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The Relationship between Physical Fitness and Academic Performance in Children Aged 10 to 12 Years Old

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Abstract

Academic performance could be conditioned by physical fitness; research suggests that students with higher fitness levels perform better in basic areas (Santana et al., 2016). This research project aims to analyze the relationship between physical strength, endurance and academic performance in kids from 10 to 12 years old. The study has a quantitative approach, non-experimental design, cross-sectional type, and descriptive scope. The FitnessGram test battery was implemented to assess physical abilities and the tests "PENSAR" were used to assess academic performance. In the total sample, it is evident that there is a positive correlation between endurance capacity and performance in mathematics and reading; furthermore, there is also evidence of a positive correlation between strength and mathematics. The physical condition has a positive correlation with the academic performance in the total sample, but this is not significant when only the female gender is analyzed. Finally, the correlation between strength and mathematics, endurance and reading are significant in the male gender, but those are presented in a negative direction.

Keywords: Academic Performance, endurance, mathematics, physical fitness, strength, and reading

Resumen

El desempeño académico podría estar condicionado por la aptitud física; las investigaciones sugieren que los estudiantes con mayores niveles de condición física consiguen mejores resultados en áreas básicas (Santana et al., 2016). Este proyecto de investigación tiene como objetivo analizar la relación entre las capacidades físicas de fuerza y resistencia con el desempeño académico de matemáticas y lectura en niños de 10 a 12 años. El estudio es de enfoque cuantitativo, diseño no experimental, tipo transversal y alcance descriptivo. La batería de pruebas de FitnessGram se implementó para evaluar las capacidades físicas y las pruebas PENSAR se utilizaron para valorar el desempeño académico. Por medio del software SPSS, se evidencia en la muestra total que existe una correlación positiva entre la capacidad de resistencia y el desempeño en matemáticas y lectura; asimismo, también se presenta una correlación positiva entre fuerza y matemáticas. La condición física tiene una correlación positiva con el desempeño académico en la muestra total, pero esta no es significativa cuando se analiza únicamente el género femenino. Finalmente, la correlación entre fuerza y matemáticas y también entre resistencia y lectura son significativas en el género masculino, pero se presentan en dirección negativa.

Palabras clave: Condición física, desempeño académico, fuerza, lectura, matemáticas y resistencia

Introduction

Many research articles have shown that the components of physical fitness and academic performance have interacted in different ways in studies conducted over the past 20 years (Donnelly et al., 2018). In some of them, it is observed that physical fitness has been positively associated with academic performance; This is revealed by observing students with higher levels of physical condition achieve better academic results (Lima et al., 2018); but in other articles no interaction between the physical and cognitive variables has been found, for this reason some authors conclude that there is still not enough evidence to establish a link between these physical fitness components with academic performance (Donnelly et al., 2018).

Some of the data found regarding the relationship between aerobic endurance and academic performance is variable (Lima et al. al, 2018; Aadland et al., 2017; Santana et al., 2016). Students with excellent aerobic endurance have been found to perform better on academic tests; likewise, students with deficiencies in aerobic endurance achieve lower results in cognitive tests (Wittberg et al., 2012). Furthermore, a systematic review concluded that 84% of the included studies exposed a positive relationship between aerobic endurance and academic performance (Santana et al., 2016).

Based on this information, it can be considered that programs designed to improve aerobic capacity would have a positive impact on academic performance (Wittberg et al., 2012); In addition, it is pertinent to state that the effect derived from a high cardiorespiratory capacity is the induction of angiogenesis (physiological process by which new blood vessels are formed) in the motor cortex and the increase in blood flow, which would enhance vascularization of the brain and would end up affecting academic performance (Santana et al, 2016; Donnelly et al, 2016). This strong relationship between aerobic endurance and academic performance is mentioned in cross-sectional studies, however, little evidence exists on the relationship of these variables in longitudinal studies (Santana et al, 2016; Donnelly et al, 2016).

In this research it is necessary to include another variable such as strength, which has also had a positive association with academic performance in mathematics and reading in cross-sectional and longitudinal studies, however, it is still not certain (Lima et al., 2018). Through a systematic review, it was established that 44% of all the research involved found a positive interaction between muscle strength and cognitive performance, but despite this, the association is still uncertain (Santana et al., 2016). Muscle strength could increase motor neuron excitability and induce a synaptogenesis process in the spinal cord,

which favors the connection between neurons and would enhance academic performance (Santana et al., 2016).

The reason for this research is based on the fact that in the study of these variables there are also some inconsistencies, which hinder the homogeneity of the information, for example, despite the fact that the relationship between physical fitness and academic performance is statistically significant, they find outliers such as those who present low physical condition and are academically successful, or also students who have a high level of physical condition and show failures in their academic performance. Generally, these cases represent between 15 and 20% of the population (London et al., 2011). Additionally, there are differences in the correlation between the male and female gender; in some cases, the link is found to a greater extent in girls and in another case in boys, which also shows the relevance of continuing to carry out research in this line (London et al., 2010; Santana et al., 2016).

Likewise, this project is carried out to investigate the incidence of sports processes on academics, since, due to the emphasis on obtaining better results in national tests, the time of the physical education subject has been reduced, which evidences that strategies to increase academic performance are totally isolated from physical activity (Donnelly et al., 2016). However, according to scientific evidence, a reduction in physical activity time could cause an increase in sedentary lifestyle, and an increase in body weight; consequently, a decrease in physical fitness and ultimately poor cognitive performance (Santana et al., 2016). This is since an excess of adipose tissue limits cognitive function and therefore, people in a state of obesity present lower academic performance (Lima et al., 2018).

Another element to consider is the amount of scientific production of each of the components of physical fitness in relation to academic performance; in addition, the percentage of positive association between each of them and finally the types of studies, which can be cross-sectional or longitudinal. Due to these results, many researchers have suggested increasing the number of investigations and samples in this field, to strengthen scientific evidence and clarify the interaction between variables in different types of studies, populations, genders, and ages (McPherson et al. al., 2018; Maher et al., 2016).

