Impact of a multicomponent physical activity intervention on cognitive performance: the MOVI-KIDS Study

Impact of physical activity on cognition

Authors

Mairena Sánchez-López, PhD\textsuperscript{1,2}, Iván Cavero-Redondo, PhD\textsuperscript{1}, Celia Alvarez-Bueno PhD\textsuperscript{1}, Abel Ruiz-Hermosa, MSci\textsuperscript{1}, Diana P. Pozuelo-Carrascosa, MSci\textsuperscript{1}, Ana Díez-Fernández, PhD\textsuperscript{1,3}, David Gutierrez-Díaz del Campo, PhD\textsuperscript{2}, María Jesús Pardo-Guijarro, PhD\textsuperscript{1,4} and Vicente Martínez-Vizcaíno, MD, PhD\textsuperscript{1,5}

1) Universidad de Castilla-La Mancha, Social and Health Care Research Center. C/ Santa Teresa Jornet s/n, 16071 Cuenca, Spain. Telephone: (34) 969 179 100 Ext: 4683. Fax: + (34) 969 179 178.

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2) Universidad de Castilla-La Mancha, Faculty of Education. C/ Altagracia, 50, 13071, Ciudad Real, Spain. Telephone: (34) 969 179 100 Ext: 3216. Fax: + (34) 969 179 178. Mairena.Sanchez@uclm.es; David.Gutierrez@uclm.es; Abel.RuizHermosa@uclm.es.

3) Universidad de Castilla-La Mancha, Faculty of Nursing, C/ Santa Teresa Jornet s/n, 16071 Cuenca, Spain. Telephone: (34) 969 179 100 Ext: 4656. Fax: + (34) 969 179 178. Ana.Diez@uclm.es

4) Universidad de Castilla-La Mancha, Faculty of Education, Campus Universitario, s/n 16071 Cuenca, Spain. Telephone: (34) 969 179 100 Ext: 4706. Fax: + (34) 969 179 178 MariaJesus.Pardo@uclm.es

5) Universidad Autónoma de Chile, Facultad de Ciencias de la Salud. 5 y Medio Norte 1670, Talca, VII Región, Chile. Telephone: (34) 969 179 100 Ext: 4683. Fax: + (34) 969 179 178. Vicente.Martinez@uclm.es

**Corresponding author**

Celia Álvarez-Bueno. E-mail: Celia.AlvarezBueno@uclm.es.

Address: Universidad de Castilla-La Mancha, Social and Health Care Research Center, Cuenca, Spain. C/ Santa Teresa Jornet s/n, 16071 Cuenca. Telephone: (34) 969 179 100 Ext: 4684. Fax: + (34) 969 179 178.
ABSTRACT

Introduction: This study examined the impact of a multicomponent physical activity (PA) intervention (MOVI-KIDS) on improving cognition in schoolchildren. This paper also analyzed the mediator role of motor fitness between MOVI-KIDS and cognition.

Methods: Propensity score analysis of data from a cluster randomized controlled trial (MOVI-KIDS study). This analysis including 240 five-seven years old children from 9 schools in the provinces of Cuenca and Ciudad Real, Spain. MOVI-KIDS program consisted of: (i) three weekly after-school sessions of recreational non-competitive PA lasting 60 min during one academic year, (ii) educational materials for parents and teachers, and (iii) school playground modifications. Changes in cognition (logical reasoning, verbal factor, numerical factor, spatial factor and general intelligence) were measured. A propensity score cross-cluster matching procedure and mediation analysis (Hayes’s PROCESS macro) were conducted.

Results: All cognitive variables pre-post mean changes were significantly higher (p ≤ 0.05) in children from intervention schools than those from control schools (effect size ranged from 0.33 to 1.48). The effect of the intervention on the spatial factor and general intelligence was partially mediated by motor fitness (indirect effect =0.92, 95% CI: 0.36;1.65; and indirect effect =1.21, 95% CI: 0.06; 2.62, respectively).

