medicine & Science in Sports & Exercise, 50*(12), 2442–2450. https://doi.org/10.1249/MSS.0000000000001730

Magistro, D., Cooper, S. B., Carlevaro, F., Marchetti, I., Magno, F., Bardaglio, G., & Musella, G. (2022). Two years of physically active mathematics lessons enhance cognitive function and gross motor skills in primary school children. *Psychology of Sport and Exercise, 63*, 102254. https://doi.org/10.1016/j.psychsport.2022.102254

Mallery, P., & George, D. (2005). *SPSS for Windows step by step: A simple guide and reference 13.0 update.* Allyn and Bacon.

Mavilidi, M. F., & Vazou, S. (2021). Classroom-based physical activity and math performance: Integrated physical activity or not? *Acta Paediatrica, 110*(7), 2149–2156. https://doi.org/10.1111/apa.15860

Núñez, M. C., & Lozano, I. (2007). *TOPIC-3: Basic mathematical competence test: Manual.* TEA Ediciones.

Paz Maldonado, E. (2018). Ethics in educational research. Journal of Pedagogical Sciences and Innovation, 6(1), 45-51. https://doi.org/10.26423/rcpi.v6i1.219

Pitchford, N. J., Papini, C., Outhwaite, L. A., & Gulliford, A. (2016). Fine motor skills predict maths ability better than they predict reading ability in the early primary school years. *Frontiers in Psychology, 7,* 783. https://doi.org/10.3389/fpsyg.2016.00783

Riley, N., Lubans, D. R., Holmes, K., & Morgan, P. J. (2016). Findings from the EASY Minds cluster randomized controlled trial: Evaluation of a physical activity integration program for mathematics in primary schools. *Journal of Physical Activity and Health, 13*(2), 198–206. https://doi.org/10.1123/jpah.2015-0046

Riley, N., Lubans, D. R., Morgan, P. J., & Young, M. (2015). Outcomes and process evaluation of a programme integrating physical activity into the primary school mathematics curriculum: The EASY Minds pilot randomised controlled trial. *Journal of Science and Medicine in Sport, 18*(6), 656–661. https://doi.org/10.1016/j.jsams.2014.09.005

Rodríguez-Martín, B., & Buscà Donet, F. (2022). Mathematical competence development in primary school physical education contexts. *International Journal of Medicine and Sports and Physical Activity Sciences, 22*(88), 807–825. https://doi.org/10.15366/rimcafd2022.88.006

Rodríguez-Guerrero, Y. I., Gil-Madrona, P., León, M. P., & Vásquez-Cruz, A. E. (2023). Relationship between fine/gross motor skills and language and math development in Colombian Caribbean children: A study in Barranquilla. *Infant and Child Development, 32*(4), e2430. https://doi.org/10.1002/icd.2430

Roesch, S., Moeller, K., & Bahnmueller, J. (2024). Finger counting, finger number gesturing, and basic numerical skills: A cross-sectional study in 3- to 5-year-olds. *Journal of experimental child psychology*, *242*, 105892. https://doi.org/10.1016/j.jecp.2024.105892

Sañudo, L. E. (2006). Ethics in educational research. *Findings, 3*(6) https://doi.org/10.15332/s1794-3841.2006.0006.05

Scott, J., Jay, T., & Spray, C. M. (2024). The role of fundamental movement skills and spatial abilities in the relationship between physical activity and mathematics achievement in primary school children. *Journal of Intelligence, 12*(2), 22. https://doi.org/10.3390/jintelligence12020022

Sember, V., Jurak, G., Starc, G., & Morrison, S. A. (2022). Can primary school mathematics performance be predicted by longitudinal changes in physical fitness and activity indicators? *Frontiers in Psychology, 13*, 796838. https://doi.org/10.3389/fpsyg.2022.796838

Sneck, S., Viholainen, H., Syväoja, H., Kankaapää, A., Hakonen, H., Poikkeus, A.-M., & Tammelin, T. (2019). Effects of school-based physical activity on mathematics performance in children: A systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 16*(1), 109. https://doi.org/10.1186/s12966-019-0866-6

Suárez-Manzano, S., Solas-Martínez, J. L., Loureiro, V., & Rusillo-Magdaleno, A. (2024). Physical activity is associated with improved mathematical computation, language reasoning, behavior and attention in ADHD girls. *Retos*, *51*, 1388–1394. https://doi.org/10.47197/retos.v51.101337

Syväoja, H. J., Kankaanpää, A., Hakonen, H., Inkinen, V., Kulmala, J., Joensuu, L., Räsänen, P., Hillman, C. H., & Tammelin, T. H. (2021). How physical activity, fitness, and motor skills contribute to math performance: Working memory as a mediating factor. *Scandinavian Journal of Medicine and Science in Sports, 31*(12), 2310–2321. https://doi.org/10.1111/sms.14049

Vetter, M., Orr, R., O'Dwyer, N., & O'Connor, H. (2020). Effectiveness of Active Learning that Combines Physical Activity and Math in Schoolchildren: A Systematic Review. *Journal of School Health, 90*(4), 306–318. https://doi.org/10.1111/josh.12878

Wang, W., & Chen, A. (2023). Can Physical Activity Breaks Assist Mathematics Learning? A Domain Learning Theory Perspective. *Journal of Teaching in Physical Education, 42*(4), 737–743. https://10.1123/jtpe.2022-0199

Wang, L., Hei, Z., Zhang, C., Liu, H., & Zhou, X. (2024). Fundamental motor skills correlate with mathematical performance rather than language performance in kindergarten children. *Asia Pacific Journal of Education*, 1–16. https://doi.org/10.1080/02188791.2024.2431699

Wienecke, J., Hauge, J., Nielsen, G., Mouritzen, K., & Damsgaard, L. (2021). Six weeks of basketball combined with mathematics in physical education classes can improve children's motivation for mathematics. *Frontiers in Psychology, 12,* 636578. https://doi.org/10.3389/fpsyg.2021.636578

Zhang, Y., Wang, L., Li, T., & Ma, X. (2024). Associations between leisure physical activity and mathematics interest: A longitudinal analysis. *SAGE Open, 14*(4), 21582440241305530. https://doi.org/10.1177/21582440241305530