The following independent variables are endurance and strength, these two abilities are predictors of a person's health status, and it is also considered that a healthy student learns more easily than an unhealthy one, due to the condition of their organs (Kohl and Cook, 2013). On the other hand, the dependent variables are mathematics and reading, studies have concluded that students with greater physical fitness respond more effectively to a wide variety of cognitive tasks related to reasoning, quantitative and critical analysis (Kohl and Cook, 2013). Unfortunately, little evidence supports this notion that more time spent strengthening physical abilities will translate into better academic results in these subjects.

Materials and methods

Methodology:

The approach of the project is quantitative because magnitudes of the two phenomena to be studied are measured and estimated; In this case, the type of research is transversal since data is collected at a single moment or term to evaluate the variables. Additionally, the scientific method is rigorously applied to obtain data. The study applies a non-experimental methodological design as it does not involve deliberated manipulation of the two variables. Finally, the scope of the project is correlational because it collects information on the variables chosen to later carry out an association process.

Sample

In this research, the sample is non-probabilistic, the Epi Info™ version 7.2 program is used to calculate the sample, in the Stat-Calc option it is described that the size of the population is 60 students, the expected frequency is 20% , the margin of error is 5%, the reliability percentage is 95%, the design effect is 1.0 and the number of groups is 1. Finally, the research will include 47 students aged 10 to 12.

Standard test

The data collection tool for the independent variable will be the battery of physical fitness tests called FITNESSGRAM, created in the United States since 1987. This protocol is written in a manual, it has also

been standardized, validated, and adopted by the scientific community to carry out research on the physical condition of children and adolescents around the world (Cvejic et al., 2013). In the pacer test, the participant must run continuously for as long as possible in a space of 20 meters at a specified pace that increases speed every minute to assess aerobic endurance capacity. Additionally, in the push up test, the highest number of repetitions in the 90-degree elbow flexion exercise must be completed to assess explosive strength capacity.

On the other hand, academic performance data was collected in the same way as it was done in 82% of the studies analyzed in the systematic review by Santana et al (2016), with national tests, in this case they would be PENSAR tests, from Milton Ochoa organization (Santana et al, 2016). This test contains a certain number of multiple-choice questions related to mathematics and reading which must be answered in the stablished time.

Statistical analysis

To carry out the correlational analysis with the results presented in the physical variables of strength and endurance and the academic variables of mathematics and reading, the Spearman model is used in the software Statistical Package for Social Sciences (SPSS), which will indicate the correlation coefficient and scatterplots. The results of correlational studies vary between 1 and -1. In this system of analysis, there are two elements, direction and magnitude. The first one which can be positive or negative, and the second one which means how strong the relationship is.

Ethical, bioethical and scientific integrity considerations

To guarantee that this research project complies with the ethical, bioethical and scientific integrity it follows the guidelines that are established by the national policy of the Ministry of Science and Technology of the Republic of Colombia. These guidelines |||allow the investigation to be carried out with honesty, transparency, rigor, justice, veracity, validity and reliability following universal models that the scientific community has adopted to develop the investigative processes (Ocampo et al., 2017). Considering that this is a study without risks, but it involves human beings of sensitive ages, it is necessary to request authorization from the institution, validate the protocols by members of the scientific community and fill out informed consents and assents forms. Finally, it is important to manifest interest conflict because the researcher works as a teacher in the school.

Results

Table 1.
Average results of anthropometric variables

BMI	**Anthropometric variables**		
	Total sample	**Female sample**	**Male sample**
Number of students	47	27	20
Age	10,94 ± 0,32	10,93 ± 0,38	10,95 ± 0,22
Weight	39,77 ± 7,49	41,93 ± 8,08	36,86 ± 5,58
Height	1,48 ± 0,07	1,49 ± 0,07	1,46 ± 0,07
BMI	18,03 ± 2,40 Healthy zone	18,66 ± 2,47 Healthy zone	17,19 ± 2,07 Healthy zone

Figure 1.

Average results of anthropometric variables

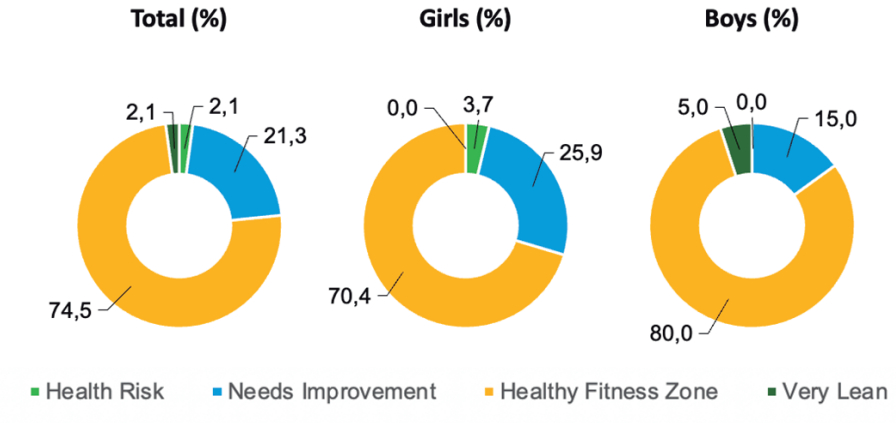


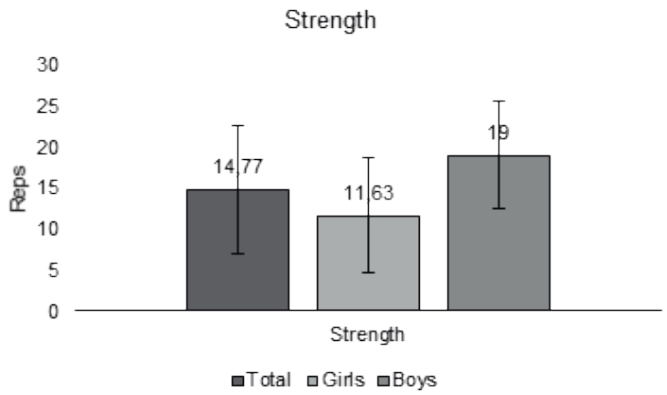
Table 2.