Conclusions: This study shows that a one-school-year multicomponent intervention consisting of a recreational non-competitive PA program, educational materials for parents and teachers, and school playground modifications improved the cognition of first grade children. Further, our results suggest that the effect of the intervention on cognition was mediated by changes in motor fitness.

Trial registration: Clinical trials.gov: NCT01971827.

Key words: exercise, cognition, fitness, randomized controlled trial, children.
INTRODUCTION

Schools are considered an ideal setting for the promotion of children’s physical activity (PA). However, PA during the school schedule is not always possible due to the demands of the curriculum. Thus, after-school PA may constitute a good strategy for children to achieve PA recommendations and prevent diseases.

The benefits of integrating physical activity (PA) into the school day might even extend beyond the physical health benefits. Emerging evidence indicates that PA could be beneficial for cognitive performance in children, therefore, affecting learning and academic achievement in school, as well as classroom behavior. While some of the benefits of PA interventions on cognition may be due to direct changes (structural and functional) in the brain, indirect effects are also plausible, such as those mediated by factors as health status and psychosocial conditions.

Although some reviews support a positive relationship between PA, cognitive development and academic achievement in children, the effects of PA interventions on cognition in younger children remain unknown. Studies promoting PA during early childhood development are of critical importance since it is know that the exercise at early age (during cerebral maturational development) produces more benefits than at later ages. Thus, an active lifestyle during childhood may have protective effects on brain health across the lifespan.

Although most published randomized controlled trials (RCTs) on this topic are heterogeneous in outcome measures, participant characteristics and methods used. Thus, Pesce, et al. demonstrated that attendance in an 6-month enriched physical education (PE) intervention was positively associated with better inhibition outcomes compared to traditional PE. Ardoy et al observed that increasing the number and intensity of PE sessions
per week has a positive effect on non verbal and verbal abilities, abstract reasoning, spatial and numerical abilities \(^3\).

As far as we know, only 4 RCTs have analyzed the effect of after-school PA interventions on several aspects of executive function in healthy children \(^{16-19}\). Among them, results from the FITKids intervention (focused on cardiorespiratory fitness, but including motor skills and cooperation games) show an improvement in working memory \(^{16}\), cognitive flexibility and attention \(^{18}\) in prepubertal children. Chaddock-Heyman et al. observed that children receiving a PA intervention (FITkids program) improved performance on a flanker task after the intervention and an increase in brain activation in the prefrontal cortex function involved in cognitive control \(^{19}\). Among overweight children, similar results have been described; thus, Davis et al. \(^{20}\) and Kraff et al. \(^{21}\) demonstrated greater changes in brain activation in the prefrontal cortex and in the neural network supporting inhibitory control for the aerobic exercise group compared to the control group. The only study conducted in kindergarten children \(^{22}\) suggest that long-term coordinative exercise benefits prefrontal cortex activity (higher accuracy and faster reaction times in inhibitory tasks).

Additionally, although the evidence about the positive association between exercise with different aspects of executive function, such as working memory or inhibition, seems robust, the effect of exercise on other skills essential for mental and physical health, and success in school and in life, such as logical or verbal reasoning, \(^{23}\) have been poorly investigated in children.

The motor fitness improvements (capacity which integrates the subjects’ speed of movement, agility and coordination) has been associated with brain structures changes and academic achievement \(^{24,25}\). Furthermore, a systematic review concluded that complex motor skills such as coordination of movement in rhythm and timed performance in movements
(motor tasks closely related to motor fitness), showed strong relationship with higher order cognitive skills. Thus, it also seems reasonable to think that motor fitness may have a crucial role in the association between PA and cognitive processes in children.

Thus, the objectives of the present study were: i) to assess the impact of a multicomponent PA intervention (MOVI-KIDS) on improving cognitive performance in 5-7 year old children; and ii) to examine the potential mediator role of motor fitness in the effect of the MOVI-KIDS intervention on cognitive performance.

