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Original Article

ASSOCIATION BETWEEN PHYSICAL FITNESS, LEARNING STRATEGIES AND ACADEMIC ACHIEVEMENT IN 9- TO 11-YEAR-OLD CHILDREN

ASSOCIAÇÃO ENTRE APTIDÃO FÍSICA, ESTRATÉGIAS DE APRENDIZAGEM E DESEMPENHO ESCOLAR EM CRIANÇAS DE NOVE A 11 ANOS

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RESUMO

O exercício físico combate fatores prejudiciais à saúde de crianças como o percentual de gordura corporal e a aptidão cardiorrespiratória. O objetivo do presente estudo foi comparar e correlacionar o $VO_{2máx}$, percentual de gordura, frequência cardíaca máxima, teste de desempenho escolar e estratégias de aprendizagem em 30 escolares de 9 a 11 anos. Os resultados mostram que houve correlações moderadas entre o teste de desempenho escolar (TDE) em escrita, as dobras cutâneas e a soma de dobras cutâneas, TDE em escrita e percentual de gordura, TDE em leitura e percentil geral de estratégias metacognitivas e TDE total e dobra cutânea subescapular. Conclui-se que o desempenho escolar possui relação com as estratégias de aprendizagem bem como com as variáveis de composição corporal e percentual de gordura.

Palavras-chave: Aptidão Física. Estratégias de Aprendizagem. Desempenho Escolar.

ABSTRACT

Physical activity combats factors that are detrimental to children's health such as body fat percentage and cardiorespiratory fitness. The aim of this study was to compare and correlate VO_{2peak}, body fat, maximal heart rate, academic achievement, and learning strategies in 30 children aged 9 to 11 years. The results showed moderate correlations between academic achievement test (AAT) score in writing, skinfolds and the sum of skinfolds, AAT score in writing and body fat percentage, AAT score in reading and overall percentile of metacognitive strategies, and total AAT score and subscapular skinfold. In conclusion, academic achievement is associated with learning strategies, as well as with body composition variables and body fat percentage.

Keywords: Physical fitness. Learning Strategies. Academic Achievement.

Introduction

Sedentary behavior in children has increased exponentially in recent years, which contributed to an exorbitant prevalence of overweight and low physical fitness[1]. This inactivity appears to negatively affect mental health and cognitive processes, especially academic achievement[2]. This is a matter of concern because of the extensive changes that occur in connective structure and function during childhood. Thus, an active lifestyle can have protective effects on the mental health and academic achievement of children[3].

Several studies have demonstrated a positive association between physical activity and cognitive function in children[3-6], although academic performance appears to differ between boys and girls[7,8], probably due to the maturation stage between sexes[9]. Furthermore, cognitive improvements after aerobic exercise seem to depend on the level of physical fitness[10-12] and socioeconomic and cultural characteristics of the individual[13]. The possible mechanisms whereby exercise affects the cognitive response include increased blood flow to the brain, nutrient availability, and an increase in neurotransmitter activity. In addition, studies have demonstrated that circulating levels of brain-derived neurotrophic factor (BDNF) are elevated after high-intensity exercises[14-16].

Academic achievement depends on different factors such as characteristics of the school, family and the individual himself[17-19] and age and sex[7-9]. School performance, which reflects academic achievement, is usually measured by scores (0 to 10) or classifications (excellent, very good, good, regular, and poor)[19]. In addition, learning strategies are techniques or methods used by students to acquire information, which contribute to a better assimilation of knowledge and consequently to greater academic achievement[20].

Studies associating variables of physical performance (VO_{2peak}, fat percentage, and maximal heart rate) with academic achievement and learning strategies, comparing boys and girls, are still sparse and inconclusive[7,8]. Therefore, the objective of this study was to analyze and correlate VO_{2peak}, body fat percentage, maximal heart rate, academic achievement test scores, and learning strategies in boys and girls aged 9 to 11 years.

Methods

Participants

Thirty children (9.6±0.6 years; 30.3±4.0 kg; 1.38±0.1 m; 15.9±1.8 kg/m²) from a municipal school in Taguatinga/DF participated in the study and were divided into two groups: boys (n= 15) and girls (n= 15). The invitation to participate in the study was displayed in the classrooms.

