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A Physical Education trial improves adolescents' cognitive performance and academic achievement: the EDUFIT study

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To analyze the effects of an intervention focused on increasing the time and intensity of Physical Education (PE), on adolescents' cognitive performance and academic achievement. A 4-month group-randomized controlled trial was conducted in 67 adolescents from South-East Spain, 2007. Three classes were randomly allocated into control group (CG), experimental group 1 (EG1) and experimental group 2 (EG2). CG received usual PE (two sessions/week), EG1 received four PE sessions/week and EG2 received four PE sessions/week of high intensity. Cognitive performance (non-verbal and verbal ability, abstract reasoning, spatial ability, verbal reasoning and numerical ability) was assessed by the Spanish Overall and Factorial Intelligence Test, and academic achievement by school grades. All the cognitive performance variables, except verbal reasoning, increased more in EG2 than in CG (all $P < 0.05$). Average school grades (e.g., mathematics) increased more in EG2 than in CG. Overall, EG2 improved more than EG1, without differences between EG1 and CG. Increased PE can benefit cognitive performance and academic achievement. This study contributes to the current knowledge by suggesting that the intensity of PE sessions might play a role in the positive effect of physical activity on cognition and academic success. Future studies involving larger sample sizes should confirm or contrast these preliminary findings.

Results from available reviews and meta-analysis indicate a positive association of physical activity with cognitive performance and academic achievement in children and adolescents (Sibley & Etnier, 2003; Hillman et al., 2008; Tomporowski et al., 2008; Trudeau & Shephard, 2008; Fox et al., 2010; Rasberry et al., 2011). Neurocognitive benefits of an active lifestyle in children and adolescents have important public health and educational implications (Ruiz et al., 2010). A potential way of promoting physical activity is through Physical Education (PE) within the school curriculum. In addition to the positive effect of PE on physical health outcomes (e.g., cardiorespiratory fitness, body composition and lipid profile) (Ruiz & Ortega, 2009), PE pursues objectives, such as cognitive, social, and emotional domains. It has also been suggested that PE at schools may have a positive effect on academic achievement (Sallis et al., 1999; Carlson et al., 2008; Trudeau & Shephard, 2008; Rasberry et al., 2011). Schools provide a unique opportunity to influence children's and adolescents' health, since the children and adolescent population has to attend to schools by law. Nevertheless, schools face increasing challenges in allocating time for PE and physical activity during the school day. Many schools are attempting to increase instructional time for Mathematics, Language or Science subjects in an effort to improve standard-based test scores. As a result, PE sessions, recess, and others extracurricular physical activities often are decreased or eliminated during the school day (Wilkins et al., 2003). This is of special concern in the case of Spanish adolescents, as highlighted by a recent European Union report which observed that Spain devotes the lowest time to PE in Europe, together with Malta and Turkey, i.e., 24–35 hours/year compared with the 102–108 hours/year in France and Austria.

Several intervention studies examined the effect of increasing the amount of PE (frequency per week or length of the sessions) on students' academic and cognitive performance and found mixed results (Dwyer