MATERIAL AND METHODDS
Study design and participants

This study was designed as a cluster randomized trial (MOVI-KIDS study) which included 21 schools (19 public and two private) from the provinces of Cuenca and Ciudad Real, Castilla-La Mancha region (Spain). The methods of MOVI-KIDS study have been reported in detail elsewhere. Of the 21 randomized schools, only 9 (4 schools of the intervention group-IG and 5 of the control group-CG) provided valid data of cognitive performance before and after the first year of intervention and were included in the analysis. Data from cognitive performance questionnaires at baseline were considered invalid when they had been administered after the period of baseline measurements (mid-October and later, and before the starting of the intervention). This time period was chosen considering that the curricular contents studied in the classroom could influence the responses of children in the cognition tests, and with the aim of avoiding variability among the children of the schools that responded in different time periods.
Ethics

The study protocol was approved by the Clinical Research Ethics Committee of the ‘Virgen de la Luz’ Hospital in Cuenca. The director’s and the board of governors’ approval was requested from each school, and all children’s parents belonging to the first grade of primary school (aged 5 to 7 years) were invited to participate in the study. Parents or legal guardians of all children included in the study provided written informed consent and children assented to participate. Furthermore, children were informed of the characteristics of the study and their opinion was taken into account in the design of the intervention. Before the starting of the MOVI-KIDS intervention, the members of the research team visited the intervention school to agree with parents, teachers and children what types of games and modifications in the playground would like them to be done. During the intervention, through the monitors of the PA program, the children were asked to express us what kind of activities they preferred to do, and these preferences were taken into account when designing the sessions of the intervention. We thought that this fact could increase compliance with the program.

Intervention

The primary objective of MOVI-KIDS was to increase the weekly amount of moderate-vigorous PA and to improve the health-related fitness and the motor competence. It was conducted from October 2013 to May 2014 and, as a multidimensional intervention based on the socio-ecological model\textsuperscript{28}, involved three levels:

\textit{a) Intervention with children}

Children allocated to IG participated in an after-school program that consisted of sports games, dance and motor skills whose main characteristics were the following:
**Physical activity program:** this program is based in a previous one (please see MOVI-2 program in www.movidavida.org). It consisted of traditional playground games and included three content blocks: sports team games, traditional games for the development of motor skills (simple tasks of balance, control of objects, jumps and bilateral body coordination) and activities with music (games and simple choreographies). A detailed description of the games can be found in www.movidavida.org. The program included three 60-minute PA sessions on weekdays, in the evening, from 4 to 6 pm. Although, considering that children from MOVI-KIDS were younger than those a previous similar intervention (MOVI-2)\(^{29}\), it is not possible to generalize the estimations of energy expenditure and intensity\(^{30}\) from this program to the new one, because MOVI-KIDS included the same MOVI-2 games (but adapted to 4-7 years old schoolchildren), we could estimate, taking into account the nature of the activities, that PA intensity of the games of MOVI-KIDS was moderate-vigorous. A total of 80 sessions were designed by two PA and sport sciences graduates and implemented by monitors with technical qualifications in PA and sports. In order to standardize program activities, the monitors attended to a 2-day workshop.

*b)* **Intervention with parents and teachers**

Parents and teachers of the IG children were involved in activities to promote active lifestyles in children such as to: a) use of reinforcement tools (e.g. a refrigerator magnet with recommendations for PA for children); b) answer a satisfaction questionnaire on the program; and c) access to the blog (http://movi3kids.blogspot.com.es/) where parents and teachers could observe children's progress, read news on reinforcing healthy lifestyles, and ask questions or make complaints to the research team.
c) **Environmental interventions**

Environmental interventions were conducted in the school’s playground. Fixed (a balance circuit and panels with incentives to be physically active during the recess) and mobile equipment (tires of different colors and sizes) were put in the playgrounds to encourage children to be more active during playtime.

The standard physical education curriculum (two h/week of physical education for the first grade of primary school with activities at low-to-moderate intensity) was applied in both control and intervention schools because it is compulsory in Spain.

