Original Article

Motor coordination and academic performance in primary school students

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ABSTRACT

Objective: There is interest in studying the relationship between cognition and motor skills for decades. However, there are few studies that provide scientific evidence on the relationship between motor coordination and academic performance. Therefore, a descriptive cross-sectional study was conducted with 163 Spanish schoolchildren aged 6-9 years. Motor coordination was measured with the GRAMI-2 Test. Academic performance was obtained through the average grades of the subjects of language, mathematics, natural science, social science, English and artistic. The variables were calculated: motor coordination index and overall academic performance. The results obtained showed that schoolchildren with a better motor coordination index had higher marks in language, mathematics, natural science and English (p between <.01 and <.05). Dividing the sample according to the global academic performance, those with a good academic performance showed a better coordination performance in lateral jumps (p = .021) and a better motor coordination index (p = .008). These results indicate the existence of a positive relationship between motor coordination and academic performance, which may be this bidirectional link. This study could have practical implications to be taken into account by physical education teachers, such as, the increase in opportunities for physical activity during school and after school hours through the development of programs based on coordinative exercise, and especially oriented towards those less competent at the motor level. **Keywords:** Motor coordination; Motor competence; Academic performance; Childhood; Primary education.

Cite this article as:
Guillamón, A.R., Cantó, E.G., & García, H.M. (2020). Motor coordination and academic performance in primary school students. *Journal of Human Sport and Exercise*, *in press*. doi:https://doi.org/10.14198/jhse.2021.162.02

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Submitted for publication November 11, 2019
Accepted for publication January 27, 2020
Published *in press* February 24, 2020
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.14198/jhse.2021.162.02

INTRODUCTION

Over the last decades, the scientific and educational interest has increased to investigate the possible relationships between physical activity, physical condition or physical education classes with cognitive performance or academic performance (Conde & Tercedor, 2015; Khan & Hillman, 2014). This interest has been largely motivated by the findings of cognitive function in areas of neuroscientific knowledge (Gunnell et al., 2019; Khan & Hillman, 2014). The study of cognitive abilities such as attention, concentration or planning capacity, among others, has a great relevance since it has been reported a close link with psychosocial development, processes of adaptation to the environment or Academic performance (Chen, Zhang, Callaghan, LaChappa, Cheny & He, 2017; Medina, 2014; Pérez, Nieto, Otero, Amengual & Manzano, 2014; Schmidt, Bezing & Kamer, 2016; Schmidt, Egger & Conzelmann, 2015).

