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Active Teaching Methodologies Improve Cognitive Performance and Attention-Concentration in University Students

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Abstract: The scientific literature shows a beneficial association between active methodologies and cognitive variables in university students. The purpose of this research was to determine the relationship between active methodologies in Physical Education and attention and concentration in a group of university students A total of forty-four undergraduate students from Pontifical University of Comillas of the Balearic Islands, Palma de Mallorca, Spain, participated in the present investigation (age: 20.48 ± 1.37 years; height: 170.77 ± 9.11 cm; weight: 68.84 ± 8.29 kg; body mass index: 23.51 ± 1.54). A D2 attention test was used to analyse their selective attention and concentration. Active methodologies were used to improve the students' physical fitness, reflected in their VO_{2max}, which was evaluated using an incremental cycloergometer test. A correlation analysis performed between the active methodologies used to improve physical fitness measures and the D2 test revealed a negative moderate correlation between HR_{max} and TR, TA and TR- ($r = -0.30$, $p = 0.04$; $r = -0.38$, $p = 0.01$; and $r = -0.35$, $p = 0.02$, respectively), and a positive moderate correlation between HR_{max} and C ($r = -0.32$, $p = 0.03$). Finally, a negative moderate correlation was found between VT and C ($r = -0.48$, $p = 0.001$). This correlation analysis was reinforced by the results of a regression analysis. In summary, the present research revealed that university students with better aerobic fitness, achieved through active methodologies and reflected in VT and higher HR_{max}, obtained better values in TA, TR and C. University students should be encouraged to engage in regular physical activity through active methodologies that tend to increase physical fitness.

Keywords: active methodologies; higher education; university; attention; concentration

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1. Introduction

Activities with a low energy expenditure during wakefulness, performed while seated or reclined, such as driving, watching TV or a tablet or reading, constitute sedentary behaviours [1]. At any age, but especially in children, adolescents and young adults, sedentary behaviours increase risks in many important aspects of health [2]. Adults in developed socio-economic countries spend ~55% to 65% of their waking hours in sedentary attitudes, as detected by accelerometry [3,4], with an increasing sedentary trend [5].

A significant number of young university students spend a high number of hours in sedentary behaviours and are progressively increasing their levels of sedentary behaviour linked to health risks [2]. There are current trends in the use of personal devices, smartphones and activity trackers, driven by commercial pressures, advertising and disclosures, which measure sedentary behaviour, physical activity, nutrition, sleep and other lifestyle factors, providing valuable information for users, researchers and healthcare providers to self-educate and promote healthy lifestyles. Despite this, meta-analysis studies have found that sedentary time among college students has increased over the past decade [6,7].

Premature death, type II diabetes, various cardiovascular diseases and metabolic syndrome have been strongly associated with sustained sedentary behaviours [8–10]. Determinants of mental well-being, such as increased risks of anxiety and depression, are also associated with high levels of sedentary behaviours [11,12].

However, compliance with modern physical activity (PA) guidelines is, to some extent, independent of the health risks of sedentary attitudes [13,14]. This apparent inconsistency may be due to the fact that the detrimental effects of excessive sedentary behaviour may not be offset by current PA guidelines even though PA may exert a protective action on health. Therefore, some researchers suggest that, to eliminate the mortality risk associated with sedentary behaviour, PA levels considerably higher than the currently recommended guidelines are needed [15].

Socio-demographic factors such as age, gender and economic status can exert substantial variation in sedentary time [16]. One of the key demographic factors may even be current work activity [17]. The highest levels of sedentary behaviours, compared to the general population, are found among clerical workers [18]. Thus, among active working-age adults, whether employed or not, so-called "office workers" are the target population of most research on sedentary behaviour and public health [19].

Society has undergone far-reaching changes in recent years. This can be clearly seen in the way we relate to each other, access information and interact with everything around us. Undoubtedly, this new reality, exacerbated by the unstoppable rise of new technologies and the situation experienced by the health pandemic, has directly affected the educational system and the role that educational centres and universities have to play with and for society [20].

In this sense, active teaching methodologies take on special relevance, as they allow the educational processes to be redirected and guided through the reflection and critical awareness of the student. Active methodologies are those that focus the teaching–learning process on the students as the protagonist of their own learning, promoting significant learning through their own practical experience, which lasts longer than rote learning, and, in our object of study, promotes, encourages and inculcates the practice of activities related to health and fitness [20].