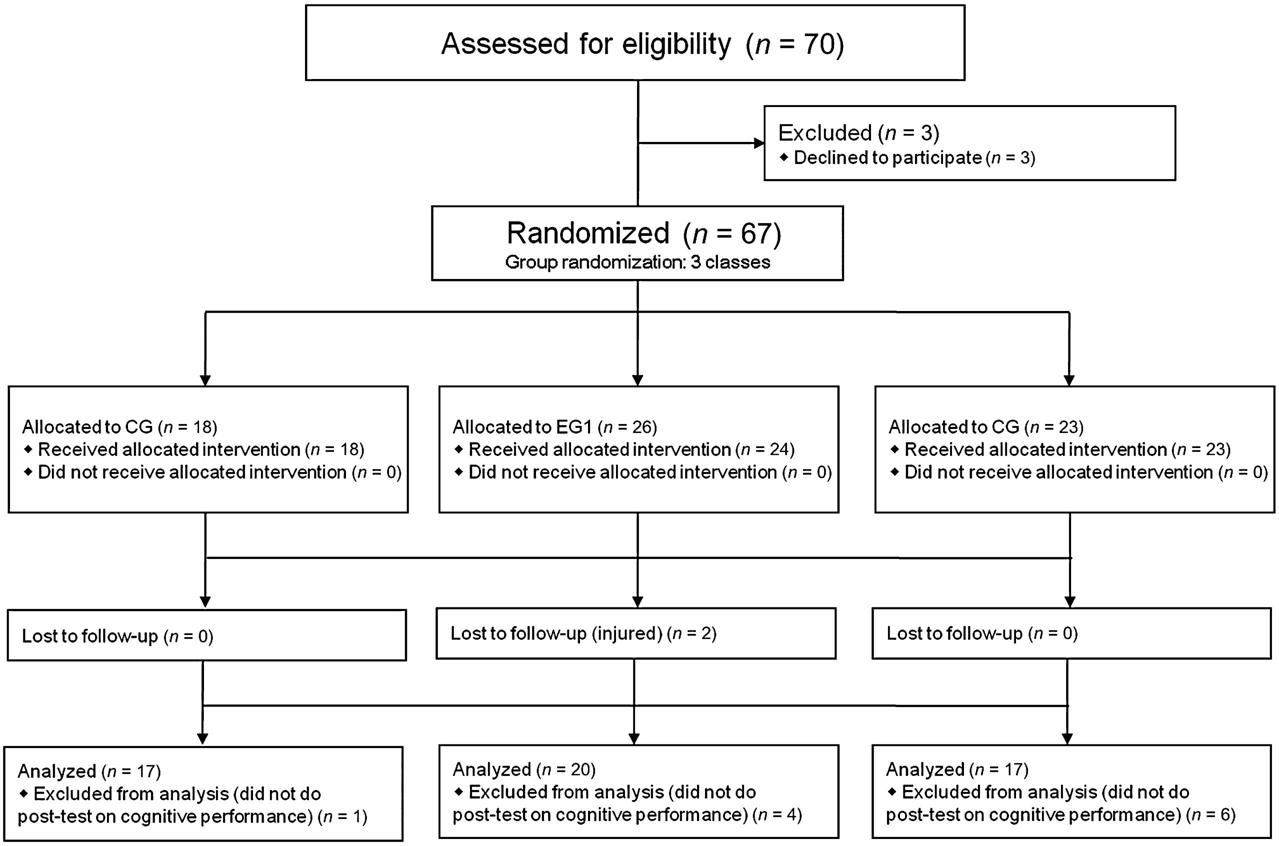

Fig. 1. Study flow.
This study was conducted in South-East Spain, 2007.
CG, Control group; EDUFIT, Education for Fitness; EG, Experimental group; ESO, Education Secondary Obligatory.

et al., 1983, 1996; Pollatschek & O'Hagan, 1989; Sallis et al., 1999; Ahamed et al., 2007; Ericsson, 2008; Ericsson & Karlsson, 2012). Davis and colleagues reported that an after school exercise program in overweight children improved (dose-response effect) their executive function, mathematical achievement and altered brain activation (Davis et al., 2011). However, the specific effect of increasing the intensity of the PE sessions on cognitive performance and academic achievement in young people is unknown.

In the present school-based intervention study conducted on adolescents, we examined the effects on adolescents' cognitive performance and academic achievement of: (1) increasing the number of PE sessions per week (volume); (2) increasing the number and the intensity of the PE sessions (volume + intensity); and (3) increasing intensity for a given number of PE sessions (intensity).

Methods

Trial design and participants

Participants were recruited from the EDUcation for FITness (EDUFIT) study. The complete methodology of the EDUFIT study has been described elsewhere (Ardoy et al., 2010). The EDUFIT study is a group-randomized controlled trial (clinicaltrial.org NCT01098968). Data collection took place from January to May 2007 in a high school from South-East Spain (Murcia). The intervention period lasted 4 months. A total of 67 adolescents (70 invited), 43 boys and 24 girls (12–14 years, Tanner II-V), belonging to three different school groups from the same high school agreed to participate in this study, i.e., participation rate = 96%. In the analyses, we used the maximum number of participants with valid data on the main study outcomes, i.e., 67 for academic achievement (school grades) and 55 for cognitive performance. The study flow is graphically represented in Fig. 1. The three natural school groups that were randomly allocated into control group (CG), experimental group 1 (EG1) or experimental group 2 (EG2). This is a group-randomized controlled trial, so that groups instead of individual were randomized. Randomization was blinded for those who performed the outcome assessment. Figure 2 shows the content and timetable of intervention.

A comprehensive verbal description of the nature and purpose of the study was given to the parents, school supervisors, and adolescents. Written consent to participate was requested from both parents and adolescents. No previous personal history of cardiovascular disease, no cognitive dysfunction, and be able to actively participate in PE classes were the study inclusion criteria; all the participants met these criteria. No incentives for participating in the study were offered to the children. The study protocol was performed in accordance with the ethical standards laid down in the 1961 Declaration of Helsinki (as revised in 2000), and approved by the Review Committee for Research Involving Human Subjects of the University of Granada (Spain).