The analysis of the factors associated with academic performance has been a constant concern among public and private institutions all over the world due to the poor results obtained in the International Student Assessment Program (PISA) tests of the Organization for Cooperation and Economic Development (OECD, 2018). This fact has been the subject of a growing body of research in schoolchildren and teenagers finding randomized control studies (Ardoy et al., 2010; Ardoy, Fernández-Rodríguez, Jiménez-Pavón, Castillo, Ruiz & Ortega, 2014) and even some systematic reviews in which different factors have been analysed (Conde & Tercedor, 2015; Fedewa & Ahn, 2011). Some studies have investigated the design of academic curriculum. In this sense, one of the subjects that generates the greatest controversy is physical education (Cañadas et al., 2015). Although some educational policies have been aimed at reducing the number of teaching hours, the results of various studies support the importance of this subject in the integral training of students, since it favours cognitive and academic performance (Ardoy et al., 2014); provides the necessary opportunities for the fulfilment of the premises for a healthy physical activity (Albarracín, Moreno & Beltrán, 2014), which contributes to combat the high prevalence of obesity (Ardoy et al., 2010); and allows during the school day that certain brain circuits affected by the fatigue of academic tasks are replenished, enhancing cognitive functions, thereby improving academic performance (Aguayo-Berrios, Latorre-Román, Salas-Sánchez & Pantoja, 2018; Domínguez-Sánchez, Alarcón-Malagón, García-Flórez & Velandia-Guillén, 2018). Other studies have analysed the influence of the sociocultural environment, concluding that the best academic evaluations were found in families with a high economic and cultural level (Córdoba, García, Luengo, Vizuete & Feu, 2012); although other works have not found differences in this regard and have reported the importance within the lifestyle of physical activity, dietary intake and micronutrient status (Desai, Kurpad, Chomitz & Thomas, 2015). In this line it has been described that the subjects with a moderate physical practice (between two and five hours per week) obtained better academic qualifications since they showed adequate rest patterns, better study habits and better planned their free time, dedicating less time to leisure sedentary (Capdevila, Bellmunt & Hernando, 2015). However, despite the well-known positive effects of physical activity on cognitive functions and psychological well-being, other studies have reported worse academic results in subjects who performed competitive physical activity (more than five hours per week), although they had a better physical condition (Cladellas, Clariana, Gotzens, Badia & Dezcallar, 2015; Valdés & Yanci, 2016). This is a matter of controversy since the available scientific evidence is mainly guided by the positive effects of physical condition on academic performance (Cancela, Ayán & Sanguos, 2015; Castro, Pérez, Cachón & Zagalaz, 2015; Chomitz, Slining , McGowan, Mitchell, Dawson & Hacker, 2009; Serrano, Castro, Moreno & Cachón, 2015; Villena, Castro, Moreno & Cachón, 2015); especially through the positive influence of aerobic capacity on the development of brain regions such as the supplementary motor cortex, the premotor cortex or the hippocampus, directly associated with indicators of academic performance such as memorization, auditory perception and motor competence (Desai et al., 2015; Pertusa, Sanz-Frías, Salinero, Pérez-González & García-Pastor, 2018; Rosa, García & Carrillo, 2019).

In this sense, several investigations have gone in depth in the analysis of motor and cognitive competence and cognition, some of them based on the belief of an indissoluble relationship between body and mind, where cognitive abilities are built from motor action. (Avilés, Ruiz, Navia, Rioja & Sanz, 2014; Varela, Thompson & Rosch, 2005); being motor coordination one of the most important factors to take into account in the child evolutionary development (Fernandes et al., 2016; Ismail & Gruber, 1967; Leonard & Hill, 2015; Planisec & Pisot, 2006; Ruiz, Rioja, Graupera, Palomo & García, 2015a; Ruiz-Pérez, Navia, Ruiz, Ramón & Palomo, 2016). In this context, for example, the relationships between multiple intelligences and motor coordination have been explored showing results that support the association between body-kinesthetic intelligence and coordinative performance (Pérez et al., 2014) which has supported by the existence of neural connections above structural or muscular factors (Diamond & Lee, 2011; López de los Mozos-Huertas, 2018). Other studies have investigated the association between motor development and language, concluding that there are consistent findings which consider relationships between motor coordination problems and language problems (Ruiz-Pérez, Ruiz-Amengual & Linaza-Iglesias, 2016). According to this, it is added that schoolchildren with motor-coordination problems are inhibited in physical education classes and do not practise extracurricular physical activity in a group. This favours a sedentary lifestyle, lower social relationships and a worse perception of themselves (Vedul-Kjelsås, Sigmundsson, Stensdotter & Haga, 2012).

However, other studies suggest the relevance of clarifying and explaining these findings, especially in the case of child population, where relationships among physical condition and motor coordination together with academic cognitive performances, and the directionality of these are contradictory (Arismendi et al., 2018; Esteban et al., 2014; Themane et al., 2006; Yu et al., 2006). Therefore, the objective of this study is to analyse the relationships between motor coordination and academic performance in a sample of primary school students.

MATERIAL AND METHOD

Design

On the basis of a non-experimental methodology, a descriptive and cross-sectional study was proposed, using the survey as an instrument for the gathering of information (Thomas, Nelson & Silverman, 2015). The study is included in a larger research, framed in a doctoral thesis developed at the Faculty of Education of the University of Murcia (Murcia, Spain).

