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"Cognition, Intelligence and Movement": Extracurricular Physical Activity as a Promoter of Intelligence in Schoolchildren

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Abstract: The main objective of this study was to assess the existence of significant relationships between motor capacity, academic performance and intelligence in a sample of 67 pre-adolescent children, between the ages of 8 and 11 years. Speed tests were carried out (10 × 5 m shuttle run and plate tapping test), and academic grades in Spanish Language and Literature, Mathematics, Natural Sciences, Foreign Language (English) and Physical Education were considered. The Raven test was administered to estimate the intelligence of the subjects. The results showed significant correlations, mainly between the motor capacities and intelligence variables but not with academic performance. Significant differences were also observed in subjects who participated in sports, with better results in motor capacities and intelligence tests compared to those who did not. The data reveal that engaging in intense physical activity and sports in general may improve academic performance.

Keywords: academic performance; physical condition; velocity; intelligence

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1. Introduction

Physical activity has become a vital tool to promote a healthy lifestyle in a society that favors unhealthy habits and low levels of physical activity. We live in a society characterized by sedentary behavior, social stress and habits that are harmful to health. This not only affects the adult population but also children and adolescents, who engage in very little physical activity, and these levels are currently decreasing [1–3].

Physical fitness can be considered a good measure of the body's capacity for exercise and also provides an important indicator of health [4,5]. This is because it is closely related to most of the body functions (skeleto–muscular, cardiorespiratory, circulatory, psycho-neurological and endocrine–metabolic) involved in the performance of daily physical activity and/or exercise [6].

The relationship between physical fitness and academic performance has been and continues to be an important source of study and analysis [3,7–10]. Due to the increasing importance of academic results, their relevance in daily life and in the family setting, the rise in global competitiveness and the debate on educational models, the performance of schoolchildren is constantly evaluated [11]. Therefore, analyzing and identifying factors that may enhance performance with respect to students' physical activity can provide significant data to better understand this topic [12].

Following this line of research, studies conducted with students between 9 and 11 years of age have shown that high academic performance or academic achievement improves as the physical condition of the participants increases [10]. Other research [13] has reported a great difference in the academic achievement of students who participate in extracurricular

sports compared to those who do not, with better grades achieved by those who participate in sports activities [2,14]. This is consistent with the conclusions of several systematic reviews [9,15] that report strong evidence of a positive relationship between physical fitness and academic performance in longitudinal studies, demonstrating the association between students' physical capacity, cognitive development and academic results.

Certain components of physical fitness, mainly aerobic endurance, muscle strength and motor capacities, have been shown to have the potential to produce different effects in the brain that promote exercise-induced improvement in cognitive performance [9,16]. For example, the work of Hillman et al. (2008) [17] positively links aerobic endurance to the ability to induce angiogenesis in the motor cortex and increase blood flow, improving cerebral vascularization, which may influence cognitive performance. In addition, another study indicates that muscle strength can alter the excitability of spinal motor neurons and induce synaptogenesis in the spinal cord [18], contributing to the establishment of an adequate network of synaptic connections and improved neuronal communication. Consequently, it is very likely that physical fitness and its association with participation in extracurricular sports produce adaptations in the brain that influence the cognitive performance of students [9].

Cognition is defined as a set of mental processes that contribute to perception, memory, intellect and action, which in turn are related and intertwined with intelligence [19]. Intelligence is therefore generally described as a cognitive ability to solve problems and understand concepts, in which processing speed, executive control, working memory, reasoning, reflection and awareness are relevant components [20]. At the cross-sectional level, one comparative study suggests that subjects who are more physically fit (based on cardiorespiratory capacity) have a higher intelligence quotient, although not significantly so, compared to those with a lower level of physical fitness [21]. Nonetheless, the evidence in the literature is scarce and the data on the relationship between intelligence and physical fitness are inconsistent.

We should also note that most of the available scientific evidence examining cross-sectional changes in the physical fitness of young people has focused on analyzing aerobic endurance capacity [9,21–24]. However, other physical capacities such as speed, strength or agility have not been as extensively evaluated [25]. This approach could lead to the misconception that other capacities do not play an important role, when they can play as much of a role as aerobic capacity in maintaining overall health [4].