**Instruments and procedures**

To improve adherence to MOVI-KIDS, participants attending at least 80% of the sessions received small gifts depicting the logo of the program's mascot as a reward. Furthermore, two meetings were conducted with the monitors, at baseline and three months later, and monthly contacts with monitors were held by phone and e-mail to get information about the children's attendance and the development of the program. This information allowed to maintain a permanent and continuous contact with the monitors and to know if the intervention was being carried out as it was designed. Apart from this, a quarterly visit to the centers was made to assess program performance and conduct satisfaction questionnaires for children and parents. These materials can be downloaded in www.movidavida.org. Finally, the monitors were responsible for accounting for adverse effects derived from the program such as dizziness, ankle sprains, muscular discomfort, etc. Also, they recorded the reasons for dropout.

The outcome variables (cognitive performance), the mediator (motor fitness) and covariates (weight status and family socio-economic status) were measured in the intervention and control participants at the start (September 2013) and at the end (June 2014).
of the PA program. In addition to sociodemographic variables (age, sex, type of school, etc.), we determined:

Outcome variables

Cognitive performance

Assessed using the Battery of General and Differential Aptitudes for schoolchildren aged six to eight years (BADyG E1). This battery has shown an excellent reliability (Cronbach's alpha = 0.92 to general intelligence), and strong predictive validity between general intelligence and scores in Language and Mathematics (r = 0.609; p = 0.001; r = 0.687; p = 0.001, respectively) and is the most commonly used battery in schools and research studies in Spain. This tool consisted of 162 items grouped in different tests that allow assessing some specific cognitive dimensions: logical reasoning (ability to establish analogy relations between concepts, flexibility to perform numerical-verbal problems and inductive reasoning), the verbal factor (ability to discover relationships between concepts and verbal comprehension), the numerical factor (ability to solve numerical problems safely and quickly) and the spatial factor (ability to make spatial turns with geometric figures and their inductive reasoning); and global computation of general intelligence (calculated as the sum of the four specific dimensions). A higher score indicates better cognitive performance. The teachers were responsible for administering the test in the classroom with the whole group.

Mediator variable

Motor fitness

Assessed by the 4×10 m shuttle run test. This test is considered a reliability and valid method to assess speed and agility in youth and has been widely used in studies with children. This test measures the ability to perform well coordinated and adaptable movement.
actions. Two parallel lines were drawn on the floor 10 m apart. Participants ran 4x10 (back and forth) as fast as possible crossing each line with both feet every time. The test was performed twice with at least five minutes of rest between attempts and the best score was recorded in seconds. Lower values indicate better performance.

Covariates

*Weight status*

Weight was measured twice (Seca® 861 scales; Vogel & Halke, Hamburg, Germany) with the child barefoot and in light clothing. Height was also measured twice, using a wall stadiometer (Seca® 222), in standardized conditions. Body mass index (BMI) was calculated as weight in kg divided by the square of the height in m. Children were classified as normal weight, overweight and obese.

*Family socio-economic status (SES)*

Data regarding family SES were gathered by using self-reported occupation and education questions completed by either the father or mother. An index of SES was calculated using the items regarding parents’ education and occupation. This index distinguishes, according to the scale proposed by the Spanish Society of Epidemiology, five categories of family SES: Lower, Upper lower, Lower middle, Upper middle and Upper.

*Statistical analysis*

Although data from this study comes from a cluster randomized controlled trial, taking into account the unbalance in the baseline measurements between CG and IG, as recommended by some authors, we decided to use propensity score procedures as a strategy to overcome this limitation. The propensity score technique, using the optimal matching approach, estimates the effect of the intervention using a model of causal inference that explain what would have happened if all the subjects of the intervention and control...
groups had the same characteristics at the beginning of the study. The propensity score derivation model was built with intervention and control groups as a dichotomous dependent variable including six covariates that could be related to the improvement of cognitive performance: cluster, age, gender, weight status, SES and general intelligence baseline. Cognitive performance outcomes were compared between MOVI-KIDS physical activity IG and CG using the t-Student test before and after propensity score matching. Effect size (ES) values around 0.2 were considered to be a weak effect, values around 0.5 were a moderate effect, values around 0.8 were a strong effect, and values larger than 1.0 were a very strong effect. Statistical analyses were performed with StataSE software, version 14 (StataCorp).