Participants

The sample consisted of 163 schoolchildren, aged 6-9 years (M ± SD = 7.53 ± 1.14 years) (see Table 1). The participants were enrolled in two public schools in the Region of Murcia (Spain). The selection process was non-random since it has been chosen for convenience. Informed consent form was requested to the management of the centres and to the parents' association to participate in the study. Moreover, they were informed about the protocol and goal of the study. The informed consent form of the school management teams was obtained, as well as the informed consent of the school children's legal parents or tutors. The inclusion criteria were to have an attendance percentage of at least 90% during the months of the academic year, and not receive educational attention as students with specific educational support needs according to Royal Decree 126/2014 of basic curriculum for the primary education (MECD, 2014). Schoolchildren who showed a clinical diagnosis of some type of cardiovascular or osteoarticular disease were excluded.

Table 1. Sample distribution according to age and sex.

	6 years old	7 years old	8 years old	9 years old	Total
Men, *n* (%)	19 (11.7)	27 (16.6)	21 (12.9)	25 (15.3)	92 (56.4)
Women, *n* (%)	21 (12.9)	16 (9.8)	13 (8.0)	21 (12.9)	71 (43.6)
Total, *n* (%)	40 (24.5)	43 (26.4)	34 (20.9)	46 (28.2)	163 (100.0)

Instruments

Motor coordination

The GRAMI-2 Motor Test (Ruiz, Rioja, Graupera, Palomo & García, 2015b) was used to measure motor coordination. This test allows global assessment of motor coordination by providing information not only at motor skill level of standardized students, but also on the detection of problems in motor evolution, being useful for physical education teachers, developmental psychologists and health professionals.

The GRAMI-2 is made up of four tests that measure the execution time used in seconds and tenths of a second, so that the lower the execution time, the better the test performance. These tests are: nine meter round trip (4 x 9 meter race); seven-meter race jumping with one leg (7m to the lame leg), travel speed race over a distance of 30 meters (30m race), three meters in displacement on two small supports (Travel on supports). The GRAMI-2 is made up of another test that measures the lateral jumps made on a non-slip platform in 15 seconds (lateral jumps), so that a greater number of jumps indicates a better performance. The last test measures the throwing distance in centimetres with a one kilo medicine ball (Medicine ball launch), so that the better the distance, the better the performance. The application of the tests has been described previously (Ruiz, Rioja, Graupera, Palomo & García, 2015a).

The reliability and validity of the GRAMI-2 tests were studied, throwing values of the intraclass and inter-exploratory correlation coefficient above .90 in both cases. No variability was detected among intra-case measures ($p <.05$), so the test showed adequate validity (Shrout & Fleiss, 1979).

The motor coordination index (ICM) variable was calculated, with values between zero and ten, as the average of the scores of the GRAMI-2 variables. School children were categorised into two groups according to the value of the ICM: lower ICM (mean <50th percentile) and higher ICM (mean ≥ 50th percentile), with the 50th percentile = 5.5.

Academic performance

Following the procedure of Ruiz-Pérez et al. (2016) the centre's studies were requested the grades of the subjects that are common in the primary education curriculum (language, mathematics, natural science, social science, English and artistic) according to Royal Decree 126/2014 (MECD, 2014) . For a more complete analysis the following variables were calculated: core (average grade of mathematics and language subjects), specific (average grade of natural science, social science, English and artistic subjects) and overall academic performance (arithmetic means of all subjects). In line with what was done by Castro, Pérez, Cachón & Zagalaz (2015), the grades were distributed in three levels of achievement: poor (average <5 points), average (5 points ≤ average> 7 points) and good (≥ 7 points).