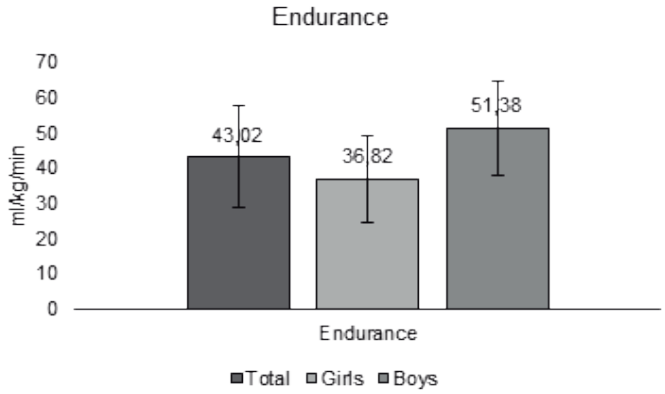
Average results of physical and academic variables

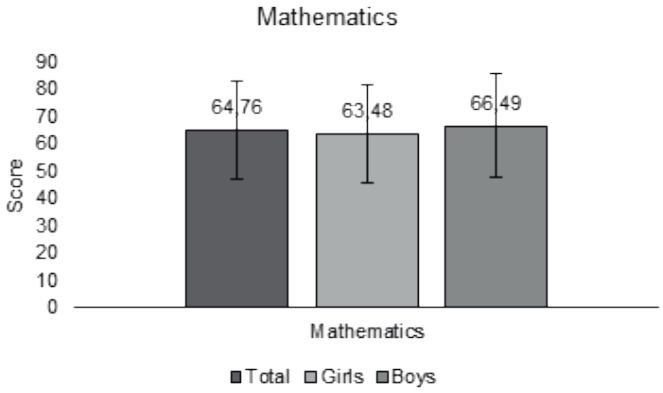
Variables	Physical and academic variables		
	Total sample	Female sample	Male sample
Number of students	47	27	20
Strength (Reps)	14,77 ± 7,78 Healthy zone	11,63 ± 7,07 Healthy zone	19,00 ± 6,62 Healthy zone
Endurance (ml//kg/min)	43,02 ± 14,56 Healthy zone	36,82 ± 12,24 Health risk	51,38 ± 13,41 Healthy zone
Mathematics (Score)	64,76 ± 18,06 Satisfactory	63,48 ± 17,78 Satisfactory	66,49 ± 18,76 Advanced
Reading (Score)	65,74 ± 18,66 Advanced	66,18 ± 20,94 Advanced	65,14 ± 15,57 Advanced

Figure 2.

Average results of physical and academic variables




Endurance
70
60
50
40
30
20
10
0
ml/kg/min
43,02
36,82
51,38
Endurance
Total
Girls
Boys


Mathematics
90
80
70
60
50
40
30
20
10
0
Score
64,76
63,48
66,49
Mathematics
Total
Girls
Boys

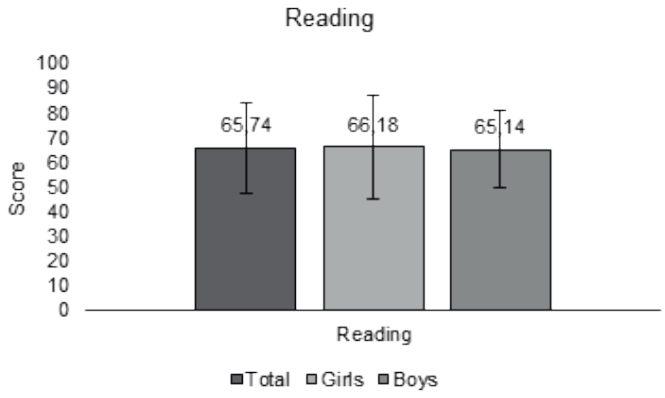
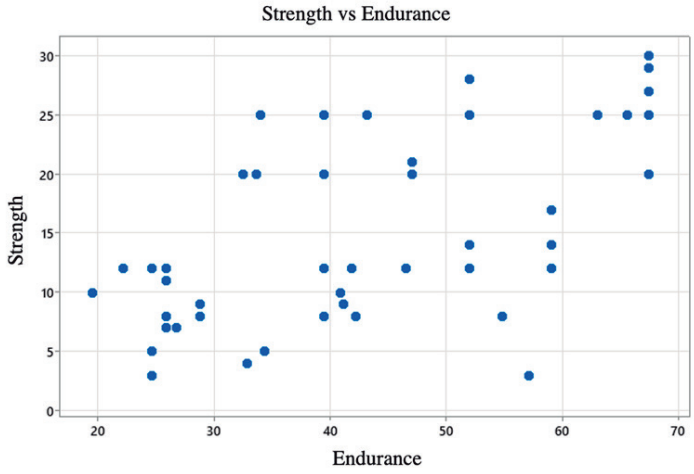
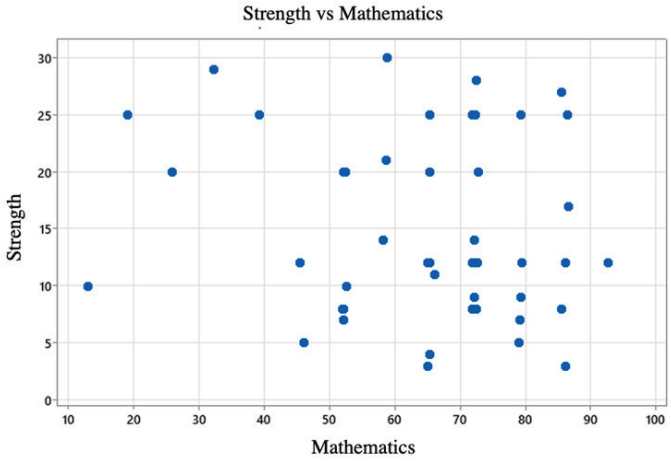

Reading
100
90
80
70
60
50
40
30
20
10
0
Score
65,74
66,18
65,14
Reading
Total
Girls
Boys

