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ORIGINAL ARTICLE

Screen time impairs the relationship between physical fitness and academic attainment in children☆

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KEYWORDS
Academic performance;
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Abstract
Objective: The purpose of this study was twofold: to analyze the association between physical fitness and academic attainment, and to determine the influence of screen time on the association between physical fitness and academic attainment.
Methods: A cross-sectional study including 395 schoolchildren from seven schools of the Maule Region, Chile (mean age 12.1 years; 50.4% boys) participated in the autumn of 2014 (March to June). Self-reported physical activity and screen time were evaluated. The study measured academic achievement (mean of the grades obtained in several core subjects), physical fitness (cardiorespiratory fitness and muscular strength), weight, height, parental education, and socioeconomic status. Linear regression analysis was used to analyze the relationships between physical fitness and academic attainment after adjusting for potential confounders by gender. Analysis of variance was used to analyze the differences in academic attainment according to fitness and screen time categories (< 2 hours/day and $\geq$ 2 hours/day).
Results: In both genders good cardiorespiratory fitness levels were associated with high language (β = 0.272–0.153) and mean academic attainment (β = 0.192–0.156) grades; however, after adjusting for screen time and other potential confounders, these associations disappear. Similarly, no relationship was observed after analyzing those children who spend more hours of screen time ($\geq$ 2 hours/day).
Conclusions: Academic attainment is associated with higher cardiorespiratory fitness levels; however, it was weakly impaired by screen time. These findings seem to suggest that parents and policymakers should minimize the negative effects of screen time on children's lives to maximize the beneficial effect of healthy habits on academic attainment.

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PALAVRAS-CHAVE
Desempenho acadêmico;
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Força muscular;
Estilo de vida sedentário

O tempo de tela prejudica a relação entre a forma física e o sucesso acadêmico em crianças

Resumo

Objetivo: O objetivo deste estudo foi duplo: analisar a relação entre a forma física e o sucesso acadêmico e determinar a influência do tempo de tela sobre a relação entre a forma física e o sucesso acadêmico.

Método: Um estudo transversal incluindo 395 crianças em idade escolar de sete escolas da região de Maule, Chile (com idade média de 12,1 anos; 50,4% de meninos), foi realizado no outono de 2014 (março a junho). A atividade física e o tempo de tela autorrelatados foram avaliados. Mensuramos o desempenho escolar (média das notas obtidas em diversas matérias principais), a forma física (aptidão cardiorrespiratória e força muscular), o peso, a estatura, a escolaridade dos pais e a condição socioeconômica. A análise de regressão linear foi usada para avaliar as relações entre a forma física e o sucesso acadêmico após o ajuste pelas possíveis variáveis de confusão por sexo. A análise de variância foi usada para avaliar as diferenças no sucesso escolar de acordo com as categorias de forma física e tempo de tela (< 2 horas/dia e ≥ 2 horas/dia).

Resultados: Em ambos os sexos, os bons níveis de aptidão cardiorrespiratória foram associados às maiores notas em línguas (β = 0,272-0,153) e à média de sucesso acadêmico (β = 0,192-0,156); contudo, após ajustar o tempo de tela e outras possíveis variáveis de confusão, essas associações desaparecem. Da mesma forma, não foi observada nenhuma relação após analisar as crianças com mais horas de tempo de tela (≥ 2 horas/dia).

Conclusões: O sucesso acadêmico está associado a maiores níveis de aptidão cardiorrespiratória; contudo, foi pouco prejudicado pelo tempo de tela. Esses achados parecem sugerir que os pais e órgãos reguladores devem minimizar os efeitos negativos do tempo de tela sobre as vidas das crianças para maximizar o efeito benéfico de hábitos saudáveis sobre o sucesso acadêmico.

Introduction

Electronic media use is a common pastime for children today and has led to negative health effects in children and adolescents.[1] These effects include less time for physical activity,[2] poorer academic performance,[3] higher risk of overweight,[4] and low levels of physical fitness,[5] *inter alia*. Therefore, strategies aimed to reduce screen time in this population have started to emerge.[6] For example, the World Health Organization goal has been to increase the proportion of adolescents who view television two or fewer hours on a school day.[7]

According to previous studies, higher levels of physical fitness[8,9] and physical activity (PA)[10] are related to enhanced overall health[11] and are also associated with higher academic attainment. However, the evidence from several studies concerning the association between physical fitness and academic attainment remains weak, due principally to lack of control for important confounders.[12] Because screen time is a significant predictor of academic attainment[2] and high screen-time during childhood is an independent predictor of lower cardiorespiratory fitness in youth,[13,14] it appears important to examine the mediating effect that screen time may have on the association between physical fitness and academic attainment. To the authors' knowledge, no study has attempted to answer this question. Therefore, the purpose of this study was twofold: to analyze the association of physical fitness and academic attainment, and to determine the influence of screen time on the association between physical fitness and academic attainment.