Mediation analysis was conducted to examine whether the association between MOVI-KIDS and cognitive performance was mediated by changes in motor fitness using the PROCESS macro for SPSS. The goal of this model was to investigate the total (c) and direct effects (a, b, c’), that indicate the unstandardized regression coefficient and significance between the independent and dependent variables in each model; and finally, the indirect effect (IE), obtained from the product of coefficients (a*b), that indicates the change in cognitive performance for every unit change in the intervention that is mediated by the proposed mediator. Age, gender and baseline motor fitness were added as covariates in these models. This macro used bootstrapping methods as recommended by Preacher and Hayes for testing mediation hypotheses, using a resample procedure of 10,000 bootstrap samples. Point estimates and confidence intervals (95%) were estimated for the IE. The point estimate was considered to be significant when the confidence interval does not contain zero. Statistical analyses were performed using IBM SPSS statistics v.21 software. The criterion for statistical significance was set as p ≤ 0.05.
RESULTS

Participation flow

Figure 1 displays the flow of schools and participating children across the intervention study. Of the 2407 children invited to participate in the MOVI-KIDS study, 1604 (66.6%) agreed to participate. Of those, 240 children (135 girls, 56.2%) had valid data of cognitive performance in both measurements. These data were used for the present analysis. There were no statistically significant differences by sex, age, physical fitness measurements or SES at baseline between children who completed the study and those who did not.

Baseline data

The baseline characteristics of the study cohort are presented in Table 1. Participants in the IG scored better on cognitive performance than participants in the CG (p<0.05), except for the verbal factor.

Cognitive performance outcomes

Changes in cognitive performance variables between the MOVI-KIDS intervention and the CG before and after propensity score matching are shown in Table 2. Before matching, all cognitive variables mean differences were significantly higher (p≤ 0.05) in children in intervention schools than those in control schools (ES ranged 0.33 to 0.87). After propensity score matching for covariates, differences remained in all cognitive dimensions (p≤ 0.05; ES ranged 0.99 to 1.48).

Mediation analysis

Mediation analysis models are depicted in Figure 2. In the first regression step (path a), the intervention was negatively related with motor fitness (lower values in this variable indicate better performance) (p<0.001). In the second step (path c), the regression coefficients of the intervention on the spatial factor and general intelligence were positive (p<0.001). In
the last regression model, motor fitness was negatively related to the spatial factor and general intelligence (path b) (p<0.05). In the third equation (path c’), when the intervention and motor fitness were simultaneously included in the model, the MOVI-KIDS intervention was positively associated with general intelligence and the spatial factor (p<0.001). Finally, the IE was significant (Figure 2A: 0.92, 95%CI: 0.36; 1.65; Figure 2B: 1.21, 95%CI: 0.06; 2.62), confirming the partial mediation role of motor fitness in the models, independent of age, gender and baseline motor fitness. The estimated percentage of total effect mediated by motor fitness was 27% for the spatial factor and 9.4% for general intelligence. The association between the MOVI-KIDS intervention and the logistic reasoning and the numerical factor were not mediated by motor fitness (data not shown).

**Process evaluation**

Compliance and satisfaction with the program

Children attended more than 75% of the PA sessions of the program, and 95.2% of parents reported that they were fairly or very satisfied with the program and 77% reported that it was rarely or never necessary to remind their children that they should go to the intervention. Over 90% of the children reported that they liked to go to the MOVI-KIDS program sessions and felt happy playing with their peers while attending the intervention.

Adverse outcomes

No injuries or other adverse events occurred during the program, or during the health and physical evaluations.