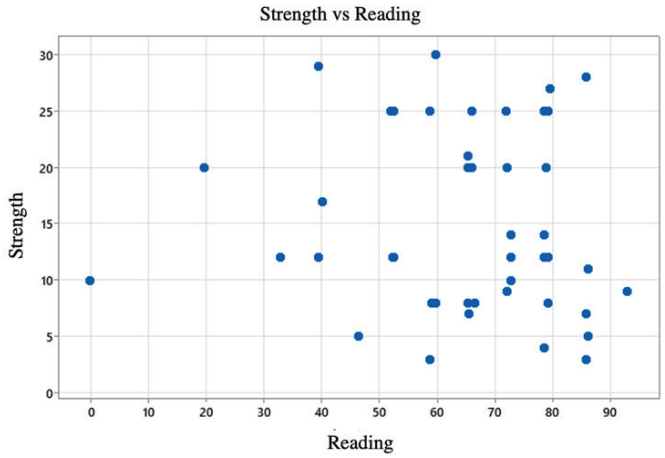
Table 3.
Correlation analysis in the total samples

Correlation analysis in the total sample			
Independent variables	Dependent variable	Coefficient	Interpretation
Strength	Endurance	.576**	Moderate positive linear correlation
	Mathematics	.573**	Moderate positive linear correlation
Endurance	Strength	.576**	Moderate positive linear correlation
	Mathematics	.997**	Strong positive linear correlation
	Reading	.355*	Weak positive linear correlation
Mathematics	Strength	.573**	Moderate positive linear correlation
	Endurance	.997**	Strong positive linear correlation
	Reading	.320*	Weak positive linear correlation
Reading	Endurance	.355*	Weak positive linear correlation
	Mathematics	. 320*	Weak positive linear correlation

Figure 3.
Analysis of the strength variable in the total sample



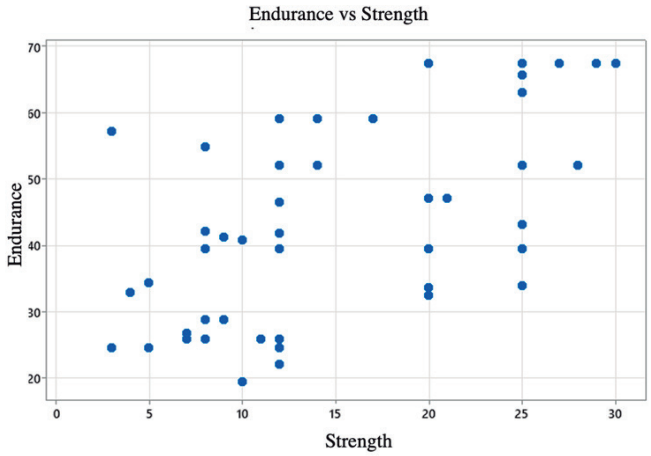


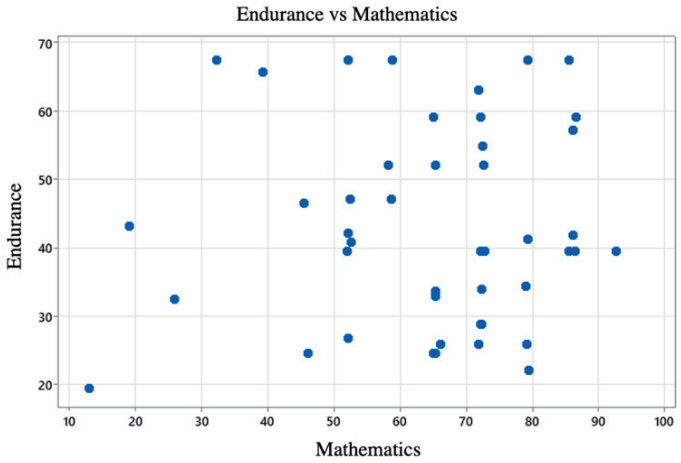


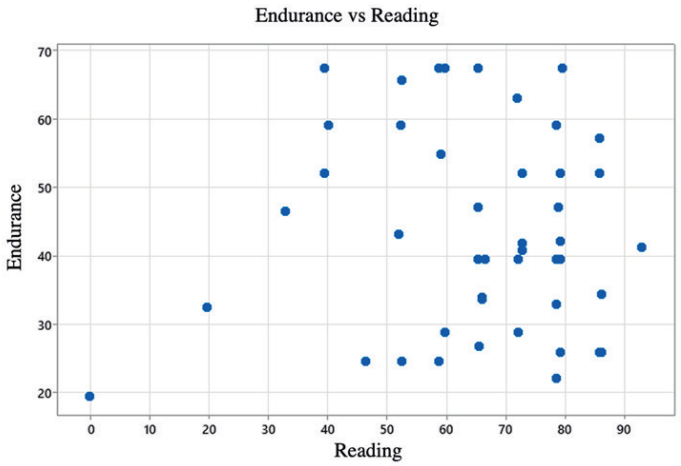
The independent variable of strength at the 0.01 level has a significantly moderate positive linear correlation with the dependent variables of endurance (.576**) and mathematics (.573**), this means that the higher levels of muscle strength, the better results in mathematics and endurance tests of the total sample.

Figure 4.

Analysis of the endurance variable in the total sample







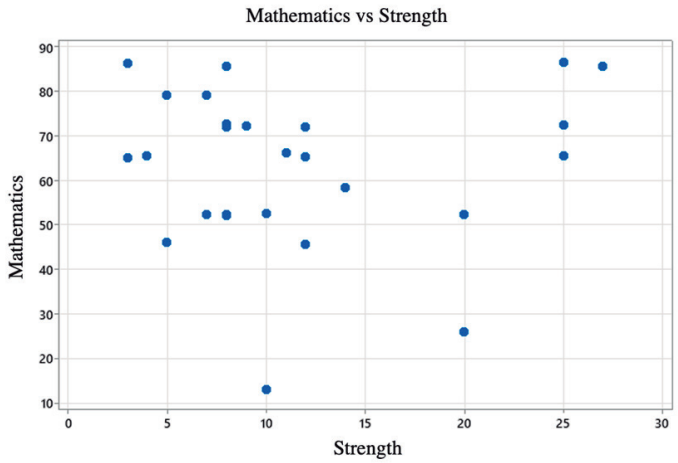
The independent variable of endurance at the level of 0.05 has a weak positive linear correlation with the dependent variable of reading (.355*), likewise, at the level of 0.01 a moderate positive linear correlation is identified with the dependent variable of strength (.576**) and finally a strong positive linear correlation with the math dependent variable (.997**). This means that the higher levels of aerobic endurance, the better results in reading, strength, and mathematics tests of the total sample.