These types of methodologies must be well applied and put into practice, as they must be structured on the basis of solid approaches that have an impact on variables that generate significant learning. If this principle is not respected, and, above all, if it is confused with the mere carrying out of isolated activities that may be fun or generate initial satisfaction among students, it does a disservice both to the student and to the teaching process itself. This is why it is necessary to make these methodologies more rigorous, and to ensure they are supported on a scientific basis [20].

In most developed countries, university students constitute more than 35% of the young adult population [21,22]. It is likely that typical student activities, such as attending lectures, studying and library consultation, which involve long periods of sitting, either in front of a book or a computer, make university students, along with office workers, a subgroup of the population at risk of accumulating high levels of sedentary behaviour [23]. The self-reported time spent in sedentary behaviours by university students may be around 8.3 h on average per day [24], though when measured using technological means, such as accelerometry, time spent in sedentary behaviours increases from 2 to 3 h [25,26]. The aforementioned studies reinforce the belief that university students engage in very sedentary behaviour [27,28], even at levels that may be similar to or higher than the behaviour of office workers [29]. Despite this, to our knowledge, the levels of sedentary behaviour among university students have not yet been systematically and thoroughly reviewed.

The development of educational, social and health policies on sedentary behaviour among university students requires a better understanding of the volume of their behaviour and their social attitudes in order to guide future interventions. Furthermore, the university years may be an important period for the development of future lifestyle patterns, as many of the health-related behaviours of adults are established during late adolescence and early adulthood, typically during young people's time at university [30].

This concept gains importance given that the cognitive function related to executive functioning in healthy young adults is highly correlated with moderate-intensity acute exercise, sedentary behaviour and cardiorespiratory fitness [31]. It is possible that the result of PA-induced changes at the systemic, molecular and cellular levels are the underlying mechanisms by which PA may improve cognition [32,33]. It is likely that PA may influence neural systems (e.g., attention, learning and memory) [34]. It is also possible that moderate to vigorous PA may increase molecular mediators (e.g., brain-derived neurotrophic factor) and that PA may induce the development of the cellular environment and promote neurogenesis and improved vascular condition, thus improving cognition [32,35].

With regard to brain protection and restoration, some authors have determined that low-intensity PA may be more beneficial than vigorous PA [36,37], as vigorous exercise may induce a marked increase in neuronal alterations induced by high levels of catecholamines, limiting the influence of PA on cognitive capacity [38]. Higher levels of activation of premotor and accessory neural areas of the brain may be encountered with high-intensity exercise, leading to lower levels of cognitive plasticity due to reduced activation of the prefrontal areas. For cognitive activity to be facilitated, moderate PA should be sufficiently intense to induce changes in brain neurotransmitters, but without producing the catecholamine surges that would occur with higher intensity or very vigorous PA.

Academic performance, selective attention or concentration, in addition to possible effects of exercise intensity on cognition, can also be linked to physical fitness [39]. Forced PA (maintaining a target heart rate; HR) versus voluntary/habitual (exercising without HR control) may have differential effects on brain function. Forced PA can usually be increased to help the individual reach or maintain a certain heart rate [40] and is highly beneficial in sparing neurotransmitters [41]. However, higher concentrations of brain-derived neurotrophic factor can be observed through habitual free-standing PA, without HR control, which also induces a lower corticosterone stress response. Higher concentrations of brain-derived neurotrophic factor and a reduced corticosterone stress response can be found with forced PA [42]. Increases in cerebral blood flow and cerebral glycolysis have also been found with forced PA [43].

For these reasons, forced PA has been frequently used in most human intervention studies examining the effect of exercise on cognition. In most trials, acute forced EF was followed by a cognitive test. In contrast, in young people, we found no studies linking free physical exercise or recreational PA with cognition.

Research is needed on whether mood and anxiety may be related to exercise and cognition, and it is unclear whether changes in mood and anxiety are related to the effects of exercise on cognition or are independent. It is necessary to know whether there are other neural systems related to cognition that may be influenced by PA or whether the changes in cognition are exclusively due to the effects induced by exercise itself.