Process

The field work was carried out during the month of January 2019 by a principal investigator being accompanied by two explorers trained in the application of the tests. A pilot test was carried out in each school, with schoolchildren not participating in the study, to evaluate the reliability and validity of the tests and develop a strict standardization of the measurement protocol, providing rigor to the study. Families were advised that schoolchildren should not change their lifestyle during the days before the administration of the tests. Participants received verbal instructions to perform each test accompanied by a practical demonstration. All measurements were performed in the same order, leaving intervals between 5-10 minutes. A 5-minute activation based on dynamic joint mobility was performed. A previous trial of each test was allowed. The measurements were carried out between 9:30 am and 11:30 am to avoid possible tiredness of the teaching day.

Statistical analysis

A descriptive study of the variables was carried out through the calculation of means and typical deviations. Normality and homogeneity were analysed from the Kolmogorov-Smirnov and Levene tests respectively, applying parametric tests in the differential analysis. Mean differences between groups were analysed using Bonferroni correction for multiple comparisons. In assessing the results, the level of bilateral significance $p \leq .05$ was taken into account. The calculations were performed with the SPSS software (v. 23.0 of SPSS Inc., Chicago, Illinois, USA).

RESULTS

Table 2 presents the average values of the motor coordination tests of the GRAMI-2 test, as well as the ICM value (5.3 ± 2.3). You can also observe the average scores in academic subjects, in addition to the overall academic performance (6.8 ± 1.7 points).

Table 2.*Basic descriptions of the study variables.*

	M ± DT	Minimum	Maximum
Test GRAMI-2			
Race 30m (s)	7.7 ± .8	5.9	10.8
Race 4 x 9m (s)	15.7 ± 1.5	13.0	21.3
7m limp leg (s)	4.6 ± .8	3.1	7.7
Displacement on supports (s)	45.6 ± 12.6	20.1	93.3
Lateral jumps (n)	19.7 ± 6.8	6.0	37.0
Throwing ball (cm)	275.7 ± 84.5	110.0	525.0
Motor coordination index[a] (0-10)	5.3 ± 2.3	1.0	10.0
Academic performance			
Language (0-10)	6.7 ± 2.0	1.0	10.0
Mathematics (0-10)	6.7 ± 2.1	2.0	10.0
Natural science (0-10)	7.3 ± 1.8	2.0	10.0
Social science (0-10)	7.0 ± 1.9	2.0	10.0
English (0-10)	6.3 ± 2.1	2.0	10.0
Art (0-10)	7.1 ± 1.6	2.0	10.0
Cores[b] (0-10)	6.7 ± 2.0	1.5	10.0
Specifics[c] (0-10)	6.9 ± 1.6	2.3	9.8
Global academic performance[d] (0-10)	6.8 ± 1.7	2.3	9.8

[a] Average of the scores of the variables of the GRAMI-2 test; [b] average of math and language subjects; [c] average of the subjects of natural, social, English and artistic; [d] arithmetic means of all subjects.

Table 3 shows the prevalence of schoolchildren with poor, average or good performance in core variables (language and mathematics) and specific (natural science, social science, English and artistic), observing a percentage of 48.5% of schoolchildren with a good performance in both core and specific subjects.

Table 3. Distribution of the sample according to the performance in the core and specific subjects.

		Count	Percentage
Core[a]	Insufficient	24	14.7
	Average	60	36.8
	Good	79	48.5
	Total	163	100.0
Specific[b]	Insufficient	24	14.7
	Average	60	36.8
	Good	79	48.5
	Total	163	100.0

[a] Cores: language and mathematics; [b] specific: natural science, social science, English and art.

Figure 1 shows how, bearing in mind the sample according to the global academic performance, the analysis showed different percentages in the distribution of the participants. Here we can observe a prevalence of 48.5% with a good performance, 38% of average performance and 13.5%. of poor performance.