The inclusion criterion was attendance of a Physical Education project promoted by the teachers of the school, with 45-minute classes twice a week consisting of traditional games and activities. The exclusion criteria were 1) physical limitations of the child that would impair temporary or definitive participation in the scheduled activities; 2) history of chronic diseases (diabetes and hypertension), and 3) presence of resting ECG abnormalities.

The study was approved by the Ethics Committee on Research Involving Humans of Universidade Católica de Brasília – UCB (Protocol No. 167-234/2011) and was only started after the child's legal guardian had signed the free informed consent form, which contained information about all procedures, risk, benefits, and importance of the study.

Procedures

The data were collected on the athletic track and in the Laboratory of Studies in Physical Education and Health (LEEFS) of UCB. Two visits to the university were necessary for this study: the first visit was used for the collection of anthropometric data and the second visit for application of the academic achievement test (AAT), Learning Strategies Scale for Basic Education (EAVAP-EF in the Portuguese acronym), and running test for assessing VO_{2peak}.

Weight was measured with a digital scale (Tech 05®, China) to the nearest 100 g, with the child barefoot and standing still until the end of the measurement. Next, height was measurement with a wall-mounted Sanny® (ES 2040) stadiometer. The child was standing with the feet together, heels against the wall, arms hanging at the side, and the head aligned in an imaginary line drawn from the lowest point of the inferior margin of the right orbit to the highest point on the upper margin of the right auditory meatus, corresponding to the Frankfurt plane as described by Marins and Giannichi[21]. The body mass index (BMI) was calculated using the formula: weight (kg)/height^2 (cm).

Body fat percentage was obtained by measuring two skinfolds (SF). The following SF were measured with a Lange Skinfold Caliper® (California, USA) to the nearest 0.5 mm under a constant pressure of 10 g/mm²: triceps skinfold taken as the midpoint of the distance between the acromion and olecranon, and subscapular skinfold measured 1 cm below the

inferior angle of the scapula. Body fat percentage (F%) was calculated by the sum of these SF using the equations proposed by Guedes and Guedes[22]:

Boys: $F\% = (1{,}21 * \sum SF) - 0{,}008 * (\sum SF^2) - 1{,}7$

Girls: $F\% = (1{,}33 * \sum SF) - 0{,}013 * (\sum SF^2) - 6{,}8$

Sexual maturation was evaluated using the Tanner scale[23], adapted by the Ministry of Health, which consists of images with captions characterizing the genitalia and pubic hair for boys and breasts and pubic hair for girls. The researcher individually explained the method and its purpose to each child. By self-assessment, the child indicated on a paper which image his condition resembled and gave this paper to the responsible researcher.

A resting ECG was performed for evaluating cardiac function at rest of the children in order to ensure the absence of any heart disease that would prevent participation in the study. For this purpose, the child lied down on a gurney for 5 minutes and the sites where the electrodes were placed were cleaned. After recording of the electrocardiogram (model MAC 500, GE Medical Systems), the child was sent together with his report to the physician of the Laboratory of Physical Evaluation and Training (LAFIT-UCB), who evaluated the resting ECG and listened to the heart beats per minute of each child in order to obtain a safer diagnosis and to permit clearance or not of the child for the VO_{2peak} test.

The University of Montreal Track Test (UMTT) was used to evaluate VO_{2peak}. The children were asked to run at a pace determined by a CatEye Velo 8 speedometer attached to a Sunset XST2000 bicycle rode by one of the researchers. The initial velocity was 7 km/h and was increased 1 km/h every 2 minutes until voluntary exhaustion, which was reached when the child could not maintain the required velocity. The track was marked with cones at intervals of 50 m so that the evaluator had control of the distance run by the child. When the child reached his maximum, running was interrupted at the next cone and the heart rate shown on the heart rate monitor (Polar® S810) attached to the child's arm was recorded. The evaluator recorded this heart rate, which was considered the maximal heart rate (HR_{max}), and the distance run by the child. This distance was applied in the following equation proposed by Ahmaidi et al.[24] for the determination of VO_{2peak}:

$$VO_{2MÁX} = 1{,}353 + (3{,}163 \times Vm) + [(0{,}0122586) \times (Vm)^2]$$

where *Vm* is the mean velocity in km/h obtained on exhaustion of the test.

