Sportis
Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad
Scientific Technical Journal of School Sport, Physical Education and Psychomotricity

Editor: University of A Coruña. A Coruña. Spain
ISSN-e 2386-8333
E-mail: sportis.journal@udc.es Web: https://revistas.udc.es
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Original article. A Multivariate Study for Determining the Relationship Between Physical Activity, Physical Fitness, and Academic Performance. Vol. 9, n.º 2; p. 284-301, may 2023. https://doi.org/10.17979/sportis.2023.9.2.9520

A Multivariate Study for Determining the Relationship Between Physical Activity, Physical Fitness, and Academic Performance

Estudio multivariado para determinar la relación entre actividad física, condición física y rendimiento académico

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Editorial shedule: *Article received 13/02/2023 Accepted: 06/04/2023 Published: 01/05/2023*
https://doi.org/10.17979/sportis.2023.9.3.9520

For cite this article you must use this reference:
Suárez-Cano, L.; Bernal-Ballén, A.; Briceño-Martínez, J.J. (2023). A Multivariate Study for Determining the Relationship Between Physical Activity, Physical Fitness, and Academic Performance. Sportis Sci J, 9 (2), 284-301 https://doi.org/10.17979/sportis.2023.9.2.9520

Authors' specific contribution: Research design (LSC, ABB and JJBM); Methodology: LSC and ABB; Data analysis: LSC, ABB and JJBM; Manuscript elaboration: LSC, ABB, and JJBM.

Declaration of Conflicting Interests: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding disclosure: The authors received no financial support for the research, authorship and/or publication of this article.

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Acknowledgements: The authors like to express their gratitude to Sergio Andrés Pineda Castillo from Biomechanics and Biomaterials Design Laboratory, The University of Oklahoma for his unevaluable support in the statistical analysis.

Abstract
The relationship between physical activity, physical fitness, and academic performance has been widely studied internationally. However, reports of this relationship are contradictory, and its impact is still a matter of controversy. For that reason, the current research determined the correlation between these three variables in a group of 56 female and 48 male Colombian students with an average age of 14.08 ± 0.89 years. A quantitative, correlational, and cross-sectional study was carried out. The physical activity was evaluated using PAQ-A questionnaire. For physical fitness, six tests from the Euro fitness battery were used. The academic performance in Spanish, Math, Natural, and Social Sciences were obtained from the grades for the participants at the end of the academic year. Correlations were determined by multivariate multiple linear regression. The obtained results suggest that aerobic endurance test had effect in the studied variables, whereas the correlation of the other tested predictors did not show any meaningful statistical result. In fact, academic performance is not affected by the physical fitness of the students at the time course grades were measured.

Keywords: Physical activity; physical fitness; academic performance; multivariate correlation.

Resumen
La relación entre la actividad física, la condición física y el rendimiento académico ha sido ampliamente estudiada a nivel internacional. Sin embargo, los reportes de esta relación son contradictorios y su impacto aún es motivo de controversia. Por ello, la presente investigación determinó la correlación entre estas tres variables en un grupo de estudiantes colombianos de los cuales 56 eran de género femenino y 48 masculino, con edad promedio de 14,08 ± 0,89 años. Se realizó un estudio cuantitativo, correlacional y transversal. La actividad física se evaluó mediante el cuestionario PAQ-A. Para la aptitud física, se utilizaron seis pruebas de la batería de test Eurofit. El rendimiento académico en Español, Matemáticas, Ciencias Naturales y Sociales se obtuvo a partir de las notas de los participantes al final del curso académico. Las correlaciones se determinaron mediante una regresión lineal múltiple multivariante. Los resultados obtenidos sugieren que la prueba de resistencia aeróbica tuvo efecto en las variables estudiadas, mientras que la correlación de los otros predictores probados no mostró ningún resultado estadístico significativo. De hecho, el rendimiento académico no es afectado por la condición física de los estudiantes durante el tiempo en el que fueron evaluados.

Palabras clave: Actividad física; condición física; rendimiento académico; correlación multivariable.