Indeed, most physical activities of children and adolescents involve high-intensity actions that require anaerobic energy production [4]. In this regard, an observational study [26] involving children aged 6 to 10 years found that they participate more frequently in intense activities of short duration than in less intense activities of longer duration. Accordingly, it is of interest to examine the influence of physical capacities such as motor capacity on parameters associated with the academic performance and intelligence of pre-adolescent children.

Therefore, in view of previous research, the aim of our study was to analyze the relationship between the results of motor capacity tests, academic performance and intelligence in pre-adolescent elementary school children. In addition, we examined whether there were significant differences between those subjects who participated in extracurricular sports and those who did not.

2. Materials and Methods

In this quasi-experimental study, a descriptive and quantitative analysis was undertaken to examine the relationship between the results of different speed tests, intelligence and academic achievement in pre-adolescent children.

2.1. Participants

The study sample comprised 67 subjects between the ages of 8 and 11 years (M = 9.16; SD = 0.51), 75% of whom participated in extracurricular sports activities (n = 51), while 25% (n = 16) did not participate in sports activities outside school hours.

After the initial selection and following an explanation of the nature of the study, informed consent was obtained from both the educational center and the parents or legal guardians. They were informed that their anonymity would be maintained at all times, following the ethical considerations of Sport and Exercise Science Research [27], and the principles of the Declaration of Helsinki [28], which define the ethical guidelines for research involving human subjects. The University of Malaga provided the identification number registered for the Ethics Committee: 65-2020-H. The legal guardians of the children provided written informed consent and throughout the intervention, and thereafter, we acted under the provisions of Organic law 3/2018, of 5 December, on the Protection of Personal Data and Guarantee of Digital Rights, regarding the protection of personal data under Spanish law.

2.2. Procedures

Motor capacity and general dynamic coordination were assessed in relation to the physical fitness of the participants using several tests from the EUROFIT fitness test battery [29], measuring the main types of speed: running speed and movement speed [30]. The time to complete each test was recorded to the nearest tenth of a second.

Running speed and general dynamic coordination was evaluated using the 10 × 5 m shuttle run test. Gestural or movement speed was measured with the tapping test or plate tapping [29].

The Raven test was administered to the students to determine their general intelligence of and ability to learn. This test consists of selecting the missing piece in the figures that appear. Students must follow a horizontal or vertical sequence and choose the missing piece [31]. This test provides data on processing in cognitive activities, reaction time, memory, performance and even nerve conduction velocity [19].

Academic performance was measured by analyzing the grades of the participants in the first quarter of the 2019–2020 academic year in five subjects: Spanish Language and Literature, Mathematics, Foreign Language (English), Natural Sciences and Physical Education.

The personal data were collected for each of the participants, including name, age, gender and whether or not they participated in extracurricular sports. All these data were included in a table together with the execution times in the different tests and the grades in the different subjects. Data collection for the physical and cognitive tests was carried out over two weeks, during 32 sessions lasting 45 min each, twice a week.

2.3. Statistical Analysis

A frequency analysis was performed for the variables of gender, age and extracurricular sports activities. To observe the influence of the practice of extracurricular activity on academic performance, a descriptive analysis and contrast statistics (t-test for independent samples) in relation with academic grades and grade point average was made. Finally, an analysis of bivariate correlations between the EUROFIT battery speed tests, the Raven test and the grade point average of the subjects was carried out to analyze the correlation between the study variables. The analysis of all the study variables was conducted using SPSS version 25 (SPSS, Inc., IBM, Chicago, IL, USA).

3. Results

The analysis of extracurricular sports activities according to the results obtained in the speed tests shows that the subjects who did not participate in school sports spent more time on each of the speed tests compared to those who did participate in extracurricular sports.

Significant differences ($p = 0.016$) were found in upper limb movement speed in the tapping test (Figure 1), with lower times obtained by those who participated in extracurricular sports (18.20 s) compared to those who did not (21.78 s).