A supplementary file shows additional information on indicators of process evaluation with the PA program (please see Supplementary information 1).
DISCUSSION

Main findings

After controlling for cluster, gender, age, SES, weight status and general intelligence baseline, we observed a significant and positive effect of the MOVI-KIDS intervention on children’s cognitive performance. Motor fitness partially mediated the relationship between the MOVI-KIDS intervention and spatial factor and general intelligence, even after controlling for age, gender and basal motor fitness. The association between the MOVI-KIDS intervention and the logistic reasoning and the numerical factor were not mediated by motor fitness.

Comparison with other studies

According to results of previous cross-sectional studies \(^{26,42}\), our intervention was associated with an increase in cognitive performance. However, it is difficult to compare the effect of MOVI-KIDS with other school PA intervention RCTs, mainly because of the heterogeneity in the design of the interventions, and the outcome variable analysed.

In line with our results, Koutsandréou et al. indicated that working memory in 9 to 10 years old children improved from both cardiorespiratory and motor-demanding exercises in after school programs lasting 10 weeks (45 minute sessions three times per week), with major benefits observed from motor-demanding exercises \(^{17}\). Another study lasting 8 weeks (35 minute sessions twice per week) in kindergarten children showed a beneficial effect of coordinative exercise (involving coordinative movements of the lower extremities at low or moderate intensity) on inhibitory aspects of executive function \(^{22}\). Similar positive results have also been found in an RCT after a 9 month long-term exercise randomized PA intervention study (70 minutes of moderate to vigorous PA each school day) aimed at increasing cardiorespiratory fitness, but also activities of muscle fitness and games centred around a skill theme (i.e. dribbling). They found that PA was associated with improvements

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in working memory in 7 to 9 year old children. In a similar sample, Hillman et al observed that at least 70 minutes of daily PA improved cognitive performance and brain function during tasks, requiring greater executive control (inhibition and cognitive flexibility) after a 9-month PA intervention that included, mainly, activities to improve cardiorespiratory capacity, but simultaneously provided opportunities to refine motor skills.

A characteristic common to all these studies, and others school-based PA interventions, is that all of them include cognitive engagement (to a lesser or greater degree) in the activities of the PA intervention. Although, as in our study, being an intervention that includes two components (cardiorespiratory fitness and motor competence), it is not possible to know which of them is the most effective. However, Schmidt et al. comparing three types of classroom-based PA interventions to a control group (PA breaks with high cognitive demands, PA breaks with low cognitive demand, sedentary with high cognitive demands) reported a positive impact on attention for the students in the group of PA with high cognitive demands group only. Similar findings have been observed in other study in which an improvement in shifting performance was found only in the PE program with a high level of physical exertion and high cognitive engagement (team games) and not in the PE program with high physical exertion but low cognitive engagement (aerobic exercise) or control condition.

**Mediation analysis**

Greater emphasis on endurance and motor exercises in MOVI-KIDS sessions could be responsible for the success in improving cognitive processes. In animal studies, it has been shown that endurance exercises increase capillary density (angiogenesis) and thereby, increase brain blood flow, whereas motor exercises cause synaptogenesis and an increased number of neuronal synapses. Further, peripheral brain-derived neurotrophic factor
(BDNF) facilitating brain function and memory processes levels are significantly elevated in response to exercise in humans\(^46,47\).

There is a lack of studies testing whether motor fitness mediates the relationship between the effect of PA programs and cognition dimensions; the only similar one that has explored the mediation effect of fitness between a PE program and executive function was in overweight children\(^48\). However, this study did not evaluate motor fitness but cardiorespiratory fitness, which makes these studies not comparable. Overall, our data suggest that the positive effect of a PA intervention on brain function could be partially explained through increases in motor fitness. It should also be taken into consideration that in this study the test used to measure motor fitness (4×10 m shuttle run test) requires coordination, agility, decision-making and spatial orientation, abilities that have been associated with increases of BDNF concentrations in peripheral blood of healthy adults\(^47\). Further, it is known that motor exercise leads to specific adaptation of the prefrontal cortex and the cerebellum, brain areas that are typically associated with cognitive operation\(^26,49\).