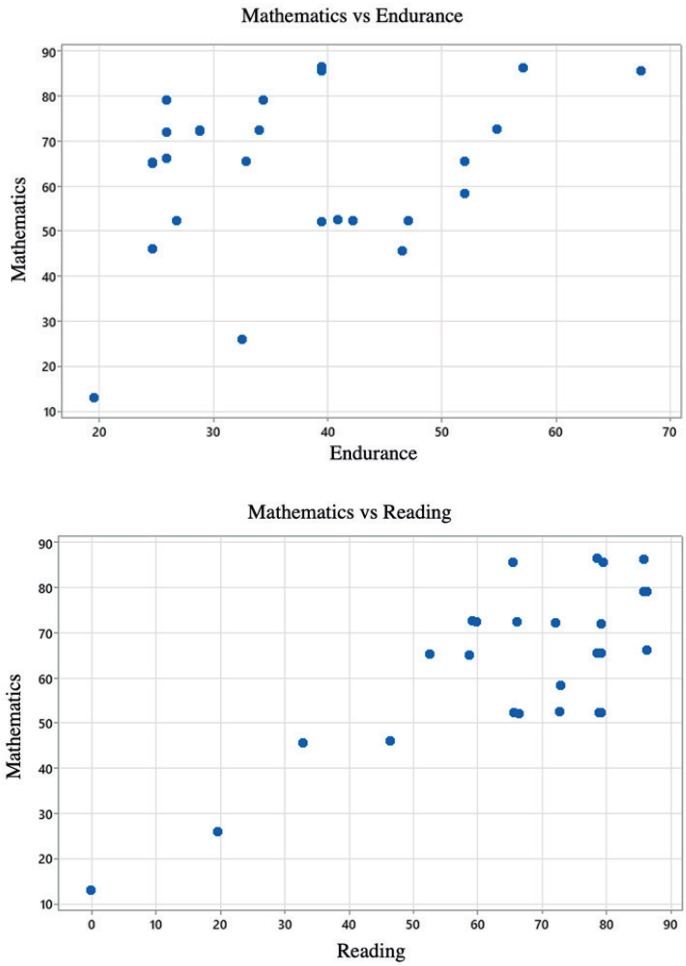
Table 4.
Correlation analysis in the female gender sample

Correlation analysis in the female gender sample			
Independent variable	Dependent variable	Coefficient	Interpretation
Strength	There is no significant correlation		
Endurance	There is no significant correlation		
Mathematics	Reading	.512**	Moderate positive linear correlation
Reading	Mathematics	. 512**	Moderate positive linear correlation

The independent variable strength and the dependent variables mathematics (.021), reading (-.103) and endurance (.294) do not present a significant correlation coefficient in the female sample. In the same way, the independent variable endurance, and the dependent variables mathematics (.091), reading (.283) and strength (.294) do not present a significant correlation coefficient in the female sample.

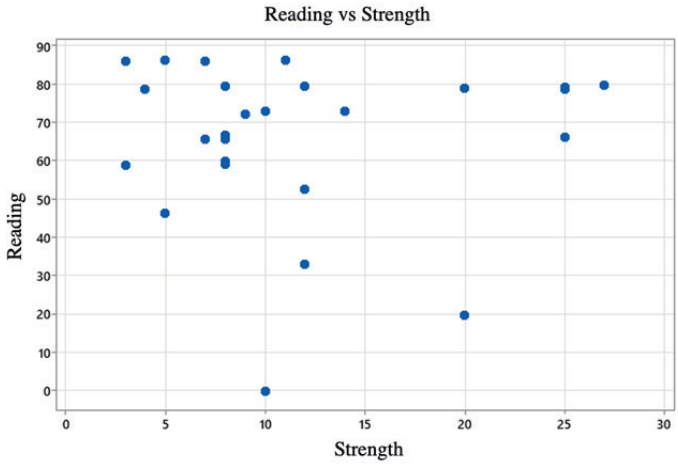
Figure 5.
Analysis of the mathematics variable in the female gender.

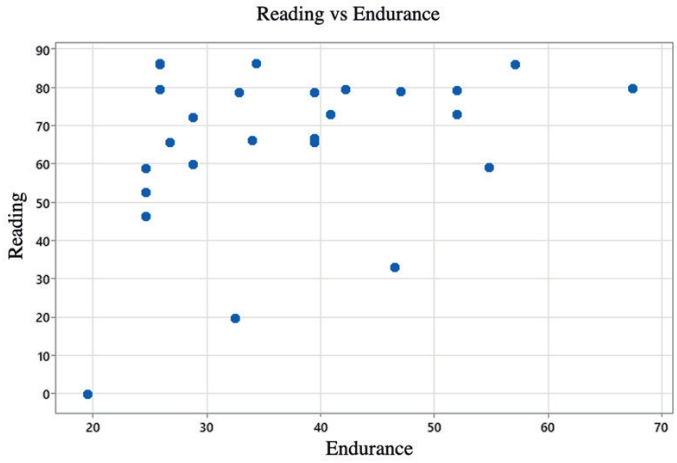


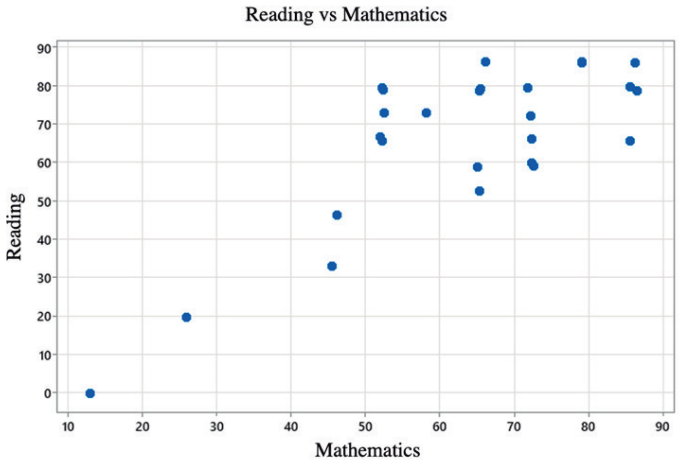


The independent variable for mathematics has a positive moderate linear correlation at the 0.01 level with the dependent variable for reading (.512*). This means that when better results are obtained in mathematics tests, higher levels are presented in reading tests in the sample of girls.