Academic achievement was estimated using the AAT developed for application in the Brazilian school setting[25]. The AAT evaluates reading skills (recognizing individual words of the context), mathematical skills (oral problem solving and written calculation of mathematical operations), and written skills (writing their own name and dictated individual words).

The EAVAP-EF was elaborated based on national and international studies. This instrument is easily applied by the evaluator and easily understood by the respondent. The items addressed in the questions basically refer to activities related to learning and study, and permit to determine whether the student uses some type of strategy during learning and to identify these strategies. Analysis of the answers to the questionnaire allows evaluation of the strategical behavior towards learning.

It should be noted that the learning strategies are discussed with a cognitive theoretical focus on the basic principles of the information processing theory. The EAVAP-EF consists

of 31 questions; of these, 13 are classified as "A" questions (absence of dysfunctional metacognitive strategies), 11 as "C" questions (cognitive strategies), and 7 as "M" questions (metacognitive strategies). The answers are scored as 2 (always), 1 (sometimes), and 0 (never). Questions 3, 7, 8, 12, 15, 19, 21, 23, 24, 25, 26, 28 and 30 are reversed scored because they are "A" questions, which are "absence of strategies". Thus, "always' receives 0, "sometimes" receives 1, and "never" receives 2.

The items addressed in the instrument are related to the strategies used for study and learning. The questions cover cognitive strategies, for example: Do you usually highlight the important parts of the text for better learning? Items related to metacognitive strategies are also addressed. For example: When you study, do you notice that you are not able to learn? The questions also include the absence of learning strategies during study, for example: Do you often get distracted or think of something else when you are reading or doing your homework? There are three response alternatives that are marked with a "X": always, sometimes ,or never.

Statistical analysis

After evaluation of normality and homogeneity of the data by the Shapiro-Wilk and Levene test, respectively, the results were reported as the mean ± standard deviation. The groups were compared by the Student t-test for independent samples. Pearson's correlation coefficient was applied to test the association between variables. The level of significance was set at 5% ($p < 0.05$). All procedures were performed using the Statistical Package for the Social Sciences (SPSS 18.0) and GraphPad Prism 6.0.

Results

The main characteristics of the boys and girls studied are shown in Table 1. Comparison between groups showed a significant difference in height, body fat, and distance run in the UMTT ($p < 0.05$). Age, weight, BMI, velocity in the UMTT, VO_{2peak} or HR_{max} did not differ between boys and girls.

Table 1. Characterization of the sample

	Boys (n = 15)	Girls (n = 15)	p
Age (years)	9.6 ± 0.7	9.8 ± 0.6	0.457
Height (cm)	134.4 ± 0.4	142.9 ± 0.5	**0.001**
Weight (kg)	29.8 ± 2.8	32.6 ± 4.3	0.087
BMI ($kg \cdot m^{2(-1)}$)	16.4 ± 1.3	15.76 ± 1.8	0.227
Body fat (%)	14.4 ± 1.0	12.4 ± 1.9	**0.002**
SBP (mmHg)	97.2 ± 6.6	95.0 ± 7.0	0.371
DBP (mmHg)	65.4 ± 6.9	61.6 ± 8.3	0.185
UMTT (m)	1,876.9 ± 455.7	1,537.5 ± 358.1	**0.031**
UMTT ($km \cdot h^{-1}$)	11.5 ± 0.8	10.9 ± 0.8	0.061
VO_{2peak} ($ml \cdot kg^{-1} \cdot min^{-1}$)	43.5 ± 2.5	41.7 ± 2.5	0.060
HR_{max} (bpm)	204.5 ± 10.0	201.1 ± 7.8	0.328

Note: Values are the mean and standard deviation. Body mass index (BMI); systolic blood pressure (SBP); diastolic blood pressure (DBP); distance run in the University of Montreal Track Test (UMTT (m)); mean velocity per hour in the UMTT (UMTT (km/h)); peak oxygen uptake (VO_{2peak}); maximal heart rate (HR_{max})
Source: The authors

No significant differences in the AAT were observed between boys and girls ($p > 0.05$) (Table 2).