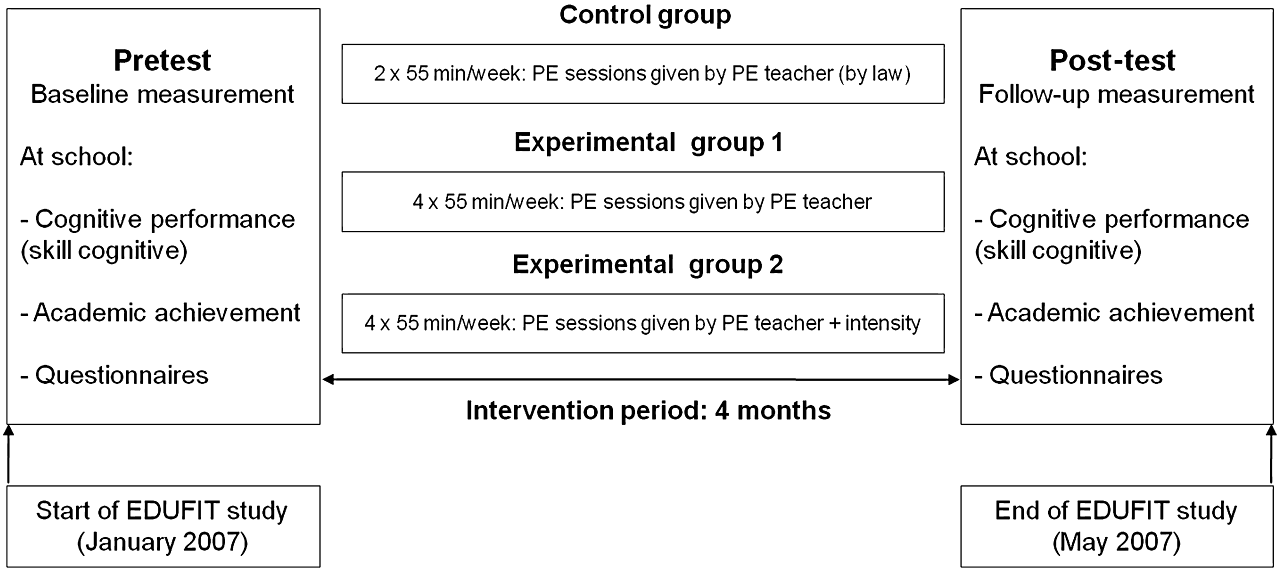

Fig. 2. Content and timetable of intervention.
This study was conducted in South-East Spain, 2007.
EDUFIT, Education for Fitness; PE, Physical Education.

Interventions

The intervention was implemented by PE teachers assigned by the school, who did not participate the pre-intervention or post-intervention assessment. Details of the intervention have been described elsewhere (Ardoy et al., 2010). A summarized scheme of the intervention is presented in Fig. 2. In short, adolescents in the CG received the usual PE sessions according to the National Education Program in Spain, i.e., 55 min sessions twice per week. This time includes the time for teachers to organize the session, and for the children to change clothes, have shower and come/go from/to the classrooms. Adolescents in the EG1 had four PE sessions per week, with the same aims, contents and pedagogical strategies than the sessions taken by the adolescents in the CG. Adolescents in the EG2 received four PE sessions per week of high intensity, i.e., activities involving a heart rate above 120 bpm were repeatedly implemented by increasing the intensity of warm-up routines, providing positive feedback and setting sport challenges. The PE sessions for the EG2 had the same aims and contents than CG and EG1. The time devoted to the rest of academic subjects was the same for the three groups, according to the Spanish Law of Education. A team of expert PE teachers helped to design the pedagogical strategies to increase session's intensity of EG2. Polar-610 heart rate monitors were used to measure the intensity of the sessions in randomly selected students ($n = 38$) from the three groups during 15 sessions, also randomly selected.

Outcomes

Cognitive performance

Cognitive performance was assessed by the M (medium) version of the Spanish Overall and Factorial Intelligence Test (IGF-M). The IGF-M questionnaire is an overall measured of cognitive performance, as well as some specific cognitive dimensions: non-verbal and verbal abilities, abstract reasoning, spatial ability, verbal reasoning and numerical ability. Each dimension ranged from 0 to 100, with higher scores indicating better performance. Overall cognitive performance was estimated as the average score computed from all cognitive variables studied. This questionnaire has shown to be reliable and valid for assessing cognitive performance in adolescents and is the most commonly used questionnaire in high schools in Spain (Yuste-Hernández, 2001).

Academic achievement

Academic achievement was assessed using the students' grades in the core subjects (Mathematics and Language) and others subjects (Natural Sciences, English, etc.). The grades were collected from the official school's records at two moments: first-trimester (December 2006, pre-intervention) and at the end of the academic year (June 2007, post-intervention). Numeric grade scores in Spain range from 1 (worst) to 10 (best). Usual assessment instruments, designed by specialists in school curriculum, teachers and academicians in each area were used. Teachers from each subject give an average score (academic grades) based on student's attitude, behavior, homework, skills and knowledge in the subject, as required by Spanish curriculum. The academic achievement used in this study were grades in Mathematics and Spanish Language (commonly considered core subjects), grades in other subjects (including Foreign Language-English, Social Sciences, Natural Sciences, Technology, Plastic-Visual Education and Music), average score from all subjects (includes core subjects, "other subjects" plus PE), and average score from all subjects excluding PE. We calculated the average score for all subjects including and excluding PE, to test how this decision could influence the results.