Figure 6.
Analysis of the reading variable in the female gender





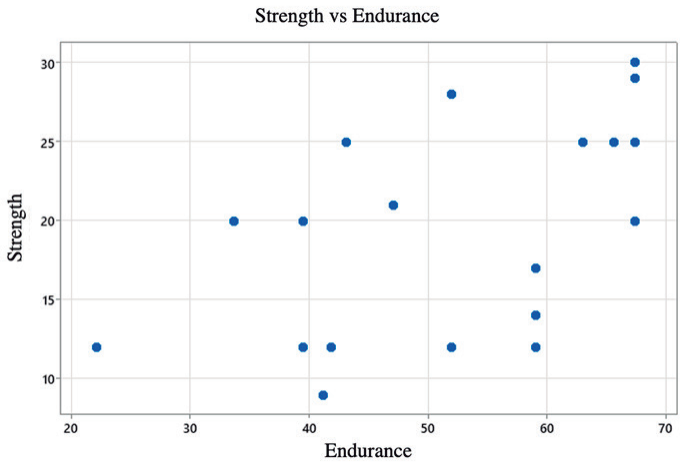


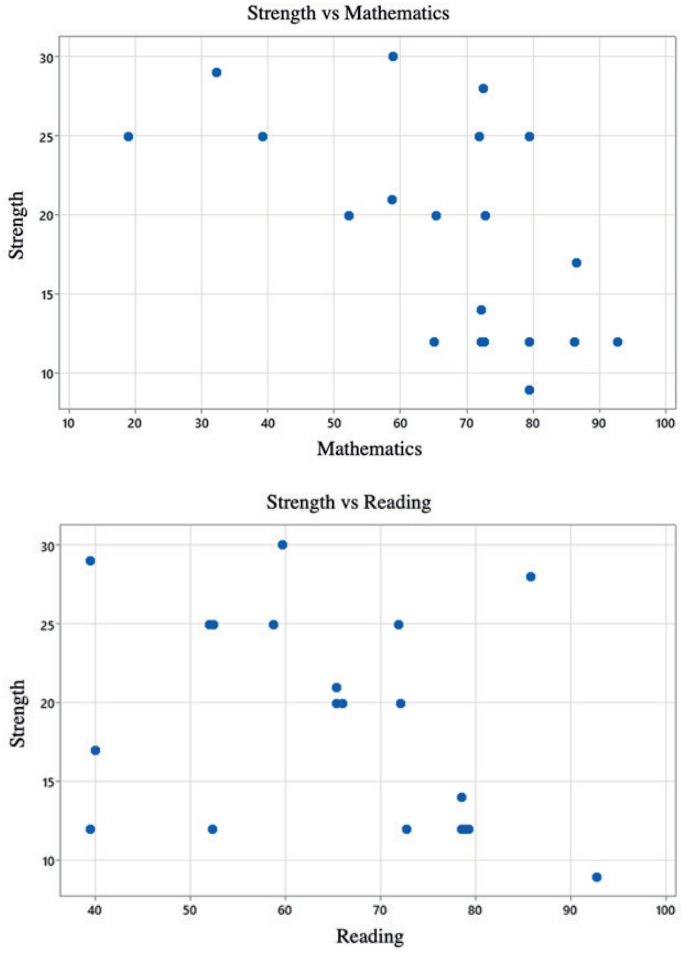
The reading independent variable has a significantly positive moderate linear correlation at the 0.01 level with the mathematics dependent variable (.512**). This means that the better results in math test, the higher level in reading skills in the female sample.

Table 5.
Correlation analysis in the male sample

Correlation analysis in the total sample			
Independent variables	Dependent variable	Coefficient	Interpretation
Strength	Endurance	.599**	Moderate positive linear correlation
	Mathematics	-.584**	Moderate positive linear correlation
Endurance	Strength	.599**	Moderate positive linear correlation
	Reading	-.548*	Moderate positive linear correlation
Mathematics	Strength	-.584**	Moderate positive linear correlation
	Reading	.467*	Moderate positive linear correlation
Reading	Endurance	-.548*	Moderate positive linear correlation
	Mathematics	.467*	Moderate positive linear correlation

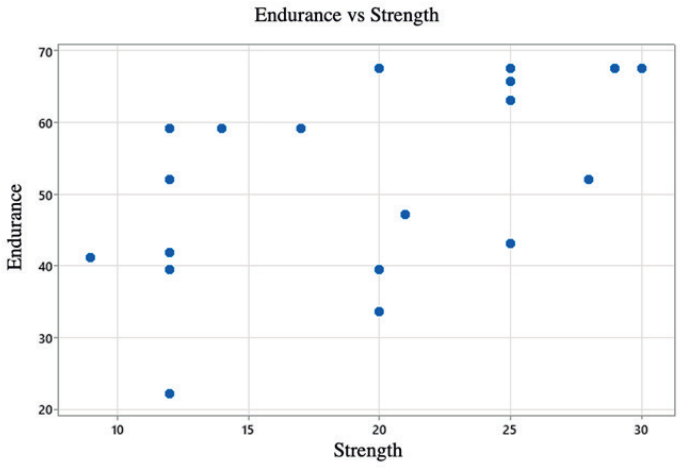
Figuere 7.
Analysis of the strength variable in the male gender.