Table 2. Academic achievement test scores

AAT score	Boys (n= 15)	Girls (n= 15)	p-value
Writing	20.8 ± 4.4	20.6 ± 6.7	0.949
Mathematics	15.1 ± 4.3	13.8 ± 4.4	0.436
Reading	64.0 ± 4.0	66.0 ± 2.9	0.136
Total	99.9 ± 10.4	100.5 ± 10.3	0.876

Note: Academic achievement test (AAT). Values are the mean and standard deviation
Source: The authors

Table 3 shows the scores of the EAVAP-EF. Girls scored higher ($p < 0.05$) in the metacognitive strategies subscale (raw score, percentage, and percentage by age group) and total score (percentage by age group) than boys.

Table 3. Learning Strategies Scale for Basic Education scores

	Boys (n = 15)	Girls (n = 15)	p-value
ADMS – RS	16.3 ± 4.2	18.3 ± 3.1	0.161
ADMS – OP	49.6 ± 22.9	61.0 ± 20.5	0.164
ADMS – PAG	33.7 ± 20.6	48.4 ± 23.4	0.079
CS – RS	10.0 ± 3.5	10.3 ± 5.5	0.871
CS – OP	49.9 ± 27.3	49.6 ± 34.7	0.976
CS – PAG	45.3 ± 28.3	46.5 ± 35.2	0.928
MCS – RS	8.0 ± 2.0	9.9 ± 1.5	**0.009**
MCS – OP	28.7 ± 20.1	53.8 ± 20.1	**0.002**
MCS – PAG	40.4 ± 26.2	63.6 ± 20.1	**0.011**
Total – RS	34.5 ± 4.5	38.6 ± 7.2	0.074
Total – OP	42.7 ± 21.2	59.4 ± 27.8	0.075
Total – PAG	34.5 ± 19.3	53.1 ± 29.2	**0.049**

Note: Absence of dysfunctional metacognitive strategies (ADMS); raw score (RS); overall percentile (OP); percentile by age group (PAG); cognitive strategies (CS); metacognitive strategies (MCS)
Source: The authors

Correlation analysis revealed a positive, moderate and significant association ($p < 0.05$) of AAT score with distance run in the UMTT ($r = 0.55$) and VO_{2peak} ($r = 0.53$) in boys. On the other hand, in girls, negative and moderate, but not significant, associations were observed between AAT score and distance run in the UMTT ($r = 0.44$) and VO_{2peak} ($r = 0.43$).

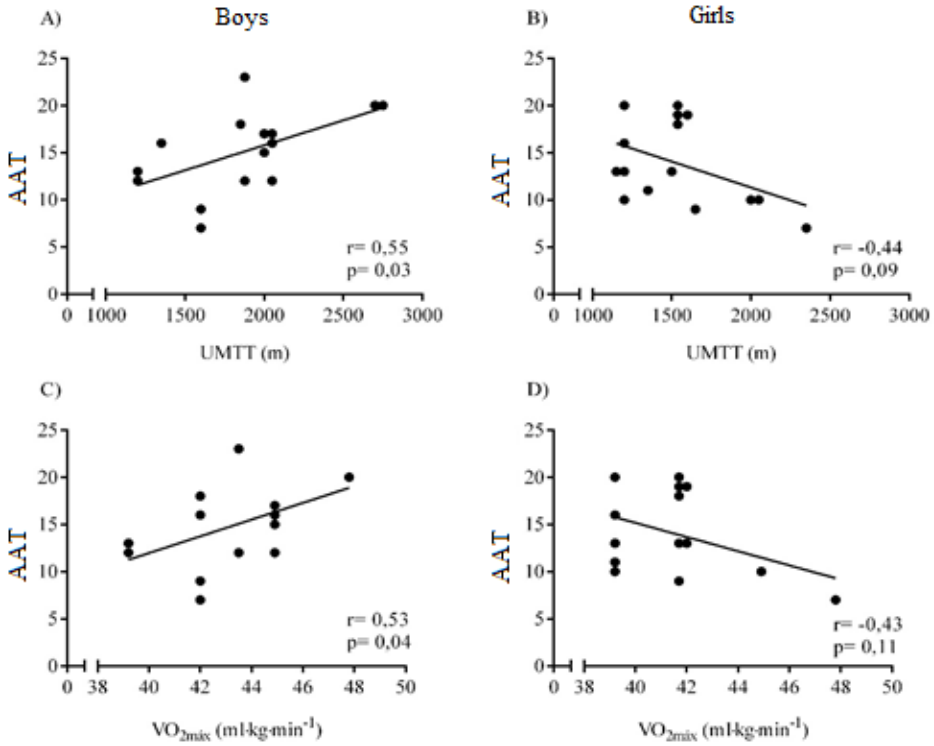

Figure 1. Correlation analysis of academic achievement test scores with distance run in the University of Montreal Track Test (UMTT) and peak oxygen uptake (VO_{2peak}) in boys and girls.
Source: The authors

Discussion

The main finding of this study was the lack of significant differences in AAT scores between boys and girls, although girls were found to use learning strategies. In addition, a positive correlation exists between academic achievement and distance run in the UMTT and VO_{2peak} in boys, while the inverse association is observed in girls but without statistical significance.