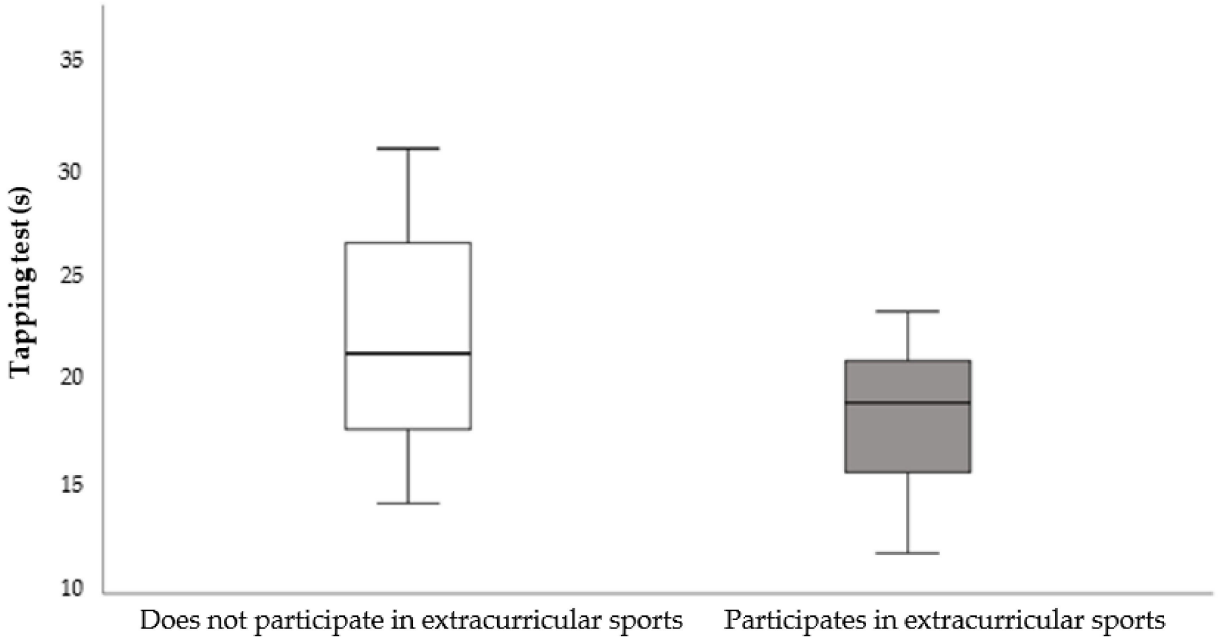

Figure 1. Box plot showing the relationship between the times (s) recorded in the EUROFIT tapping test and the sports participation of the subjects.

Significant differences ($p = 0.29$) were also found in the 10 × 5 m shuttle run test (Figure 2), with a mean of 19.48 s for subjects who did not participate in extracurricular sports and 18.20 s for those who did.