Methods

Participants

All the seventh-grade primary schoolchildren from seven schools in the Maule region (Chile) were invited to participate, and 395 (87%) accepted. They attended public, partially subsidized, and private schools from rural areas. The sample was selected for convenience. Subjects were excluded if they had special education needs or any type of dysfunction limiting their physical activity. The study protocol was approved by the Ethics Committee of the Autonomous University of Chile and subsequently by the director of each school. Following this approval, a letter was sent to parents of all children in the seventh grade, inviting them to a meeting where the objectives of the study were outlined, and written informed consent for the participation of their children in the study was obtained. After all signed forms were collected, researchers met with the physical education teacher to obtain autumn 2014 data (March to June).

Body Composition

Participants wearing light clothing were weighed twice using a digital scale with an accuracy of 100 g. Height was measured twice to the nearest 0.1 cm, without shoes, using a wall-mounted stadiometer. The mean of these measurements was used to calculate body mass index (BMI) as weight in kilograms divided by the square of the height in meters (kg/m^2). Waist circumference (WC) was determined by the average of two measurements taken with a flexible tape at the waist (at the midpoint between the last rib and the iliac crest). A mean of two readings was taken in the morning, under controlled temperature and humidity conditions, with the child shoeless, fasting, and after urination and a 15 min rest.

Physical fitness tests

Physical fitness tests were assessed according to the Alpha Battery, valid and reliable in children.[15] Cardiorespiratory fitness (CRF) was measured using the 20 m shuttle run test. The initial speed was 8.5 km/h; this was increased by 0.5 km/h min^{-1} (stage duration = 1 minute) and the last half stage completed was recorded.[16] Scores of the last stage number were converted to predict maximal oxygen uptake: VO_2max (ml/kg/min) = 31.025 + 3.238 x (speed-km/h)−3.248 x (age) + 0.1536 x (speed x age). Muscular strength (MS) was measured with the standing broad jump test (lower limb explosive strength assessment). Participants jumped horizontally to reach maximum distance (in centimeters). This test was performed twice, and the best score was recorded. The CRF and MS were categorized as follows: poor (first quartile), satisfactory (second and third quartiles), and good (fourth quartile).

Academic attainment

Academic attainment was assessed using the students' grades in the core subjects (mathematics and language). Grades were collected from the official school records at four moments in the first semester (March, April, May, and June 2014). Numeric grade scores in Chile range from 1 (worst) to 7 (best). The average score was calculated for all subjects.

Self-reported screen time

Screen time was assessed by asking participants to report the number of hours per typical day in the past seven days with a three-part question: ''About how many hours a day do you usually watch television, play computer or video games, and use a computer (for purposes other than playing games, for example, emailing, chatting, or surfing the Internet or doing homework) in your free time?'' This question was used in the Health Behavior in School-aged Children (HBSC) study.[17] Finally, daily screen time averages were calculated by adding the three components together. Screen time was dichotomized (0 = < 2 h/d; 1 = ≥ 2 h/d) based on international guidance on limiting pediatric screen time.[18]

Self-reported physical activity

The questionnaire employed to assess PA was the Physical Activity Questionnaire for Adolescents (PAQ-A), Spanish version.[19] In brief, the PAQ-A was designed to assess adolescents' levels of moderate and vigorous physical activity. Physical activity was defined as 'sports, games, or dance that make you breath hard, make your legs feel tired, or make you sweat'. Subjects were asked to quantify their physical activity levels during their spare time in the previous seven days. Nine items scored on a five-point Likert scale were averaged to derive an overall physical activity score ranging from one to five (higher scores indicating higher levels of physical activity).