With the current state of knowledge, it can be stated that moderate PA may be the preferred intensity level for improving concentration-related cognitive functioning in healthy college students, whereas acute light- or vigorous-intensity PA does not seem to have any association. While vigorous PA can induce large increases in catecholamine levels, it is possible that light PA is not intense enough to induce changes in brain neurotransmitters [32]. Furthermore, it is not clear why only one of the parameters linked to concentration, and not with the other cognitive tests, is associated with moderate acute PA. This is especially surprising because benefits of moderate acute PA have been found on cognitive memory [34], reasoning [44] and attention [45].

On the other hand, active teaching methodologies in Physical Education are well known by teachers, but only a very small percentage of them put them into practice [46]. Active methodologies in Physical Education are constituted by pedagogical and didactic processes centred on the needs of the students, leading to improvements in competence and participation through action, reflection and cooperation [47]. Active methodologies adapt to the physical and psychological needs of the practitioners by developing motivation and, ultimately, persistence in practice.

This study sought to examine the possible relationship between PA levels obtained through the use of active teaching methodologies and academic performance. Therefore, it was necessary to study the relationship between attention, physical activity levels and academic performance in order to better understand the link, if any, between cognitive skills, academic performance and physical fitness. Based on the above, it was hypothesised that active methodologies improve aerobic fitness, and improve attention and academic performance in grades. Therefore, this study aimed to observe the possible relationships between aerobic fitness obtained with active teaching methodologies, the level of attention in a specific test (D2 attention test) and the academic performance of university students.

2. Materials and Methods

2.1. Participants

A total of forty-four undergraduate students from Pontifical University of Comillas of the Balearic Islands region in Palma de Mallorca, Spain, were part of the present research, age: 20.48 ± 1.37 years; height: 170.77 ± 9.11 cm; weight: 68.84 ± 8.29 kg; body mass index: 23.51 ± 1.54. The university students were divided into two groups, either the (i) low-level group or (ii) high-level group, depending on their fitness level, as estimated from the VO_{2max} incremental test. All of them were participating in programmes of active methodologies for the improvement of aerobic capacity during the academic year in which this research was carried out.

The inclusion criteria were (i) the ability to participate in all assessments; (ii) not having a health problem that could bias any result or prevent them from taking an incremental test during the study; and (iii) reported normal vision and did not declare any history of neuropsychological impairments. The university students were informed about the main aims of the research and signed an informed consent form before the start of the study. In addition, the study was conducted in accordance with the ethical principles of the Helsinki declaration for human research and was approved by the Research Ethics Committee of the Pontifical University of Comillas (2021/66).

2.2. Measures

2.2.1. Anthropometry

Height and body weight were measured at the beginning of the session (between 9:30 a.m. to 11:30 a.m.). Height was measured using a stadiometer (SECA 225, Hamburg, Germany) to the nearest 0.1 cm, and university students were asked to remove their shoes and other accessories that could influence the measure. Weight was measured without shoes with a bioelectrical impedance analysis (BIA) device (BC-730, Tanita, Tokyo, Japan) to the nearest 0.1 kg. Body mass index (BMI) was calculated as body weight (kg) divided by height squared (m).

2.2.2. Physical Fitness

A Polar M400 heart rate monitor (Polar Electro, Kempele, Finland) was used to register the heart rate (HR) during the submaximal incremental test, and HR was coded using Polar FlowSync. In addition, during the test, ventilatory gas exchange was recorded using a Viasprint 150 P cycloergometer connected to a Jaeger Master Screen gas analyser.

The university students visited the laboratory once. As soon as participants arrived, the HR monitor's recording band was positioned and the submaximal incremental exercise test on a cycloergometer with a mask connected to a metabolic cart began. To ensure the security of university students, we followed the guidelines proposed by the ACSM [48]. The Astrand protocol [49] was used during the assessment. The Ventilatory Anaerobic Threshold (VAT) was calculated using the gas exchange method (RER) [(RER) = CO_2 produced/O_2 consumed]; in this case, the VAT was determined to have been reached when the RER was equal to 1.00 [50,51]. The test was finalised when the VAT was reached, or when the student could not continue.

2.2.3. D2 Attention Test

The D2 attention test was used to evaluate the visual scanning ability and sustained attention [52]. The D2 attention test involved discriminating among 47 characters in 14 rows. During the test, the university students would be given 20 s to complete each row. The test was applied in groups and the stimuli contained the letters "d" or "p," which may be accompanied by one or two lines on the top, on the bottom, or both. Briefly, the "d" must be crossed out with two stripes (regardless of the position). See Table 1, for more information about the variables analysed and the scores.