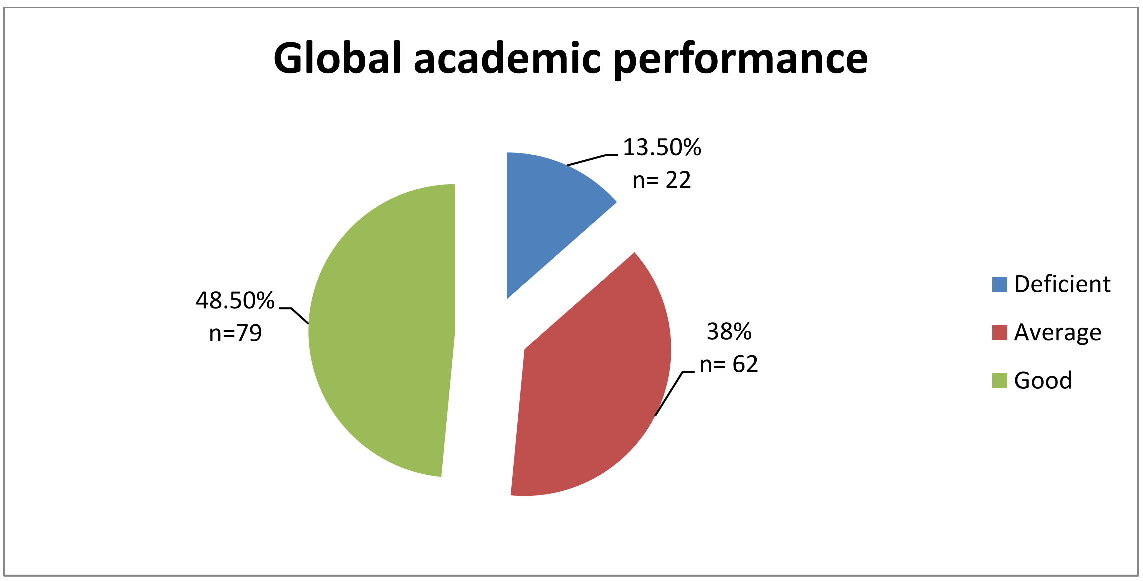

Figure 1. Sample distribution according to overall academic performance.

Table 4 shows the average values of the motor coordination tests, as well as the ICM according to the academic performance levels, after applying a unifactorial analysis of variance (ANOVA). As described in Table 5, this analysis showed statistically significant differences in the lateral jump test (F = 3.691; p = .027) and in the ICM (F = 2.599; p = .05). The multiple comparisons test (Bonferroni method) detected that schoolchildren with poor overall academic performance had a worse physical performance in the lateral jump test compared to their peers with an average performance (16.2 v. 20.0; p = .021) or good (16.2 v. 20.5; p = .008). No differences were observed between the groups with good and average performance (20.5 v. 20.0;

p = .692). Significant differences in ICM were also detected between the poor and good overall academic performance groups (4.3 v. 5.6; p = .024).

Table 4. Descriptive analysis of motor coordination according to academic performance.

	Global academic performance[a]	Media ± DT	IC 95% Lower	IC 95% Superior
Run 30m (s)	Insufficient (n = 22)	7.7 ± .8	7.4	8.1
	Average (n = 62)	7.6 ± .7	7.4	7.8
	Good (n = 79)	7.6 ± .8	7.4	7.8
4 x 10m with obstacles (s)	Deficient (n = 22)	16.1 ± .8	15.4	16.7
	Average (n = 62)	15.6 ± 1.4	15.3	16.0
	Good (n = 79)	15.7 ± 1.4	15.3	16.1
Jump limp leg (s)	Insufficient (n = 22)	4.7 ± 1.6	4.4	5.0
	Average (n = 62)	4.5 ± 1.5	4.3	4.7
	Good (n = 79)	4.6 ± .8	4.4	4.7
Displacements between supports (s)	Insufficient (n = 22)	47.3 ± .7	41.9	52.6
	Average (n = 62)	45.9 ± .8	42.8	49.1
	Good (n = 79)	44.8 ± .8	42.1	47.6
Lateral jumps (n)	Insufficient (n = 22)	16.2 ± 10.4	13.4	18.9
	Average (n = 62)	20.0 ± 13.1	18.3	21.7
	Good (n = 79)	20.5 ± 12.8	19.0	21.9
Ball throw (cm)	Insufficient (n = 22)	262.0 ± 12.6	226.3	297.7
	Average (n = 62)	272.2 ± 5.2	250.9	293.5
	Good (n = 79)	282.3 ± 6.1	263.4	301.1
Motor coordination index[b] (0-10)	Insufficient (n = 22)	4.3 ± 2.3	3.4	5.3
	Average (n = 62)	5.3 ± 2.2	4.7	5.8
	Good (n = 79)	5.6 ± 2.2	5.1	6.1