Girls had a significantly lower fat percentage than boys, which was within the recommended range, suggesting a healthy lifestyle[26]. However, no association was found with academic achievement in either group. Similar results have been reported by Everland-Sayers et al.[27] who studied North American children using the Terra Nova test and observed no significant association between BMI and academic achievement in mathematics or reading/writing and arts.

Regarding the AAT, no significant differences in the scores of the instrument were observed between the groups studied. One possible explanation for these findings is the fact that girls used learning strategies, which may favor the learning process. In fact, studies have shown that the greater the use of learning strategies, the higher the AAT score in children from Ensino Fundamental I (elementary education years 1-5)[28]. For boys, to maintain school performance similar to that of girls with less use of learning strategies, the higher physical activity level seems to promote benefits in academic achievement, as demonstrated by the positive associations between AAT score and distance run in the UMTT and VO_{2peak}.

Similarly, Kwak et al.[7] found an association of physical fitness with academic achievement in boys but not in girls.

Several studies have demonstrated a positive association between physical activity level and cognitive function in children[3-6]. In a meta-analysis, Chang et al.[12] showed that exercise intensity is the primary factor in improving cognitive function. Recently, Hotting et al.[15] evaluated the effects of a 30-minute exercise session at low (< 57% HR_{max}) and high intensity (~ 80% HR_{max}) on memory consolidation 20 minutes and 24 hours after exercise in a sample of 81 young adults (22 ± 2.36 years). The results showed that high-intensity exercise significantly increased the levels of BDNF concomitant with a small number of forgotten words. The cited studies suggest that physical activity level, particularly exercise intensity, positively influences cognitive function which, in turn, improves academic achievement in boys.

Eveland-Sayers et al.[27] observed a negative association between 1600-m run time and mathematical scores, as well as a positive association between muscular fitness (combination of sit-and-reach and curl-ups) and mathematical scores. On the other hand, the authors found no significant correlations between 1600-m run times and reading/writing and arts scores or between muscular fitness and reading/writing and arts scores.

There are several mechanisms underlying the cognitive improvements associated with exercise, including increased blood flow to the brain and alterations in the levels of neurotransmitters such as acetylcholine, serotonin, adrenaline and noradrenaline, which are related to cognitive function by providing energy and cerebral catecholamines[14-16]. Additionally, there is evidence of an increase in BDNF, which is related to the development of neuronal activity during learning, memory, and synaptic plasticity[29]. Thus, BDNF is likely to play an important role in the results obtained in this study, but this was not investigated.

The repertoire of learning strategies was evaluated using the EAVAP-EF. This is a consolidated instrument in the national literature[30] and several studies have characterized the types of strategies used by students[20]. The results showed higher scores for the metacognitive strategies subscale and total score by age group in girls compared to boys. Dembo[20] indicates the use of learning strategies as mediators for good academic achievement. However, the present study found no significant correlation between the EAVAP-EF and AAT.

One limitation of this study is the small sample size, which may influence the statistical power of the tests. Nevertheless, the findings indicate positive effects of physical activity level on the academic achievement of children. Furthermore, we did not measure any neuroelectric biomarker, which could help explain possible mechanisms associated with cognitive improvement in response to physical activity level. However, previous studies support the explanation of these mechanisms demonstrated in the present study[2,14,31]. Variables other than physical fitness can also influence academic achievement in children, such as socioeconomic and cultural factors, age, sex, anxiety, depression, and low class attendance. These variables are considered confounders that were not controlled in the present study. Future studies should address these possible limitations.

Conclusion

There are no differences in AAT scores between boys and girls, although girls use more learning strategies than boys. In addition, academic achievement is positively associated with distance run in the UMTT and with VO_{2peak} in boys.

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