Table 1. Variables analysed of D2 attention test.

	D2 Attention Test	
	Variables	**Acronyms**
1	Processed elements	TR
2	Successes	TA
3	Omissions	O
4	Commissions or errors	C
5	Last stimulus analysed in the row with the most attempted elements	TR+
6	Last stimulus analysed in the row with the least attempted elements	TR−

Source: modified from [52].

2.2.4. Active Methodologies to Improve Physical Fitness

A compendium of active methodologies was used to improve aerobic physical fitness. These methodologies were based on cooperative learning and gamification. In cooperative learning, the participants carried out physical activities in which the subjects were jointly responsible for their own training and that of the other members of the group, establishing delimited and specific work corners in which the subjects carried out aerobic improvement activities. In the gamification processes, games were played that required maintaining a level of physical activity that would allow aerobic improvement while maintaining the recreational objectives of the training.

2.2.5. Procedure

All the tests were collected in the laboratory of the university where they carried out their studies. The assessment was carried out in one session. Thus, the students arrived at the laboratory, and were weighed and measured. Then, participants were given the D2 attention test and finally their physical condition was evaluated with incremental test on the cycloergometer to calculate their VO_{2max}. Before the start of the study, the university students received instructions regarding the protocol of the D2 attention test and performed different targets to familiarise themselves with the test. In all cases, the explanation was performed by one educational psychologist.

2.2.6. Statistical Analysis

Descriptive statistics were represented as mean $\pm$ SD. Tests of normal distribution and homogeneity (Kolmogorov–Smirnov test and Levene's) were conducted on all data before the analysis. The group was divided into two new groups (high-level group vs. low-level group) based on the values of VAT, and posteriorly both groups were compared by different one-way ANOVA to determine the difference between groups. In this case, the effect size was indicated with partial eta squared for Fs. A Pearson correlation coefficient r was used to examine the relationship between values of anthropometric measures (age, height, weight and BMI), fitness assessment (submaximal incremental test (HRmax, VT, Load and W/kg) and (Handgrip: D: Dominant and ND: Non-Dominant)) and D2 test (TR, TA, O, C, TR+ and TR−). The interpretation of the magnitude of these correlations was according the following criteria: $r \leq 0.1$, trivial; $0.1 < r \leq 0.3$, small; $0.3 < r \leq 0.5$, moderate; $0.5 < r \leq 0.7$, large; $0.7 < r \leq 0.9$, very large; and $r > 0.9$, almost perfect. Finally, regression analysis was used to identify which fitness variables can better explain the results of the D2 tests. All variables were examined separately in this regression analysis. Data analysis was performed using SPSS v.26 for Mac (SPSS Inc., Chicago, IL, USA). The level of significance was $p < 0.05$.

3. Results

The one-way ANOVA tests were performed with anthropometrical measures (height, weight and BMI), fitness assessment (submaximal incremental test (HR_{max}, VT, load and W/kg) and (Handgrip: D: Dominant and ND: Non-Dominant) and D2 test (TR, TA, O, C, TR+ and TR−), revealing significant effects of group only in height, VT, load and W/kg ($F = 4.40$, $p = 0.04$, $\eta^2 = 0.09$; $F = 47.70$, $p = 0.001$, $\eta^2 = 0.53$; $F = 8.12$, $p = 0.01$, $\eta^2 = 0.16$; $F = 9.19$, $p = 0.001$, $\eta^2 = 0.18$, respectively). In addition, the data revealed a significant effect of group in C, $F = 6.23$, $p = 0.02$*, $\eta^2 = 0.13$ (see Table 2).

Table 2. Anthropometrical measures, physical fitness and D2 test measures (mean ± SD).