[a] Arithmetic mean of all subjects; [b] average of the scores of the variables of the GRAMI-2 test.

Table 5. Multiple comparisons among academic performance groups in two proofs of motor test GRAMI-2.

Dependent variable	(I) Global academic performance[a]	(J) Global academic performance[a]	Dif. medias (I-J)	EE	IC 95% Lower	IC 95% Superior	p
Lateral jumps (n)	Insufficient (n = 22)	Average	-3.85*	1.65	-7.1	-.6	.021
		Good	-4.29*	1.61	-7.4	-1.1	.008
	Average (n = 62)	Insufficient	3.85*	1.65	.6	7.1	.021
		Good	-.45	1.13	-2.7	1.8	.692
	Good (n = 79)	Insufficient	4.29*	1.61	1.1	7.5	.008
		Average	.45	1.13	-1.8	2.7	.692
Motor coordination index (0-10)	Insufficient (n = 22)	Average	-.98	.56	-2.1	.1	.083
		Good	-1.24*	.54	-2.3	-.1	.024
	Average (n = 62)	Insufficient	.98	.56	-.1	2.1	.083
		Good	-.26	.38	-1.1	.5	.492
	Good (n = 79)	Insufficient	1.24*	.54	.2	2.3	.024
		Average	.26	.38	-.5	1.1	.492

[a] Aritmetic media of all the subjects.

Finally, in table 6 it can be seen how, by dividing the sample according to the ICM (minor v. Major), the ANOVA test detected significant differences in language (p = .024), mathematics (p = .009), natural (p = .010), English (p = .007), core (p = .011), specific (p = .023) and overall academic performance (p = .015).

Table 6. *Analysis of the academic performance according to the motor coordination.*

	ICM[a]	M ± DT	EE	IC 95%		p
				Lower	Superior	
Language	A (*n* = 70)	6.3 ± 2.1	.232	5.8	6.7	.024
	B (*n* = 93)	7.0 ± 1.8	.201	6.6	7.3	
Mathematics	A (*n* = 70)	6.2 ± 2.1	.251	5.7	6.7	.009
	B (*n* = 93)	7.1 ± 2.1	.218	6.6	7.5	
Natural science	A (*n* = 70)	6.8 ± 1.9	.215	6.4	7.2	.010
	B (*n* = 93)	7.5 ± 1.7	.187	7.2	7.9	
Social science	A (*n* = 70)	6.7 ± 1.9	.227	6.3	7.2	.149
	B (*n* = 93)	7.2 ± 1.9	.197	6.8	7.5	
English	A (*n* = 70)	5.7 ± 2.2	.251	5.2	6.2	.007
	B (*n* = 93)	6.6 ± 1.9	.218	6.2	7.0	
Art	A (*n* = 70)	6.9 ± 1.7	.192	6.5	7.3	.262
	B (*n* = 93)	7.2 ± 1.5	.167	6.8	7.5	
Cores	A (*n* = 70)	6.2 ± 2.1	.231	5.8	6.7	.011
	B (*n* = 93)	7.1 ± 1.8	.201	6.6	7.4	
Specifics	A (*n* = 70)	6.5 ± 1.7	.195	6.1	6.9	.023
	B (*n* = 93)	7.1 ± 1.5	.169	6.8	7.5	
Global academic performance	A (*n* = 70)	6.4 ± 1.8	.202	6.01	6.8	.015
	B (*n* = 93)	7.1 ± 1.5	.175	6.7	7.4	

[a] ICM = motor coordination index; A = minor ICM, B = greatest ICM. The cut-off point was set to P_{50} = 5.5.