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Introduction

Frequent physical activity (PA) is an important habit for maintaining vital functions, and it is an essential part of physical wellness, and a healthy lifestyle (Gualdi-Russo & Zaccagni, 2021; Lacombe, Armstrong, Wright, & Foster, 2019). However, about 23 % of adults and 81 % of school-aged adolescents worldwide are not sufficiently active, and among this range, women are the least active (World Health Organization, 2019).

Statistics in Latin America shown that more than a quarter of the population over 14 years of age does not practice PA or a sport (Aguilar-Farias et al., 2018; Ramirez, Vinaccia, & Gustavo, 2004). Additionally, it was reported that a student should perform from 30 minutes to one hour of daily PA to have an impact on school grades, (Gonzalez & Portoles, 2014; Strong et al., 2005).

Data in Colombia revealed that schoolchildren dedicate approximately 4 hours per day to sedentary activities. Moreover, that age group spends a high number of hours watching television and playing video games (Alvear, Muñoz, Castro, Castro, & Beltran, 2015). On the contrary, only 3 out of 10 Colombian children achieve the recommended levels of PA (González et al., 2018). This indicates a prevalence of physical inactivity of 74.9 % and the high level of sedentary lifestyles in young people is a global public health problem, therefore, PA has become an inexhaustible source of research in both the field of education and health.

Physical fitness (PF) can be defined as a set of measurable health-related attributes that include cardiorespiratory fitness, muscular strength, endurance, body composition, flexibility, balance, agility, coordination, reaction time and power (Santana et al., 2017). Whitin this context, it has been established that one of the most significant benefits of PF is related to cognitive functions.

Diverse studies have revealed substantial associations between PF and Academic performance (AP) in different areas, specifically in math, in reading comprehension and fluency, arithmetic and algebraic problem solving, and general AP from preschool to university (Cid, 2018; Navarro-Aburto, Diaz-Bustos, Muñoz-Navarro, & Perez-Jimenez, 2017; Pertusa, Sanz-Frias, Salinero, Perez-Gonzalez, & Garcia-Pastor, 2018). AP is identified as the mental abilities to deploy effective, creative, socially accepted behavior and it implies

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the development of executive functions. These abilities are involved in generating, monitoring, regulating, executing, and readjustment of appropriate behaviors to achieve complex goals, especially when they require a novel and creative approach. In this sense, executive functions and metacognitive skills contribute to AP, and they can be considered as an even more important predictor of school success than general intelligence level (Pino Muñoz & Aran Filippetti, 2019).

Numerous scientific papers related to the benefits that PA brings to AP has been published in the last decades (Castelli et al., 2014; Chu, Chen, Pontifex, Sun, & Chang, 2019; Donnelly et al., 2016; Erwin, Fedewa, & Ahn, 2012; González-Howard, 2019; Hillman, Erickson, & Kramer, 2008; Marques, Santos, Hillman, & Sardinha, 2018; Martins et al., 2018; Singh, Uijtdewilligen, Twisk, Van Mechelen, & Chinapaw, 2012) and it has been acknowledged that PA is associated with cognition, structural, and functional brain health in children and adolescents (Singh et al., 2019). Moreover, moderate and vigorous levels of PA improve AP in adolescents and university students (Cid, 2018; Conde & Sanchez, 2015). Nonetheless, studies addressing the association between these two variables are contradictory, and it has been established that PA is either positively, or there is no relationship between these 2 domains (Coe, Peterson, Blair, Schutten, & Peddie, 2013; Mullender-Wijnsma et al., 2015).