	All Group (*n* = 44)	**Low-Level Group (*n* = 22)**	**High-Level Group (*n* = 22)**	***F* ∣ *p* ∣ d**	**CI 95% Lower**	**CI**	**CI 95% Upper**
Anthropometric measures							
Height (cm)	170.77 ± 6.50	168.00 ± 7.64	173.55 ± 9.77	$F = 4.40$ ∣ $p = 0.04$ * ∣ $\eta^2 = 0.09$	170.70	2.71	173.49
Weight (kg)	68.84 ± 8.29	68.63 ± 12.19	69.06 ± 8.92	$F < 1$	65.38	3.46	72.31
BMI (%)	23.51 ± 1.54	24.22 ± 3.40	22.80 ± 1.44	$F = 3.25$ ∣ $p = 0.08$ ∣ $\eta^2 = 0.07$	22.86	0.64	24.15
Physical fitness							
HRmax (bpm)	173.41 ± 16.10	175.68 ± 17.29	171.14 ± 14.87	$F < 1$	168.24	5.17	178.58
VT ($mL \cdot kg^{-1}\ min^{-1}$)	31.07 ± 8.08	25.25 ± 5.81	36.89 ± 5.37	$F = 47.70$ ∣ $p = 0.001$ ** ∣ $\eta^2 = 0.53$	29.23	1.84	32.90
Load (w)	191.28 ± 49.67	172.21 ± 43.69	211.36 ± 47.39	$F = 8.12$ ∣ $p = 0.01$ * ∣ $\eta^2 = 0.16$	191.45	13.49	205.28
W/kg	2.80 ± 0.64	2.53 ± 0.57	3.06 ± 0.59	$F = 9.19$ ∣ $p = 0.001$ * ∣ $\eta^2 = 0.18$	2.62	0.18	2.98
Handgrip ND (kg)	40.80 ± 8.18	39.35 ± 8.45	42.25 ± 7.77	$F = 1.40$ ∣ $p = 0.24$ ∣ $\eta^2 = 0.03$	38.27	2.54	43.34
Handgrip D (kg)	47.28 ± 7.95	45.79 ± 8.13	48.78 ± 7.51	$F = 1.60$ ∣ $p = 0.21$ *∣ $\eta^2 = 0.04$	44.71	2.57	48.86
D2 test							
TR	382.16 ± 75.74	369.55 ± 76.70	394.77 ± 74.37	$F = 1.23$ ∣ $p = 0.27$ ∣ $\eta^2 = 0.03$	359.79	22.37	404.52
TA	138.23 ± 35.46	129.36 ± 35.40	147.09 ± 34.02	$F = 2.87$ ∣ $p = 0.10$ ∣ $\eta^2 = 0.06$	128.49	9.73	147.96
O	22.70 ± 17.24	26.77 ± 19.68	18.64 ± 13.65	$F = 2.54$ ∣ $p = 0.12$ ∣ $\eta^2 = 0.06$	36.79	4.54	40.62
C	5.75 ± 6.72	8.14 ± 8.25	3.36 ± 3.51	$F = 6.23$ ∣ $p = 0.02$ * ∣ $\eta^2 = 0.13$	4.01	1.89	7.49
TR+	38.70 ± 6.60	39.09 ± 7.12	38.32 ± 6.18	$F < 1$	36.79	1.91	40.62
TR−	18.73 ± 6.92	17.59 ± 6.08	19.86 ± 7.64	$F = 1.19$ ∣ $p = 0.28$ ∣ $\eta^2 = 0.03$	16.83	1.89	20.62

Note: CI: Confidence Intervals; TR: processed elements; TA: successes; O: omissions; C: commissions or errors; TR+: last stimulus analysed in the row with the most attempted elements; TR−: last stimulus analysed in the row with the least attempted elements. * denotes significance at $p < 0.05$, and ** denotes significance at $p < 0.01$.

A correlation analysis was performed between the anthropometrical measures (age, height, weight and BMI) and the D2 test (TR, TA, O, C, TR+ and TR−) for selected students (see Table 3).

Table 3. Correlation between anthropometrical measures and D2 test for selected students.