DISCUSSION AND CONCLUSIONS

The results of our study indicate the existence of a direct relationship between motor coordination and academic performance in Spanish schoolchildren from 6 to 9 years. We can observe that those students with a better coordination performance established from the ICM had higher grades in language, mathematics, natural science and English. When dividing the sample according to the global academic performance (poor, average or good), those with a good academic performance showed a better coordination performance in lateral jumps and a better ICM.

Although the size of the effect of the differences found is low (d ≤ .03 in all variables), probably due to the number of participants in the study, the results found should not be downplayed. The existence of a positive link between motor coordination and academic competence could be a reason to strength the role of the physical education area among the educational community, as well as to raise the teacher's status (Albarracín et al., 2014 ; Cañadas et al., 2014); having even observed a positive effect of physical education sessions on other executive functions related to academic performance such as attention (Aguayo-Berrios et al., 2018; Schmidt et al., 2015) and concentration (Chen et al., 2017). Along these same lines, randomized control studies have shown the need to increase the number of teaching hours, as well as the level of intensity of the sessions (Ardoy et al., 2010, 2014); while other research underscores the need to incorporate active breaks during the school day to improve cognitive and attention performance (Domínguez-Sánchez et al., 2018; Schmidt et al., 2016).

When comparing the results of our research with other works carried out with subjects of the same nationality and who used similar study instruments, it was observed that not all motor tests behaved equally. Thus, in relation to the lateral jump test, it was appreciated that those with better performance were grouped around average or good academic performance, which coincides with what has already been established by Ruiz-Pérez et al. (2016). However, it is not consistent with what was reported by these authors regarding the displacement test on supports in which they did observe significant differences between the groups good versus poor academic performance. In fact, recent findings invite us to think that motor coordination, especially vasomotor, could have effects on cognitive function and academic performance in schoolchildren and adolescents (Fernandes et al., 2016).

In our study, no significant differences were found in artistic and social science, perhaps due to the absence of tests of fine motor skill assessment and their subsequent relationship with artistic skills in the case of the first; or the linking of the coordinative capacities with the capacity of memorization that usually is used in the case of the second. This disparity in the results could also be due to the fact that the level of motor coordination of the sample was not excessively high and, therefore, exerted a negative influence, although this explanation is not entirely consistent.

In general, the results of our study are close to those reflected in other investigations that have analysed the relationship between physical condition and academic performance, as far as the subject of mathematics is concerned (Cancela et al., 2015). In relation to this, Ruiz et al. (2014) conclude that logical-mathematical intelligence is the best predictor of academic performance, which is in some sense consistent with what was reported in our study, since those schoolchildren with better grades in mathematics (also in language, natural science and English) showed a better overall academic performance; finding that corroborates what was observed in the study by Ardoy et al. (2014). The conclusions of other studies suggest that, when the assessment of the physical condition includes the motor component, a positive relationship with academic performance (Pertusa et al., 2018; Serrano et al., 2015) and cognitive (Conde & Third, 2015). It has even been suggested that the improvement of the physical condition could favour academic performance (Rosa et al., 2019). In this regard, more objective information could have been provided if variables such as sociocultural level, nutritional status, diet quality, micronutrient status or physical activity level had been controlled (Desai et al., 2015). However, bearing in mand the results of different published works about relationship between lifestyle, motor skills and academic performance it follows that the worst academic assessments are obtained when inadequate rest patterns are joined by a high number of hours of physical activities in after-school hours (more than 5 hours per week), although the level of motor competence of these students is higher (Cladellas et al., 2015; Valdés & Yanci, 2016).