Positive relationships between PA and cognitive capacity have been reported, which is linked to a greater thinking flexibility, and a better ability to maintain information in memory which can contribute to improve AP (Ardoy et al., 2014; Noakes & Spedding, 2012). Negative associations, on the other hand, among AP and overweight in children and adolescents has been exhaustively described (Andreu & Aparicio, 2016; de Greeff, Bosker, Oosterlaan, Visscher, & Hartman, 2018; Erwin, Fedewa, & Ahn, 2012; Lopez de los Mozos Huertas, 2018; Marquez Rosa, Rodriguez Ordax, & De Abajo Olea, 2006; Pertusa et al., 2018; Ruiz-Ariza, Ruiz, de la Torre-Cruz, Latorre-Roman, & Martinez-Lopez, 2016; Sullivan, Kuzel, Vaandering, & Chen, 2017; Valdes & Yanci, 2016). Some studies indicate that frequent PA brings benefits for students' physical and mental health (Marquez Rosa et al., 2006; Zafra, 2013).

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Although the scientific community has made important efforts to establish the relationship between PA, PF and AP, the evidence indicates a lack of information in specific regions (Althoff et al., 2017; Guthold, Stevens, Riley, & Bull, 2018; Onambele-Pearson, Ventre, & Brown, 2018; Sallis et al., 2016). Therefore, this research evaluated PA, PF, and AP in 8th grade Colombian students using a multivariate multiple linear regression (MMR) method, and it has described the potential relationship between them.

Methods and Materials

Participants

This is a quantitative, correlational, and cross-sectional study. A total of 104 Colombian students belonging to the 8th grade of secondary school of an educational institution were selected for the research. The group consisted of 56 females and 48 males, with an average age of 14.08 ± 0.89 years. Fathers, mothers, or mentors of the students were previously informed of the research procedures and gave their consent for their participation. Additionally, the Ethic Committee approved the research.

Instruments

Questionnaire PAQ-A. The Physical Activity Questionnaire for Adolescents (PAQ-A) (adapted to the Colombian context) was applied to evaluate PA performed by the students (Herazo-Beltran & Domiguez-Anaya, 2012). The instrument consisted of 10 questions about the number of hours that the participants dedicate to physical activity in the last 7 days, and one extra question about the activities that students do during the play time was included.

To assess PF, a battery of six standardized tests was used: Body mass index (BMI) assessment; aerobic endurance test (AET); 5x10 agility test (AT); upper limb muscular strength test (Hangrip) (MST); long jump test without impulse (LJTWI); and flexibility test (sit and reach) (SAR).

For AP, the final performance of the academic year in mathematics, social sciences, Spanish language, and natural sciences was obtained using the reports issued by the institution. The assessment scale goes from 1 to 5.

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To analyze the collected information, parametric tables established by the Eurofitness battery were used as a reference. Although the Eurofitness tables were designed for European students, there are several reports that have used Eurofitness tables in Latin-American population and the battery has been validated in order to have relevant data related to the studied group (Agudelo Velásquez et al., 2019; Kain et al., 2008; Mac Donncha et al., 1999; Peña Reyes et al., 2003; Ramirez-Vélez et al., 2015; Ramos-Sepúlveda et al., 2016; Rodriguez Castillo, 2020; Ruiz et al., 2006; Tovar Mojica et al., 2008).

Data collection and analysis procedure

The instruments were applied in physical education classes using the interactive platform Edmodo The battery of physical tests was carried out in two class sessions (PA and SAR tests in the first session; BMI, AET, AT, MST and LJTWI in the second). All statistical modeling procedures included each standardized test as a predictor for the numerical course grade for math, social sciences, natural sciences, and Spanish language, as the outcome of the model. Thus, an MMR model can be described as

$$y = B_o + B_1X_i + B_2X_2 + \ldots + B_jX_i$$

where y is the predicted course grade, B_j are the model coefficients for the j^{th} predictors, and X_i are the numerical values of the predictors. Inclusion or exclusion of predictors for the model was decided by performing a multivariate analysis of variance (MANOVA). Contributing predictors were selected based on this test and model was updated accordingly. Statistical significance was accepted with $p < 0.05$. All statistical analyses were performed using R language in RStudio IDE.

Results

The present study describes the correlation between PA and PF with AP within a sample of Colombian students. Table n.° 1 shows the obtained average discriminated by gender in each category whereas table n.° 2 exhibits the average for the six test which were carried out to determine PF for the participants.