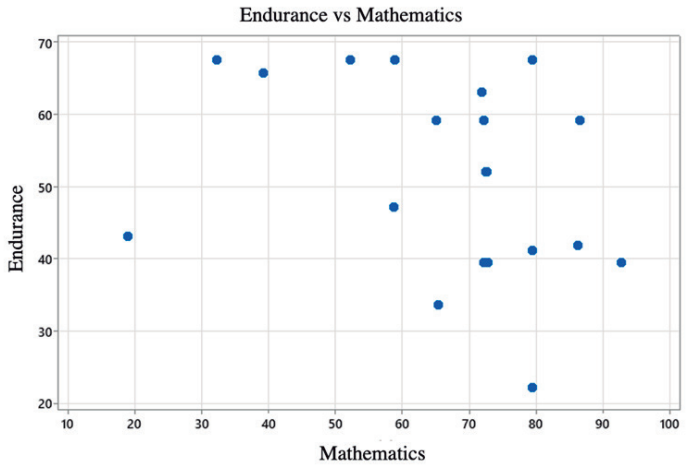


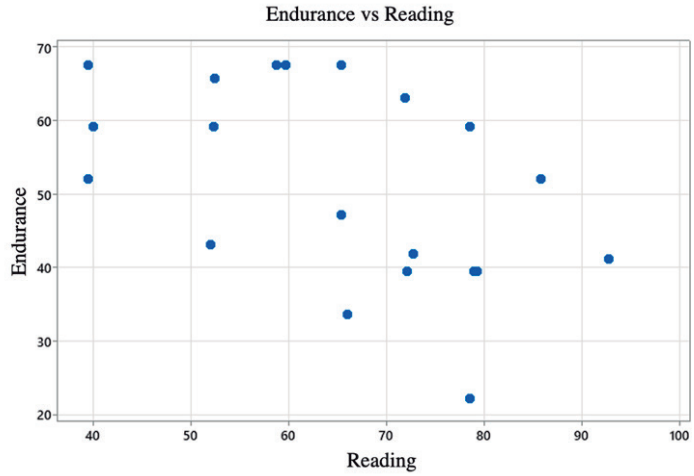


The strength independent variable at the 0.01 level has a significantly moderate positive linear correlation with the endurance dependent variable (.599**) and also a negative linear correlation with the math dependent variable (-.584**). This means that the better results in strength test, the higher level in endurance test in the sample of boys. However, the lower strength results, the better levels in mathematics test in the sample of boys and viceversa

Figure 8.
Analysis of the endurance variable in the male gender.







The independent variable of endurance at the 0.01 level has a significantly moderate positive linear correlation with the strength dependent variable (.599**) and a negative linear correlation with the reading dependent variable (-.548**). This means that the better results in endurance test, the higher levels in strength test in the sample of boys. However, the lower results in endurance, the better levels in reading tests in the sample of boys and viceversa.

Discussion

This study reveals a strong positive correlation between endurance and mathematics, while a weaker correlation is observed with reading. This correlation is aligned with several investigations, the most associated variable in other studies is cardiorespiratory capacity. (Santana et al., 2016) In addition, a moderate positive correlation of strength with mathematics is found, but the relationship of this ability with reading is uncertain, as it has been found in other articles (Santana et al., 2016). In this sense, it is established that physical condition is associated with greater academic performance. These results could be conditioned by the relationship between physical fitness and brain areas that perform complex cognitive functions and their structure (Donelly et al., 2016).

The mechanisms that have been established to understand and explain the evidenced correlation between physical fitness and academic performance in this research are three: first, it has been found that physical fitness can stimulate the production of the substance BDNF (brain-derived neurotrophic factor), which regulates nerve cell survival, differentiation processes, and plasticity in the brain, which enhance cognitive function. Second, physical abilities improve the microstructure of gray matter in the brain, this increases the speed and efficiency of neu-

ral activity. Third, physical fitness increases angiogenesis, this phenomenon improves capillary density and cerebral vascularization, which affects cognition processes (Ruiz et al., 2016).

Gender has been established as one of the confounding variables in 36.4% of the studies included in one of the systematic reviews found (Rodríguez et al., 2020); in this research it is also considered in the same way, since when the independent variables are the physical capacities in the female gender, there is no significant correlation with the academic performance variables. In contrast, when the independent variables are those of academic performance in the same gender, there is a moderate positive correlation between mathematics and reading.

On the other hand, in the results of the correlation of the male gender, it is evident that strength capacity has a moderate negative correlation with mathematics and resistance, likewise, there is a moderate negative correlation with reading; but the academic variables of mathematics and reading have a moderate positive correlation between them. These data are divergent from most of the results found in systematic reviews that analyze the differences between gender; in one of them it has been possible to identify that 70% of studies show that the relationship between physical and cognitive variables in girls is better, 10% of studies show the opposite result and 20% of studies find significant differences between genders (Rodríguez et al., 2020).

Additionally, other studies that include some variables close to this research and that could be investigated in other projects have collected enough information to conclude that physical fitness is a better predictor of academic performance than obesity, measured through the body mass index (London et al., 2010; Wittberg et al., 2012). It has not been determined whether the low academic performance associated with obesity is due to body composition itself or to factors derived from it such as low self-esteem, depression, or social rejection (Santana et al, 2016; Lima, et al, 2018). In the same way, it is possible to associate a lower socioeconomic stratum with a lower level of physical fitness (London, 2010).

Finally, in the review of articles, positive relationships are found between physical fitness and other variables that were not included in this study, such as behavior, concentration, diet, excessive use of technology (London et al., 2010). It can be concluded that the benefits of physical fitness on aspects related to health, emotions and society are very well documented, but it is necessary to study other variables such as academic performance, executive functions, and cognition, due to the lack of scientific evidence and inconsistency of findings (Donnelly et al., 2016; Wittberg et al., 2012).

Conclusion

Based on this research it can be concluded that in the total sample there is a strong positive relationship between the physical capacity of endurance with mathematics (.997**), this same capacity has a weak positive relationship with reading (.355*). Likewise, strength capacity presents a moderate positive relationship with mathematics (.573*). The relationship between physical fitness and academic performance observed in this research aligns with findings from previous studies, where a relationship was established in 55% to 80% of cases (Rodríguez et al., 2020; Santana et al., 2016).