**Limitations**

Our study has some limitations that should be highlighted: i) The MOVI-KIDS intervention mixes different types of exercise in its after-school PA program (cardiorespiratory and the focus on the refinement of gross motor skills) and includes three levels of action (PA after-school program for schoolchildren, educational materials for parents and teachers, and school playground modifications), thus it is difficult to establish which is the most effective one; ii) in our study, the outcome does not measure the executive function core skill (inhibitory control, working memory and cognitive flexibility) but non-executive cognitive function (spatial aptitude) and higher-order executive functions (logical and verbal reasoning)\(^2,23\) thus, making comparisons with other research difficult. iii)
Although the teachers know and use frequently the cognition tests, the fact that they administered the cognition battery instead of the trained research team members may affect the reliability of the results. iv) An important limitation of this study is that physical activity patterns of the participants were not controlled during the intervention. Finally, it is commonly known that aerobic fitness could be the variable that in some degree mediates the relationship between exercise and cognition\(^{10,50}\), but at the baseline measurement we realized that this test, as described for children 6 to 18 years old in the ALPHA battery\(^{33}\), was not applicable for children younger than 6 years.

PERSPECTIVES

This study shows that a one-school-year multidimensional intervention consisting of a recreational non-competitive PA after-school program, educational materials for parents and teachers, and school playground modifications improved the cognitive performance of first grade children and it is feasible to be implemented in schools. Further, our results suggest that the effect of the intervention on cognition was mediated by changes in motor fitness. These PA programs should include both quantitative (cardiovascular and motor fitness) and qualitative (motor skills) aspects of exercise.

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**Competing interests**

The authors declare that they have no competing interests.

**Authors’ contributions**

VMV and MSL designed the study. MSL was the principal investigator and guarantor. MSL, DGDC and VMV were the main coordinators of the study. CAB, MJPG, ARH, ADF, DPPC conducted the study. ICR gave statistical and epidemiological support. MSL wrote the article with the support of VMV and ICR. VMV and MSL obtained the funding. All authors established the methods and questionnaires, provided comments on the drafts, and have read and approved the final version.
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Table 1. Descriptive characteristics of MOVI-KIDS children.

<table>
<thead>
<tr>
<th></th>
<th>Overall n=240</th>
<th>Intervention Group n=82</th>
<th>Control group N=158</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age mean (years)</strong></td>
<td>5.84 ± 0.38</td>
<td>5.78 ± 0.42</td>
<td>5.87 ± 0.35</td>
<td>0.070</td>
</tr>
<tr>
<td><strong>Girls, n (%)</strong></td>
<td>135 (56.25)</td>
<td>48 (58.5)</td>
<td>87 (55.1)</td>
<td>0.607</td>
</tr>
<tr>
<td><strong>Overweight/Obesity, n (%)</strong></td>
<td>59 (24.58)</td>
<td>23 (28.0)</td>
<td>36 (22.8)</td>
<td>0.369</td>
</tr>
<tr>
<td><strong>Urban environment school, n (%)</strong></td>
<td>118 (49.2)</td>
<td>30 (36.6)</td>
<td>88 (55.7)</td>
<td><strong>0.005</strong></td>
</tr>
<tr>
<td><strong>Public school, n (%)</strong></td>
<td>168 (70.0)</td>
<td>65 (79.3)</td>
<td>103 (65.2)</td>
<td><strong>0.024</strong></td>
</tr>
<tr>
<td><strong>Socioeconomic level, n (%)</strong></td>
<td></td>
<td></td>
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<tr>
<td>Low-Low/middle</td>
<td>43 (17.9)</td>
<td>12 (14.6)</td>
<td>31 (19.6)</td>
<td>0.339</td>
</tr>
<tr>
<td>Middle</td>
<td>119 (49.6)</td>
<td>49 (59.8)</td>
<td>70 (44.3)</td>
<td><strong>0.023</strong></td>
</tr>
<tr>
<td>Middle/high-High</td>
<td>78 (32.5)</td>
<td>21 (25.6)</td>
<td>57 (36.1)</td>
<td>0.220</td>
</tr>
<tr>
<td><strong>Motor fitness</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4×10 m shuttle run test (sec)</td>
<td>16.37 (1.72)</td>
<td>16.35 (1.85)</td>
<td>16.38 (1.65)</td>
<td>0.907</td>
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<td><strong>Cognitive performance</strong></td>
<td></td>
<td></td>
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<tr>
<td>Logic reasoning</td>
<td>27.23 ± 8.64</td>
<td>25.34 ± 8.82</td>
<td>28.21 ± 8.40</td>
<td><strong>0.014</strong></td>
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<tr>
<td>Verbal Factor</td>
<td>22.70 ± 5.28</td>
<td>22.36 ± 5.30</td>
<td>22.87 ± 5.29</td>
<td>0.482</td>
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<tr>
<td>Numerical Factor</td>
<td>16.98 ± 7.88</td>
<td>14.15 ± 8.33</td>
<td>18.44 ± 7.24</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Spatial Factor</td>
<td>15.51 ± 6.75</td>
<td>13.72 ± 6.72</td>
<td>16.44 ± 6.59</td>
<td><strong>0.003</strong></td>
</tr>
<tr>
<td>General Intelligence</td>
<td>55.19 ± 15.95</td>
<td>50.24 ± 15.75</td>
<td>57.76 ± 15.49</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Data are reported as mean ± SD or number (%). In cognitive dimensions a higher score indicates a better cognitive performance.
Table 2. Differences in cognitive performance between MOVI-KIDS intervention and control groups before and after propensity score matching.