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Table n.° 1. Obtained results for gender in the total average and Standard Deviation of the studied variables.

GENDER	PA	PF	AP
MEN	2.54 ± 0.73	2.80 ± 0.68	3.02 ± 0.56
WOMEN	2.37 ± 0.60	2.38 ± 0.54	3.11 ± 0.52
TOTAL	2.45 ± 0.66	2.58 ± 0.64	3.07 ± 0.54

Table n.° 2. Results on the assessment of PA for the standardized tests in average and Standard Deviation

GENDER	STANDARDIZED TEST					
	AT (s)	AET (Pailer)	LITWI (cm)	MST (kg)	SAR (cm)	BMI (kg/m^2)
MEN	20.35 ± 1.23	6.42 ± 1.72	172.81 ± 20.16	27.83 ± 7.12	14.50 ± 7.81	19.50 ± 2.90
WOMEN	22.08 ± 1.35	4.19 ± 1.02	140.04 ± 18.61	20.54 ± 3.56	16.85 ± 6.77	21.17 ± 3.28
TOTAL	21.3 ± 1.55	5.28 ± 1.76	155.45 ± 25.17	23.86 ± 6.54	16.12 ± 7.30	20.38 ± 3.12

To analyze the correlation between PA and PF with AP we performed an MMR. A linear correlation was calculated using all the PF variables as predictors for the grade for each course as outcome. Table n.° 3 shows the MANOVA test for the model. We found that the only PF parameter that had a significant effect in the MMR model was AET. Table n.° 4 shows the linear models obtained for each one of the course grades analyzed as outcome variables of the model. All other PF predictor variables did not have a significant effect on the model. Spanish and Social Sciences courses linear models had the lowest p-values of 0.387 and 0.342, respectively. Grades seemed to decrease with increased AET in the Spanish course, and the opposite effect was observed in Social Sciences. However, the low significance of the models can only indicate these effects are random. Overall, the statistical analysis indicates that there is no correlation between PA and PF with AP.

Table n.° 3. MANOVA Test

	TEST STAT	APPROX F	Pr(>F)
SEX	0.010766	0.2503	0.908793
AT	0.050309	1.2184	0.308442
AET	0.154526	4.2037	0.003594**
LJTWI	0.036894	0.8811	0.478529
MST	0.040072	0.9601	0.433312
SAR	0.096099	2.4453	0.051953
BMI	0.024290	0.5726	0.683202
PAQ	0.027052	0.6395	0.635648

** 0.001

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Table n.° 4. Linear regression models for numeric course grades vs. AET

Course	Model	R2	p-value
Social Sciences	y = 0.32x + 28.62	0.008873	0.342
Natural Sciences	y = 0.01x + 23.39	$1.745x10^{-5}$	0.966
Math	y = 0.11x + 29.49	0.000977	0.753
Spanish	y = -0.30x + 30.77	0.007337	0.387

Discussion

The collected information shows that men have a higher level of PA and PF in comparison to women, although women exhibit better AP in each of the assessed courses. In general, women have better academic performance than men, and are rated better in behavioral skills than boys. Female students generally earn better grades than their male counterparts, and teachers rate them as having better competencies and skills (Quadlin, 2018). One of the reasons can be explained because girls tend to give more emphasis to effort, whereas boys appeal more to ability and luck as causes of their academic achievement (Ortiz Alvarado, Rodriguez Ontiveros, & Ayala Gaytán, 2019). Furthermore, it has been reported that women obtain better academic results because of the learning strategies and study habits they usually employ (Santos Rego, Lorenzo Moledo, Priegue Caamaño, Torrado Quintela, & others, 2020). Additionally, there is a personality factor which might be responsible for the AP for both genders. The literature has shown that females' lower scores in disconstraint-related personality characteristics, including their ability to focus their attention, manage their behavior and consciously suppress impulses for the sake of higher goals, predict better educational experiences and outcomes (Carvalho, 2016; Jordani et al., 2019; Kallio et al., 2020; Rosselli et al., 2020).