The average result of body mass index, strength and endurance in the total sample, female and male gender is in the healthy zone, which is positive because it is considered that a healthy student performs with greater ease in cognitive and physical aspects than an unhealthy one, this due to the condition in which their organs are found, (Kohl and Cook, 2014; London et al., 2010; Wittberg et al., 2012; Lima et al., 2018).

Moreover, the average results of mathematics in the total sample and female gender are at a satisfactory level, but in the male gender it is advanced. On the other hand, the academic variable of reading in the total sample, the female and male gender are classified as an advanced level. This is favorable, since research has found that high academic performance is associated with higher economic indicators, job opportunities and quality of life in adulthood (OECD, 2022).

In addition, when the results of academic and physical variables by gender are analyzed, it is evident that the male sample obtains better results in the variables of mathematics, strength and endurance. On the other hand, when the results of the female gender are observed in detail, it can be identified that girls achieve better results in the reading variable. However, in the physical variables, the girls obtain very low levels of endurance, it is alarming that 55% are classified as a health risk. In the comparison between genders, the results are inconsistent, as has been found in many projects; however, none of them found that physical condition negatively affects academic performance; on the contrary, its impact on growth is highlighted and health (Donelly et al., 2016).

Finally, proposals to improve academic performance in educational institutions should consider physical fitness as one of the enhancing elements. It is recommended to do them based on the methodology established for the creation of public health programs called HI-5 (Health Impact in 5 years), which aims to generate a positive impact on the health of the community in a period of 5 years in a cost-effective way. For this, the strategy called Comprehensive School Physical Activity Programs is used, which requires the intervention of 5 actors to contribute among all to the enhancement of physical condition and thus favor the academic performance of students. Firstly, the institution must guarantee the curricular development of the Physical Education subject, secondly, the Physical Education department will be in charge of promoting activities, tournaments and events during free time spaces. Thirdly, the family will contribute to the education on physical activity at home, fourthly, the teachers of other areas will support the project with active breaks in the class sessions and finally the student will try, whenever possible, to enroll in an activity that promotes physical and mental health before or after the school day (CDC, 2022).

Referencias

Aadland, K., Moe, V., Aadland, E., Anderssen, S., Resaland, G., & Ommundsen, Y. (2017). Relationships between physical activity, sedentary time, aerobic fitness, motor skills and executive function and academic performance in children. *Mental Health and Physical Activity,* 12, 10-18. https://doi.org/10.1016/j.mhpa.2017.01.001

Cvejic, D., Ostojic, S., & Pejović, T. (2013). Assessment of physical fitness in children and adolescents. Facta Universitatis, 11, 135-145. Retrieved 15 August 2022 de Greeff, J., Bosker, R., Oosterlaan, J., Visscher, C., & Hartman, E. (2018). Effects of physical activity on executive functions, attention and academic performance in preadolescent children: a meta-analysis. *Journal of Science and Medicine in Sport*, 21(5), 501-507. https://doi.org/10.1016/j.jsams.2017.09.595

Donnelly, J.E. et al. (2016) "Physical activity, fitness, cognitive function, and academic achievement in children," Medicine & Science in Sports & Exercise, 48(6), pp. 1197–1222. Available at: https://doi.org/10.1249/mss.0000000000000901

Donnelly, J. (2017). The Relationship Between Physical Fitness and School Performance. *Journal Of Social, Behavioral, And Health Sciences*, 11(1). https://doi.org/10.5590/jsbhs.2017.11.1.16

Kohl, H. W., III, Cook, H. D., Committee on Physical Activity and Physical Education in the School Environment, Food and Nutrition Board, & Institute of Medicine (Eds.). (2013). Educating the Student Body: Taking Physical Activity and Physical Education to School. National Academies Press (US).

Lima, R., Larsen, L., Bugge, A., & Andersen, L. (2018). Physical Fitness Is Longitudinally Associated With Academic Performance During Childhood and Adolescence, and Waist Circumference Mediated the Relationship. Pediatric Exercise Science, 30(3), 317-325. doi: 10.1123/pes.2017-0206

London, R. and Castrechini, S. (2009). Exploring the link between physical fitness and academic achievement. Stanford, CA: John W. Gardner Center for Youth and their Communities.

Maher, C., Lewis, L., Katzmarzyk, P., Dumuid, D., Cassidy, L., & Olds, T. (2016). The associations between physical activity, sedentary behaviour and academic performance. *Journal Of Science And Medicine In Sport,* 19(12), 1004-1009. https://doi.org/10.1016/j.jsams.2016.02.010

McPherson, A., Mackay, L., Kunkel, J., & Duncan, S. (2018). Physical activity, cognition and academic performance: an analysis of mediating and confounding relationships in primary school children. *BMC Public Health*, 18(1). https://doi.org/10.1186/s12889-018-5863-1

Ocampo, C., Gualdrón, Ó., Olaya, A., Pontón, J., POLÍTICA DE ÉTICA, BIOÉTICA E INTEGRIDAD CIENTÍFICA1–48 (2017). Bogotá DC; Colciencias, DIRECCIÓN DE FOMENTO A LA INVESTIGACIÓN.

OECD (2022), Education at a Glance 2022: OECD Indicators, OECD Publishing, Paris, https://doi.org/10.1787/3197152b-en.

Ruiz-Ariza, A. et al. (2016) "Influence of physical fitness on cognitive and academic performance in adolescents: A systematic review from 2005–2015," International Review of Sport and Exercise Psychology, 10(1), pp. 108–133. Available at: https://doi.org/10.1080/1750984x.2016.1184699.

Santana, C., Azevedo, L., Cattuzzo, M., Hill, J., Andrade, L., & Prado, W. (2016). Physical fitness and academic performance in youth: A systematic review. Scandinavian Journal Of Medicine & Science In Sports, 27(6), 579-603. doi: 10.1111/sms.12773

Wittberg, R. A., Northrup, K. L., & Cottrell, L. A. (2012). Children's aerobic fitness and academic achievement: a longitudinal examination of students during their fifth and seventh grade years. *American journal of public health,* 102(12), 2303–2307. https://doi.org/10.2105/AJPH.2011.300515