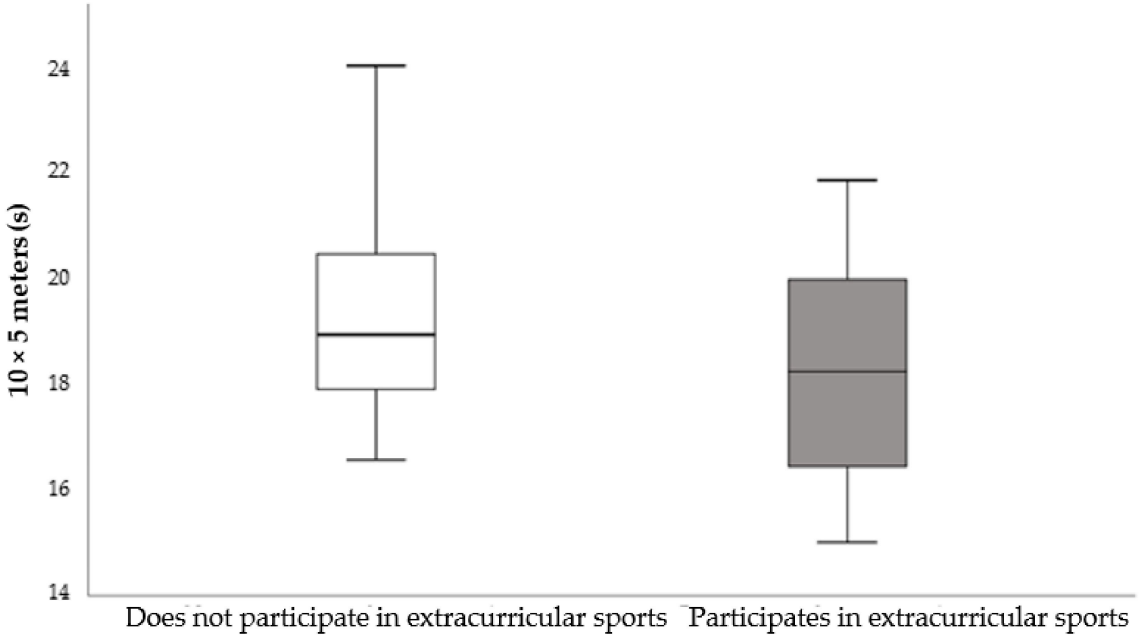

Figure 2. Box plot showing the relationship between the times (s) recorded in the EUROFIT 10 × 5 m shuttle run test and the sports participation of the subjects.

The results of the Raven Intelligence test relative to participation in extracurricular sports of the participants (Figure 3) revealed that the subjects who participated in extracur-

ricular sports obtained higher mean scores (31.03 points out of 60, percentile 53.64) than those who did not participate in extracurricular sports (24.27 points out of 60, percentile 72.24), and these differences are statistically significant.

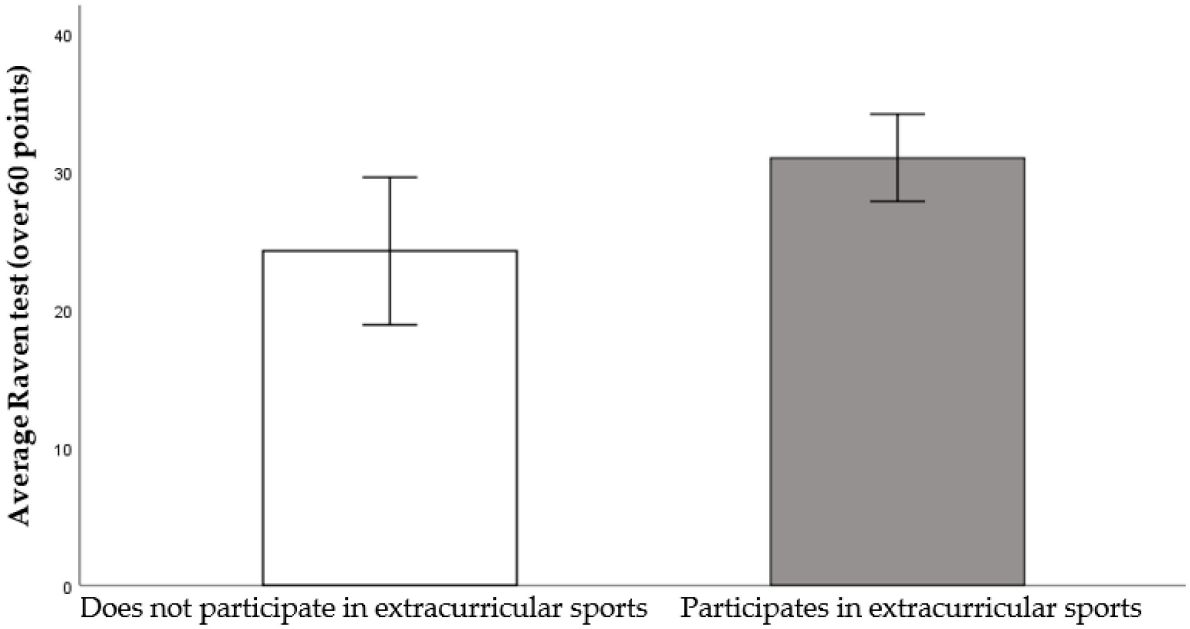

Figure 3. Analysis of the average scores recorded on the Raven test in relation to the sports participation of the subjects.