	TR	TA	O	C	TR+	TR−
Age (yrs)	r = −0.08 ∣ p = 0.56	r = −0.01 ∣ p = 0.97	r = −0.12 ∣ p = 0.40	r = 0.09 ∣ p = 0.54	r = −0.10 ∣ p = 0.47	r = 0.09 ∣ p = 0.53
Height (cm)	r = 0.16 ∣ p = 0.29	r = 0.20 ∣ p = 0.18	r = −0.17 ∣ p = 0.26	r = −0.15∣ p = 0.31	r = 0.11 ∣ p = 0.45	r = 0.22 ∣ p = 0.13
Weight (kg)	r= −0.05 ∣ p = 0.72	r= −0.01 ∣ p = 0.94	r = −0.10 ∣ p = 0.51	r = 0.05∣ p = 0.71	r = −0.12 ∣ p = 0.42	r = 0.07 ∣ p = 0.63
BMI (%)	r = −0.21 ∣ p = 0.17	r= −0.17 ∣ p = 0.24	r = 0.01 ∣ p = 0.99	r = 0.22 ∣ p = 0.13	r = −0.28∣ p = 0.06	r = −0.08 ∣ p = 0.56

Note: CI: Confidence Intervals; TR: processed elements; TA: successes; O: omissions; C: commissions or errors; TR+: last stimulus analysed in the row with the most attempted elements; TR−: last stimulus analysed in the row with the least attempted elements. BMI: Body Mass Index.

Posteriorly, another correlation analysis was performed between physical fitness (HR_{max}, VT, Load and W/kg) and the D2 test (TR, TA, O, C, TR+ and TR−) for selected students (see Table 4).

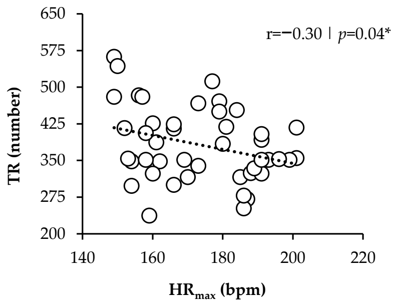
Table 4. Correlation between physical fitness and D2 test for selected students.

	TR	TA	O	C	TR+	TR−
HRmax	r = −0.30 ∣ p = 0.04 *	r = −0.38 ∣ p = 0.01 *	r = 0.27 ∣ p = 0.074	r = 0.32 ∣ p = 0.03 *	r = 0.04 ∣ p = 0.07	r = −0.35 ∣ p = 0.02 *
VT	r = 0.17 ∣ p = 0.26	r = 0.09∣ p = 0.52	r= −0.01∣ p = 0.98	r = −0.48∣ p = 0.001 **	r = 0.10∣ p = 0.50	r = 0.09 ∣ p = 0.55
Load	r = −0.01∣ p = 0.92	r = −0.05∣ p = 0.71	r = 0.02∣ p = 0.88	r = −0.17∣ p = 0.26	r = 0.05∣ p = 0.72	r = 0.01∣ p = 0.93
W/kg	r = 0.01∣ p = 0.96	r = −0.07∣ p = 0.63	r = 0.08∣ p = 0.56	r = −0.20∣ p = 0.18	r = 0.11∣ p = 0.044	r = −0.03∣ p = 0.82

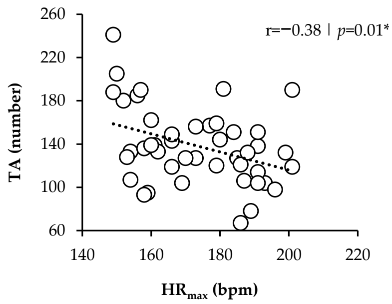
Note: CI: Confidence Intervals; TR: processed elements; TA: successes; O: omissions; C: commissions or errors; TR +: last stimulus analysed in the row with the most attempted elements; TR−: last stimulus analysed in the row with the least attempted elements. HRmax: Heart Rate maximal; VT: Ventilatory Threshold. * denotes significance at $p < 0.05$, and ** denotes significance at $p < 0.01$.

The correlation analysis performed between anthropometrical measures and D2 test did not reveal any correlation between any variable. However, the correlation analysis performed between the physical fitness measures and D2 test revealed a negatives moderate correlation between HRmax and TR, TA and TR− ($r = -0.30$, $p = 0.04$, $r = -0.38$, $p = 0.01$ and $r = -0.35$, $p = 0.02$, respectively). In addition, a positive moderate correlation was revealed between HRmax and C ($r = -0.32$, $p = 0.03$). Finally, a negative moderate correlation was found between VT and C ($r = -0.48$, $p = 0.001$). See Figure 1 for more information.