Confounders

Potential confounders identified in previous literature were included in the analyses. The mother's and father's education and socio-economic status (SES) was recorded in a questionnaire. Parents were asked about their highest level of education (both mother and father) and were categorized as primary, secondary, and university education. SES was measured using a scale based on Graffar's modified method,[20] taking into a count three categories according to school (High, Medium, and Low SES). These categories have been used in other recent studies with Chilean children.[10]

Data analysis

The continuous variables were expressed as the mean ± standard deviation and as frequency distribution for categorical data. Statistical normality was tested using the Kolmogorov−Smirnov test. Due to their skewed distribution, CRF and MS were log-transformed. To measure gender differences, one-way ANOVA was used. This study determined the influence of physical fitness parameters on academic attainment using multivariate linear regression analysis (enter procedure) adjusting for age, BMI, SES, PA, and paternal education (model 1), and also screen time in a second step (model 2) by gender. Finally, ANCOVA models were estimated to test differences in mean academic attainment (mean of the scores in mathematics and language) by CRF and MS quartiles and amount screen time (0, < 2 hours/day; 1, ≥ 2 hours/day), adjusting for variables included in model 1. For boys, mean values for CRF were: poor < 12.4 ml/kg/min (n = 68); satisfactory ≥ 12.4 - 27.6 ml/kg/min (n = 59); and good > 27.6 ml/kg/min (n = 72); for MS: poor < 154 cm (n = 49); satisfactory ≥ 154-182 cm (n = 98); and good > 182 cm (n = 52). For girls, mean values for CRF were: poor < 12.4 ml/kg/min (n = 30); satisfactory ≥ 12.4-22.5 ml/kg/min (n = 90); and good > 22.5 ml/kg/min (n = 76); for MS: poor < 121 cm (n = 46); satisfactory ≥ 121-155 cm (n = 98); and good > 155 cm (n = 52). Pairwise post-hoc comparisons were examined using the Bonferroni test. Finally, effect size was calculated using the estimated marginal means, and was categorized as small (0.20-0.50), moderate (0.51-0.80), or large (> 0.80).[21] The statistical analyses were conducted with SPSS version 22 (SPSS Inc., Chicago, IL, USA).

Table 1 Characteristics of the study sample.

	Total (n = 395)	Boys (n = 199)	Girls (n = 196)	p
Age, years	12.1 ± 0.7	12.2 ± 0.6	12.2 ± 0.7	
Body composition				
Height, m	1.56 ± 0.07	1.57 ± 0.08	1.56 ± 0.06	0.262
Weight, kg	55.3 ± 11.1	56.1 ± 12.0	54.4 ± 10.16	0.140
BMI, kg/m^2	22.6 ± 5.1	23.0 ± 5.5	22.2 ± 4.58	0.129
Waist circumference, cm	70.1 ± 8.0	70.2 ± 8.1	69.9 ± 7.92	0.668
Health-related physical fitness				
CRF: VO_2max, ml/kg/min	19.1 ± 9.8	20.4 ± 10.1	17.8 ± 9.3	0.008
MS: Standing broad jump, cm	154.3 ± 29.5	168.8 ± 27.3	139.5 ± 23.9	< 0.001
Academic achievement				
Language	5.0 ± 0.9	4.8 ± 0.9	5.2 ± 1.8	< 0.001
Mathematics	5.3 ± 2.6	5.3 ± 3.6	5.2 ± 0.8	0.606
Mean academic achievement[a]	5.3 ± 0.6	5.3 ± 0.7	5.2 ± 0.6	0.058
Self-reported sedentary behavior				
Screen time, h/day	2.7 ± 1.3	2.9 ± 1.4	2.4 ± 1.1	< 0.001
Exceeding recommended limits[b], n (%)	122 (30.9)	75 (37.7)	47 (24.0)	< 0.001
Self-reported physical activity				
PAQ-A	1.90 ± 0.3	1.96 ± 0.3	1.84 ± 0.3	0.006
Father's education				
Primary, n (%)	23 (5.9)	16 (8.0)	7 (3.6)	0.347
Middle, n (%)	304 (77.0)	152 (76.4)	152 (77.6)	
University, n (%)	68 (17.2)	31 (15.6)	37 (18.9)	
Mother's education				
Primary, n (%)	13 (3.3)	7 (3.5)	6 (3.1)	0.638
Middle, n (%)	324 (82.0)	157 (78.9)	167 (85.2)	
University, n (%)	58 (14.7)	35 (17.6)	23 (11.7)	
SES				
Low, n (%)	70 (17.7)	32 (16.1)	38 (19.4)	0.581
Middle, n (%)	267 (67.6)	143 (71.9)	124 (63.3)	
High, n (%)	58 (14.7)	24 (12.1)	34 (17.3)	

BMI, body mass index; CRF, cardiorespiratory fitness; MS, muscular strength; SES, socioeconomic status; PAQ-A, Physical Activity Questionnaire for Adolescents Spanish version.
Values are mean ± SD.
[a] Mean of the scores in mathematics and language (scale 1-7).
[b] ≥ 2 h/d of screen time.