The observed relationship between academic performance and motor coordination showed that those with good academic performance obtained a higher ICM when compared to their peers with poor performance, which is consistent with what was reported in the study by Ruiz-Pérez et al. (2016). Previous studies have tried to bring light to this type of findings by referring, on the one hand, to the presence of common neuropsychological mechanisms in motor performance and academic performance (Diamond & Lee, 2011) or, on the other hand, to the existence of a relationship between multiple intelligences and motor performance, where body-kinesthetic intelligence has revealed as the best cognitive predictor of motor coordination (Ruiz et al., 2014). Other theories that start from the enactment or embodied cognition have focused on the ability of the human being to learn through the body and movement where the motor experience, as the basis of cognitive abilities, and the environment also play a role determinant in brain development (Avilés et al., 2014; Varela et al., 2005); which has been the subject of analysis in various investigations where a consistent relationship between physical activity and cognitive development has been demonstrated (Gunnell et al., 2019; Khan & Hillman, 2014), regardless of socio-cultural environment (Fedewa & Ahn, 2011 ; Conde & Tercedor, 2015).

These results, although sometimes derived from cross-sectional research, could coincide with those studies where motor coordination has been considered as one of the mediating factors between multiple intelligences and motor competence, and how this association affects academic performance (Ruiz et al. , 2014); and provide empirical evidence in favour of proposals where motor activity has been considered as an opportunity to improve cognitive abilities (Medina, 2014); or those interventions that have rebelled the positive role of physical education in cognitive and academic performance (Ardoy et al., 2010, 2014; Donnelly et al. 2013), especially motivating girls towards the taste for physical education and sport, since it has been observed that those students, especially boys, with better academic performance also had a greater motivation towards physical education (Cañadas et al., 2015).

However, some studies do not support the hypothesis of a relationship between academic performance and motor skills, whether through physical activity, physical condition or motor coordination (Esteban et al., 2014; Themane et al., 2006; Yu et al., 2006). The explanation could be based on the fact that the relationship between academic performance and motor skills seems to be influenced by the type of cognitive ability involved in the subjects under study (Cancela et al., 2015). While Arismendi et al. (2018) focus on the low level of motor development found among the participants, which could be related in turn to the reduced number of opportunities for physical activity due, in part, to the realization of a Single school physical education session. Ruiz-Pérez et al. (2016) are also, in a sense, sceptical suggesting that, in order to establish conclusive relationships, these should be more consistent at observed in the available literature alluding to the fact that the intellectual tendency of the last decades has been to consider the relationship between cognitive abilities and motor skills, perhaps derived from the works of Ismail & Gruber (1967) in which an association was more clearly established between academic performance and coordinating abilities.

Although the findings of this work consolidate the scientific evidence on this phenomenon of study in primary school students, there are still aspects to be resolved after its completion, preventing the extraction of causal relationships between the variables, as well as the observation of the evolution over time. This shows the existence of limitations in this work, especially at the methodological level. The cross-sectional design, sample size and selection, as well as the use of field tests to assess motor coordination are some of them. However, it can be highlighted as one of the strengths of the work the assessment of motor coordination through a field test easily administrable in the school environment, to large populations, in a relatively short time and that allows to provide relevant information on development motor of school-age individuals.

With the indicated precautions, the results of this study indicate the existence of a positive relationship between motor coordination and academic performance and this two-way link can be, concluding that higher levels of motor coordination are related to better performance in language, mathematics, natural science and English. However, investigations are required in order to contrast the existing association more significantly and explain the causes of such association. From the field of physical education and sports, longitudinal and prospective studies could determine the way in which having a better (or worse) motor coordination can influence the academic performance of people throughout schooling and in subsequent periods. This study could have practical implications to be taken into account by physical education teachers, for example, the increase in opportunities for physical activity during school and after school hours through the development of programs based on coordinative exercise, and especially oriented towards those less competent at the motor level.

AUTHOR CONTRIBUTIONS

The study was designed by AR, EG and HM; data were collected and analysed by AR and HM; data interpretation and manuscript preparation were undertaken by AR, and EG. All authors approved the final version of the paper.

SUPPORTING AGENCIES

No funding agencies were reported by the authors.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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