<table>
<thead>
<tr>
<th>Cognitive performance</th>
<th>Before matching</th>
<th>After matching</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intervention Group</td>
<td>Control group</td>
</tr>
<tr>
<td>Logic reasoning</td>
<td>11.17 ± 8.38</td>
<td>8.68 ± 7.17</td>
</tr>
<tr>
<td>Verbal Factor</td>
<td>5.33 ± 4.26</td>
<td>0.81 ± 6.47</td>
</tr>
<tr>
<td>Numerical Factor</td>
<td>11.94 ± 8.97</td>
<td>7.61 ± 7.73</td>
</tr>
<tr>
<td>Spatial Factor</td>
<td>6.41 ± 7.28</td>
<td>2.76 ± 6.81</td>
</tr>
<tr>
<td>General Intelligence</td>
<td>23.68 ± 15.38</td>
<td>11.18 ± 13.90</td>
</tr>
</tbody>
</table>

Data are reported as mean ± standard deviation or number (%). ES: Effect size

Propensity score matching adjusted by cluster, gender, age, socioeconomic status, weight status and general intelligence at baseline.
Assessed for eligibility 22 Schools from Cuenca and Ciudad Real provinces, Spain, (n=1788)

Randomization 21 Schools (n=1608)

Refused to Participate 1 School (n=180)

Allocated to MOVIKIDS intervention 11 Schools (n=688)
Allocated to CONTROL 10 Schools (n=910)

Lost to Follow up (n=79): - Change of school - Health problems

Analysed 4 Schools (n=82) Excluded from analysis for not providing any data on cognitive performance 7 Schools (n=537)

Lost to Follow up (n=95): - Change of school

Analysed 5 Schools (n=158) Excluded from analysis for not providing any data on cognitive performance 5 Schools (n=657)
A. Spatial factor

\[ \Delta \text{Motor fitness} \]

\[ a = -0.87^{**} \]

\[ \text{Movikids} \]

\[ c = 3.42^{**} \]

\[ c' = 2.50^* \]

\[ b = -1.06^* \]

\[ IE = 0.92 \ (95\% CI; 0.36-1.65) \]

\[ \%Med: 27.0\% \]

B. General intelligence

\[ \Delta \text{Motor fitness} \]

\[ a = -0.87^{**} \]

\[ \text{Movikids} \]

\[ c = 12.87^{**} \]

\[ c' = 11.66^{**} \]

\[ b = -1.39^* \]

\[ IE = 1.21 \ (95\% CI; 0.06-2.62) \]

\[ \%Med: 9.4\% \]