From the PA and PF point of view, there are contradictory reports which have analyzed the gender difference. It can be assumed that parents and teachers influence is a crucial factor to explain these differences. Studies have found that men are more likely to have physically active friends and this feature is among the strongest correlates of one's own PA (Vilhjalmsson & Kristjansdottir, 2003). Studies on gender differences indicated that men are more active than women, indeed (McCarthy & Warne, 2022). The results presented in this study are in concordance with other reports (Davis, Wojcik, & DeWaele, 2016; Gallego,

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Sanchez, Vacas, & Zagalaz, 2016). Additionally, men with higher PA and PF experience lower risks of disabilities, have higher bone mineral density, which can be interpreted as men exhibit a better state of health (Fink, Weege, Pham, & Shackelford, 2016), and that condition might be an indicative or AP enhancement.

PF is considered a powerful marker of health in children and adolescents. For that purpose, several instruments have been developed and for the majority of them, there was a lack of data on reliability and validity (Ortega et al., 2015). However, useful information can be obtained, and it might indicate specific features for a group of participants. Although there are differences evidenced in both genders for the six assessed tests for PF, it is worthy to mention the slight variance for BMI for men and women. This test is used to evaluate fatness of children, and it has been assumed that the measurement does not depend on age, race, and sex (Martinez et al., 2017). Nonetheless, during puberty, males rapidly increase muscle mass and reduce body fat mass because of increases in testosterone, growth hormone, and insulin-like growth factor. Females, on the other hand, experience rapid increases in fat mass during their puberty, which may be largely due to increases in estradiol (Knutson, 2005). Additionally, the observed differences in the other tests can be attributed to physiological characteristics (Busing & West, 2016).

Overall, the analysis of the collected data does not demonstrate a correlation between the PF and AP. No significant correlations were observed, despite the ANOVA testing deeming AET as the only predictor showing a marginal effect on the measured outcome variables. Our study demonstrates that, for the tested sample, academic performance is not affected by the physical fitness of the students at the time course grades were measured.

Although the results presented in here might serve as a starting point for future research's, it is notorious that it is necessary to enlarge the number of participants as well as obtain information within other age group. Thus, the proposed model may be tested. Additionally, the data shown in this work are limited to an urban population. It is necessary therefore, to extend the methodology to other rural areas in which different habits exist and more significant statistics results might be presented to the scientific community.

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Conclusions

PA and PF level present a low relationship with AP statistically speaking, but it is significant for this type of study and coincides to a large extent with the scientific evidence found so far. The positive and negative correlations of the studied population stand out when it is disaggregated by sex, finding significant data in relation to the SAR, BMI and AET in women, where the most significant factor is related to overweight and low PF related to poor AP. The scientific literature has reported copious information on the relationship between PA, PF and AP. Unfortunately, this correlation has not been sufficiently evidenced in local contexts, although it is to be expected that this correlation has similar tendencies to those reported. Nevertheless, it is necessary that empirical evidence provides this data, in order to adjust educational practices and favor improvement in students' AP. The sample has a notoriously low PA and PF index. As can be expected, these two variables are closely related, and when regular PA is not present, PF is seriously affected. Moreover, this inactivity is present in a young population, although it is plausible to intuit that the sample is the result of sedentary lifestyle habits (confirmed by the BMI data obtained).

AP is affected by various factors that intervene in the context or habits acquired in the organizational practices of the participant's free time. It is observed that in women the positive relationship of PA is related to AP in the areas of mathematics and Spanish, in contrast to men who did not present significant positive relationships. With respect to the variable of PF and AP, it is established that the most positive data in the correlations are again presented in females with the SAR and AET, however assessing the large inverse relationship presented with BMI, it is determined that overweight is directly related to low AP. In the case of men, there is a notable negative correlation between the strength tests, indicating good PF, but with very low AP. Future extensions of this work might help shedding light into the potential effect of an exercise routine in improvement academic grades habits in students. For example, students facing issues with concentration and discipline might benefit from the structured routine of physical exercise, which can be studied using interventional controlled longitudinal studies.

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