Similarly, when comparing the analysis of academic grades in relation to sports participation (Table 1), we observed that those subjects who engaged in sports outside school hours obtained significantly better academic results ($p \leq 0.1$) in the areas of Spanish Language and Literature, Mathematics, Natural Sciences, Foreign Language (English) and Physical Education. In addition, students who participated in extracurricular sports had a higher academic average (7.93) than those who did not participate in sports (6.78) (Figure 4).

Table 1. Descriptive (M ± SD) and contrast statistics (*t*-test for independent samples) of "Does not participate in extracurricular sports" (n = 16) and "Participates in extracurricular sports" (n = 51), academic grades and grade point average.

Subject (Points from 0 to 10)	Does Not Participate in Sports (M ± SD)	Participates in Sports (M ± SD)	*p*
Language	6.88 ± 1.08	7.82 ± 0.93	0.001 **
Mathematics	6.94 ± 1.38	8.14 ± 1.05	0.001 **
English	7.31 ± 1.19	8.51 ± 0.98	0.000 **
Natural Science	5.81 ± 1.47	7.35 ± 1.16	0.000 **
Physical Education	7.00 ± 1.03	7.84 ± 0.64	0.000 **
Grade Point Average	6.78 ± 1.01	7.93 ± 0.74	0.000 **

** $p \leq 0.01$.

When we compared the scores obtained in the Raven test and academic performance (using the grade point average of the students as a reference) in relation to the results of the EUROFIT speed tests: 10 × 5 m shuttle run and tapping test (Table 2), we found significant correlations between the scores in the intelligence test and motor capacity, but no positive correlations were found between the results in the speed tests and grade point average.

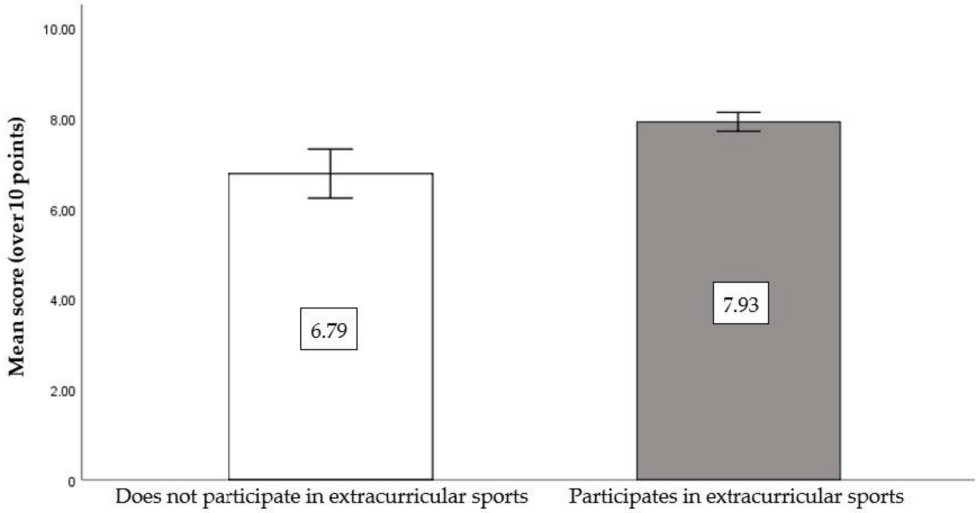

Figure 4. Analysis of the grade point average in the different subjects in relation to the sports participation of the subjects.

Table 2. Analysis of bivariate correlations between the EUROFIT battery speed tests, the Raven test and the grade point average of the subjects (n = 67).

	M ± SD	**10 × 5 m**		**Tapping Test**	
		CP	***p***	***CP***	***p***
Raven test (points)	29.18 ± 8.67	−0.095	**0.034 ***	−0.105	**0.042 ***
Average grade (points)	7.36 ± 0.94	−0.272	0.581	−0.257	0.542

*$p < 0.05$.