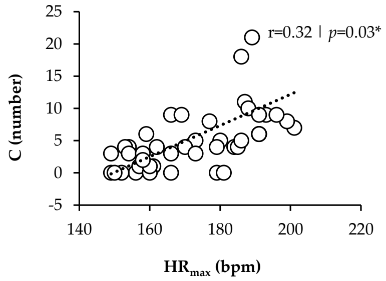
At this point, a multiple regression analysis (Table 5) was performed to verify which anthropometrical and physical fitness variables could be used to better explain the values obtained in the D2 attention test. The multiple regression results for HR_{max} showed significant effects on TR, TA, C and TR− (r = 0.30, r = 0.38, r = 0.58 and r = 35, respectively). Another multiple regression analysis, in this case for VT, revealed significant effects for C (r = 0.39, r) (see Table 4).



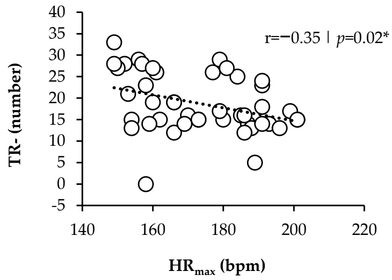
(**a**). Correlation between TR and HRmax (mean ± SE)



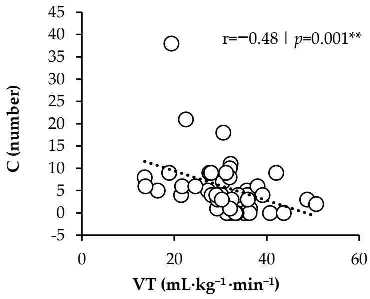
(**b**). Correlation between TA and HRmax (mean ± SE)



(**c**). Correlation between C and HRmax (mean ± SE)



(**d**). Correlation between TR− and HRmax (mean ± SE)



(**e**). Correlation between C and VT (mean ± SE)

Figure 1. Representation of significant correlations between physical fitness variables (HR_{max} and VT) and D2 test values (TR, TA, O, C, TR+ and TR-). * Denotes significance at $p < 0.05$, and ** denotes significance at $p < 0.01$. (**a**) Correlation between TR and HR_{max} (mean ± SE). (**b**) Correlation between TA and HR_{max} (mean ± SE). (**c**) Correlation between C and HR_{max} (mean ± SE). (**d**) Correlation between TR− and HR_{max} (mean ± SE). (**e**) Correlation between C and VT (mean ± SE).

Table 5. Values of regression analysis examining the physical fitness (HR_{max} and VT) and D2 test (TR, TA, C, TR−) for selected students.

		R	R^2	Adjusted R^2	F	P	SE
HR_{max}	TR	0.30	0.09	0.07	4.27	0.04 *	73.01
	TA	0.38	0.14	0.12	7.10	0.01 *	33.18
	C	0.58	0.33	0.32	21.30	0.001 **	5.53
	TR−	0.35	0.12	0.10	5.94	0.01 *	6.55
VT	C	0.39	0.15	0.13	7.25	0.007 *	6.23

Note: TR: processed elements; TA: successes; OC: commissions or errors; TR−: last stimulus analysed in the row with the least attempted elements. HR_{max}: Heart Rate maximal; VT: Ventilatory Threshold. * denotes significance at $p < 0.05$, and ** denotes significance at $p < 0.01$.

4. Discussion

The purpose of this study was to settle the relationships between physical fitness, cognitive functioning, and decision-making in a group of university students. Several studies have previously determined the impact of physical fitness on cognitive processes such as attention, especially in the university environment [53–55]. In this context, different effects can be found depending on the type of physical activity performed. For instance, Arboix-Alió et al. [56] showed better positive effects on attention and concentration after a session of pre-sport physical activity. Similarly, Chen et al. [57] found that adolescents' attention and concentration (using the D2 test) improved significantly after Physical Education sessions with coordination exercises. On the other hand, Pirrie et al. [58] investigated the effects of physical activity with diverse intensities, from moderate to vigorous, on different mental processes (preparation, attention and simultaneous and subsequent processing). In opposition to initial expectations, they found no positive effects on attention or on simultaneous or sequential processing. Based on an extensive appraisal of these effects, these results may due to the kind of physical activity completed; that is, variables such as the intensity, duration or nature of the activity may be important in determining their effect on attention [53].