Results

Table 1 presents descriptive characteristics of the study sample by gender. There were no differences in age, body composition variables, parental education, or SES. Overall, boys scored higher than girls in fitness tests, screen time, and PA. For their part, girls had higher values than boys in language and mean academic attainment.

Multiple regression models predicting academic attainment, using physical fitness levels as predictors, and controlling for age, gender, BMI, SES, PA, and parental education by gender are shown in Table 2. CRF was positively associated with language ($\beta = 0.272$, $R^2 = 0.156$; $\beta = 0.153$, $R^2 = 0.177$ in boys and girls, respectively) and mean academic attainment ($\beta = 0.192$, $R^2 = 0.125$; $\beta = 0.156$, $R^2 = 0.132$ in boys and girls, respectively) in model 1; however, after adjusting by screen time in model 2 these associations disappeared.

Table 3 shows mean differences in academic achievement by categories of CRF and MS according to amount screen time, adjusting for age, gender, BMI, SES, PA, and parental education. Academic attainment was higher in children with good CRF levels (ES = 1.25, p = 0.010; ES= 1.28, p = 0.015 in boys and girls, respectively) and low-medium screen time (< 2 hours/day) than in children with poor fitness. However, in children of both genders with high screen time (≥ 2 hours/day) this difference was not significant.

Discussion

The main findings of the present cross-sectional study were that CRF was related to academic attainment in both genders independent of potential confounders. However, these associations did not remain significant after adjusting for screen time. Results of this study suggest that screen time

Table 2 Associations of physical fitness with academic attainment in children by gender.

	Math			Language			Mean academic attainment		
	β (95% CI)	p	R^2	β (95% CI)	p	R^2	β (95% CI)	p	R^2
Boys									
Model 1									
CRF	0.102 (-1.559, 6.758)	0.219	0.056	0.272 (0.658, 2.365)	0.011	0.156	0.192 (0.021, 0.210)	0.016	0.125
MS	0.006 (-8.355, 9.947)	0.946	0.046	0.108 (-0.034, 3.408)	0.067	0.101	0.102 (-0.022, 0.276)	0.075	0.103
Model 2									
CRF	0.100 (-1.613, 6.734)	0.227	0.057	0.172 (-0.653, 2.367)	0.081	0.057	0.101 (-0.020, 0.210)	0.098	0.106
Muscular strength	0.005 (-8.429, 8.923)	0.955	0.048	0.100 (-0.244, 3.411)	0.099	0.093	0.061 (-0.123, 0.276)	0.453	0.094
Girls									
Model 1									
CRF	0.047 (-0.760, 1.370)	0.572	0.025	0.153 (0.048, 1.885)	0.022	0.177	0.156 (0.049, 0.251)	0.015	0.132
MS	0.103 (-0.687, 3.044)	0.214	0.033	0.170 (-0.118, 3.508)	0.066	0.083	0.150 (-0.008, 0.254)	0.095	0.071
Model 2									
CRF	0.059 (-0.703, 1.460)	0.490	0.026	0.151 (-0.070, 1.902)	0.078	0.076	0.048 (-0.099, 0.054)	0.563	0.051
MS	0.095 (-0.815, 2.985)	0.261	0.031	0.104 (-0.231, 3.591)	0.085	0.043	0.117 (-0.013, 0.254)	0.105	0.070

CRF, cardiorespiratory fitness; MS, muscular strength; CI, confidence interval.
Model 1, adjusted for age, body mass index, SES, PA, and parental education. Model 2, adjusted for the same covariates as Model 1 and screen time.

Table 3 Mean differences of academic attainment[a] and physical fitness according to screen time categories.