4. Discussion

The purpose of this study was to examine the relationship between speed tests, intelligence and academic performance. The results of the various tests showed a significant correlation between motor capacity and intelligence quotient, but with no apparent influence on academic performance. In addition, a number of significant correlations were found that may be of interest in determining the importance of participation in extracurricular sports on the physical condition and cognitive performance of the participants.

Using the data obtained in the speed tests as a reference and bearing in mind the extracurricular sports activity of the subjects, we noted that those participants who engaged in sports outside school hours obtained significantly better results than those who did not engage in any type of sports activity, both in the limb movement speed tests and in the running speed tests. This positive association supports the findings of other studies [14], emphasizing the importance of extracurricular sports activities for physical fitness in pre-adolescent children to promote improved motor capacity and the active use of leisure time as well as to reduce the onset of diseases associated with sedentary lifestyles [4].

Examination of the results of the general intelligence of the subjects in the Raven test as related to their sports participation revealed that the students who participated in extracurricular sports obtained a significantly higher average than those who did not. We can therefore suggest that extracurricular physical activity could positively influence on the results of the intellectual capacity tests. This finding supports the concept that physical exercise influences cognitive development in pre-adolescents during the primary education stage.

The development of physical fitness during the early stages of life may lead to changes in the regional and functional structure of the brain [9,17]. One of the factors that may explain the parallel development of cognitive and motor performance induced by participating in sports could be the relationship between physical exercise, the release of neurotransmitters such as catecholamines and the increase in cognitive involvement [32].

In addition, physical activity favors the processes of angiogenesis and vascularization in specific brain structures such as the motor cortex, which may have a positive influence on cognitive performance and general intelligence. In this respect, several studies have shown a positive relationship between physical fitness and cognitive performance in school-age subjects [21,22,33].

In terms of academic performance, we found that students who participated in extracurricular sports achieved better academic results, with significant differences in various subjects such as Spanish Language and Literature, Mathematics, Natural Sciences, Foreign Language (English) and Physical Education. We also observed that students who participated in extracurricular sports had a higher academic average than those who did not.

Our findings are consistent with the conclusions of other studies indicating that participation in physical activity improves the academic performance of students [2,34], which implies that physically active students, in addition to enjoying many health benefits, have a higher level of academic achievement.

The results of the students' speed tests revealed significant correlations with general intelligence but not with academic performance. Some studies have shown that other physical abilities such as aerobic capacity are associated with general intelligence in young people [19] and may influence cognitive processes, memory, attention and executive functions in the brain. This could promote exercise-induced improvements in general intelligence and academic achievement [22,35,36]. Conversely, there is little evidence that physical capacities such as muscle strength or motor capacity have the same influence on student grades or intelligence. Nevertheless, more studies are needed to determine the influence of motor capacities on academic performance and intelligence.

The present study has several limitations. Firstly, the sample size was relatively small and did not allow us to perform multiple comparisons test, thus the results should be viewed with caution. On the other hand, all the participants of the sample belonged to the same educational center. In this way, it would be interesting to take a sample of different educational centers to compare the results of a more varied population. Therefore, more studies with a higher sample size are needed to understand the influence of the variables on academic performance in children.

5. Conclusions

The results of the analysis of extracurricular sports participation and the data from the speed tests in relation to general intelligence and academic performance in pre-adolescent youths indicate a direct correlation between the different types of speed and intelligence, although not with academic achievement. A significant positive relationship was also identified between extracurricular sports activities, motor capacities (speed), general intelligence and academic grades in different areas of knowledge. Nonetheless, further studies are needed on the relationship between physical capacities such as speed and cognitive performance in pre-adolescent youths.

Author Contributions: J.C.F.-G. and J.G.-G. conceived and conceptualized the study. M.A.S., M.R.-P. and J.C.F.-G. collected and analyzed the data. M.R.-P., J.G.-G. and J.C.F.-G. conducted the necessary literature reviews and drafted the first manuscript. M.R.-P., J.C.F.-G. and J.G.-G. provided critical feedback and helped shape the analysis and manuscript. All authors contributed to the revision and writing of the final draft. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of University of Málaga (protocol code 65-2020-H and date of approval 30 September 2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available upon request from the corresponding author.

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