This study shows that physical fitness, as measured according to the HR_{max} variable, had significantly positive results on the ability of the students to process the elements of the D2 test and on their ability to achieve success in the attentional tasks; that is, the greater their aerobic capacity, the better their cognitive performance in attention and concentration. The study identified statistically significant relationships amongst the study variables and contributes to increasing the scientific evidence that has previously pointed to the relationship between physical fitness and cognitive functioning at these ages [59,60]. In this context, Páez-Maldonado [39] demonstrated that calculating cardiorespiratory fitness in children (10–12 years) using the maximal oxygen uptake (VO_{2max}) formula provides a greater insight into the relationship with cognitive processes. The authors documented a significant relationship between selective attention and performance, or VO_{2max} (sprint coefficient of performance $r < 0.30$, VO_{2max} coefficient of performance $r > 0.40$).

In particular, this research revealed that schoolchildren who obtained better results in cardiorespiratory fitness tests (VT) also exhibited greater performance in terms of attention and concentration. This is in agreement with previous research that showed a positive association between physical fitness and cognitive functioning, strong in the cognitive variables of attention and concentration [39,61,62]. Likewise, cardiorespiratory fitness operationalised through VT is the component that explains a greater variation in the relationship between physical fitness and cognitive functioning [56]. As Fernandes M. de Sousa et al. [63] have also shown, cardiorespiratory fitness is related to the level of cognitive functioning in schoolchildren.

In addition, it can also be observed from our results that the errors made in the decision-making process when performing the attention and concentration test were related to a lower physical condition in VT values. These data would be consistent with those found by Sabarit et al., [64]. This suggests that selective attention capacity and cognitive processing speed can be considered to be positively associated with greater decision-making and better efficiency in performing the task [65]. These results are in line with previous studies that pointed out this phenomenon and suggested that schoolchildren with better physical and cognitive functioning are better equipped to focus their attention on relevant stimuli and thus avoid shifting their interest towards elements that could affect the decision-making process and thus their results in the task [56,62,63].

The improvement of cardiorespiratory capacity has been shown to be one of the main causes of good cognitive performance at this age [60]. Many authors conclude that the adaptation patterns of children's brains differed after cardiovascular interventions [66,67]. Such cardiorespiratory fitness seems important, as it enhances cognitive effects through increased cerebral blood flow and changes in brain structure [68]. Brain stimulation through various training programs improves brain plasticity in different regions with specific cognitive demands [69].

Regarding the limitations of the research, it is recommended that future research consider variables such as study or rest time, along with the use of new technologies, which may influence the association between physical fitness, cognitive performance and academic performance. One of the strengths of this study is the method used to measure the aerobic capacity of the students. However, only certain dimensions of physical fitness were assessed. Therefore, future research should consider assessing different dimensions of health (e.g., cardiorespiratory fitness, muscular fitness, cognitive exercise fitness), which may provide more accurate information, and allow researchers to gain a comprehensive understanding of the relationship between specific dimensions of physical health, cognitive functioning and academic performance. In the future, the use of more specific fitness tests in children may help to understand these associations.

5. Conclusions

When analyzing the results of studies that use active teaching methodologies to improve physical fitness and examined their effects on cognitive performance, attention and concentration, it is important to consider both the quantitative and qualitative characteristics of the active methodologies used to improve these abilities in university students.

The use of active teaching methodologies related to fitness in university students, while improving students' aerobic capacity, can influence coordination and cognitive demands, which can in turn improve various cognitive levels, resulting in increased engagement in selective attention, concentration and decision-making skills, and so on. Specifically, improving physical fitness is thought to help activate the temporal lobe, which in turn affects cognitive functions.

Furthermore, cardiorespiratory fitness is the best measure of cognitive functioning and academic performance. This suggests that young university students should be encouraged to use active methodologies in regular physical activities both to increase physical capabilities and to promote cognitive improvements, attention and focus. Therefore, leaders of public and private organisations, universities and sports clubs should focus on using active methodologies that encourage active lifestyles and promote the acquisition of physical activity in young adults. Active teaching methodology programs related to fitness could be included within teaching organisations and university academic programs and reflected in the respective academic records of the students, helping facilitate their participation in these initiatives and ultimately improve their academic performance.

In summary, the present research revealed that university students who use active methodologies to improve their aerobic fitness, reflected in higher VT and FC_{max}, obtained better values in TA, TR and C. University students should be encouraged to use regular active methodologies to improve their physical and cognitive conditions.

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