	Poor (P)	Satisfactory (S)	Good (G)	F	p	Effect size		
						P *vs.* S	S *vs.* G	P *vs.* G
Boys								
Low-medium screen time (< 2 h/w)								
CRF[b]	4.89 ± 0.77	5.02 ± 0.72	5.77 ± 0.64	3.172	0.014	0.18	1.08	**1.25**
MS[b]	5.02 ± 0.66	5.21 ± 0.74	5.45 ± 0.74	2.823	0.064	0.14	0.32	0.61
High screen time (≥ 2 h/w)								
CRF[b]	5.14 ± 1.03	4.84 ± 0.76	5.08 ± 0.98	0.686	0.508	0.35	0.28	0.02
MS[b]	5.13 ± 0.60	4.93 ± 0.86	5.17 ± 1.39	0.295	0.746	0.27	0.20	0.04
Girls								
Low-medium screen time (< 2 h/w)								
CRF[b]	4.88 ± 0.41	5.25 ± 0.49	5.38 ± 0.65	2.940	0.018	0.01	0.57	**1.28**
MS[b]	5.15 ± 0.72	5.28 ± 0.75	5.33 ± 0.76	1.018	0.365	0.18	0.07	0.24
High screen time (≥ 2 h/w)								
CRF[b]	5.18 ± 0.61	5.40 ± 0.68	5.35 ± 0.59	0.469	0.631	0.33	0.08	0.29
MS[b]	5.18 ± 0.69	5.24 ± 0.53	5.47 ± 0.60	0.702	0.504	0.11	0.41	0.45

CRF, cardiorespiratory fitness; MS, muscular strength.
Values are expressed as mean ± SD.
The effect size corresponding to mean pairs that showed statistical significance (p-values less than 0.05 for post hoc hypothesis two-sided testing with the Bonferroni correction for multiples comparisons are set in bold).
Analyses adjusted for age, body mass index, SES, PA, and parental education.
[a] Mean of the scores in Mathematics and Language (scale 1-7).
[b] Categories of CRF and muscle strength are category poor (P), satisfactory (S), and good (G), representing the first, second-third, and fourth quartiles, respectively.

may have a harmful influence on academic attainment in children, disfavoring the benefits of health-related physical fitness components. However, due to the method used to evaluate the academic performance, these findings should be interpreted with caution.

A growing body of evidence suggests that physical fitness may play a key role in academic attainment in youth.[8,9,22] In this sense, paralleling the findings of the present cross-sectional study, several studies have shown a positive relationship between CRF and academic attainment, in both genders[8,23] or in boys.[9] Therefore, CRF appears to improve cognition through increased levels of circulating factors that positively influence cognitive function and brain health.[22] Furthermore, the relationship between MS and academic attainment is less well documented, and previous research in this area has yielded equivocal results. Several studies have shown a relationship[12,23,24] or, in line with the present study, have not shown a relationship.[8,9] Discrepancies in these findings could be due to differences in evaluations, the tests used for this purpose (standing long-jump, handgrip test, curl-ups, etc.), and the potential confounders considered in the analyses.

The relationship between screen time and academic attainment is not completely known. Several studies have shown that screen time interferes with academic activities, and hence has adverse consequences on academic attainment.[3,25] In contrast, other studies have found a positive relationship[26,27] or reported no association.[28] The present results showed that screen time was inversely associated with academic attainment in both genders (data not shown). Furthermore, a recent large study in English youths[13] and a two year longitudinal study[14] showed a negative association between screen time and CRF independent of PA. Thus, CRF and academic attainment are associated with screen time. The present results suggest that the relationship between both is not independent of screen time. Therefore, it seems that this parameter should be taken into account as the confounding variable in this relation. The data could also support some potential cognitive benefits of current recommendations to limit daily screen time to < 2 hours.[3] These findings, among others, highlight the need for establishing programs focused on educating parents about recommended limits and the importance of consistent rules regarding screen time.[29] Thus, it may limit the so-called ''time displacement theory'',[30] encouraging greater participation in PA, or another activity such as reading, doing homework, or sleeping that provides positive benefits on learning and academic attainment.

In conclusion, academic attainment is associated with higher CRF levels, but it seems this relationship was somewhat impaired by screen time. The present findings, among others, highlight that screen time influences on children should be recognized by schools, policymakers, product advertisers, and entertainment producers, thus establishing strategies to minimize the negative effects.

Limitations

First, the present study is a cross–sectional design, which does not allow for drawing any conclusions on the causal direction of the associations. Second, using final academic grades to index academic attainment provided objective information, but makes it difficult to compare with standardized tests used by others authors. Similarly, using school-based grades given by teachers is subject to bias. Third, this study did not ask about the use of ''new media'' technologies (including cell phones, tablets, and social media), a dominant force in children's lives.[29] Fourth, other tests to determine muscular fitness are required (e.g., handgrip test).[9] Finally, data obtained on PA levels and screen time (self-reported questionnaire) may not provide an accurate overall representation of these important variables.

Conflicts of interest

The authors declare no conflicts of interest.

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