Other measurements

Physical fitness assessment

As previously described (Ardoy et al., 2010, 2011), we assessed cardiorespiratory fitness with the 20-m shuttle run test. Muscular fitness was assessed by the standing long jump test, and speed-agility as assessed by the 4×10-m shuttle run test. All the tests were performed twice, and the best score was retained, except the 20-m shuttle run test, which were performed only once. These tests are valid and reliable in young people (Ortega et al., 2008a; Castro-Pinero et al., 2010a, b; Artero et al., 2011). Detailed descriptions of the protocols used for fitness testing were previously published (Ardoy et al., 2011; Ortega et al., 2011).

Anthropometric measurements

Weight was measured in underwear or light clothes (e.g., swimming or certain sport clothes), and without shoes with an electronic scale (Type SECA 861) to the nearest 0.1 kg, and height was measured barefoot in the Frankfort horizontal plane with a telescopic height measuring instrument (Type SECA 225) to the nearest 0.1 cm. Body mass index was calculated as body weight in kg divided by the square of height in meters. Safety issues related the fitness and anthropometric measurements included in this study were discussed elsewhere (Espana-Romero et al., 2010).

Sexual maturation

It is well-known that adolescents with the same chronological age, might largely differ in maturation stage, which might be more influential on some of the study outcomes than chronological age (Ortega et al., 2008b). Different stages of pubertal development were assessed following the methodology described by Tanner and Whitehouse (1976) as was done in the national multicenter study AVENA (Alimentación y Valoración del Estado Nutricional de los Adolescentes; Food and Assessment of Nutritional Status in Adolescents) (Gonzalez-Gross et al., 2003). Five stages were recognized for each of the following characteristics: genital development and pubic hair in males, and breast development and pubic hair in females.

Field-work team

Anthropometric and fitness measurements were performed by experience research staff that had previously participated using the same protocols in large-scale population studies at a national [the AVENA project (Ortega et al., 2007)] and European [the HELENA project (Nagy et al., 2008; Ortega et al., 2011)] level. All of them were certificated by the International Society for the Advancement of Kinanthropometry.

Statistical methods

Data are presented as means and standard errors. Analyses were performed with the Predictive Analytics SoftWare (formerly SPSS) Statistics Command Syntax Reference software version 18.0 for Windows and the level of significance was set to 0.05.

The intervention effects on cognitive performance and academic achievement were studied by one-way analysis covariance (ANCOVA) including group as fixed factor; pre-post intervention difference (change) as the dependent variable; and sex, sexual maturation (Tanner), attendance and baseline values of the dependent variable studied as covariates. Pairwise comparisons were performed (post-hoc) with Bonferroni correction. Partial correlations between changes in fitness and changes in study outcomes were performed for all the participants together, after adjusting for sex, sexual maturation, attendance, and baseline values of the outcome studied (these variables were included into the partial correlation models as covariates).

Results

Characteristics of the study sample

Baseline characteristics of the adolescents studied are shown in Table 1. Adolescents from the CG were older than those from the EG1 and EG2 groups ($P = 0.001$), yet no differences were observed in sexual maturation ($P = 0.21$). Weight, height and body mass index were similar among the study groups. As previously reported (Ardoy et al., 2011), mean and maximum heart rate was significantly higher in the EG2 (mean = 147 and maximum = 193 bpm) compared with CG (mean = 116 and maximum = 174 bpm) and EG1 (mean = 129 and maximum = 177 bpm), confirming that PE sessions for the EG2 were more intense than for the other two groups (data not shown).

Effects of the intervention on cognitive performance and academic achievement

Tables 2 and 3 show the baseline, follow-up and change (post-pre) values for cognitive performance (Table 2) and academic achievement (Table 3) after adjustment for sex, sexual maturation and attendance. Most of the cognitive performance variables did not differ among the study groups at baseline, except for verbal ability and numerical ability that were marginally lower in the CG compared with the EG2 ($P = 0.04$ and $P = 0.03$, respectively). Consequently, all the models were further adjusted for baseline levels of the outcome studied, e.g., if the study outcome (entered as dependent variable in

Table 1. Baseline characteristics of the participants

	Participants ($n = 67$)		CG ($n = 18$)		EG1 ($n = 26$)		EG2 ($n = 23$)		P
Age, years	13.0	(0.1)	13.8	(0.1)	12.9	(0.1)	12.7	(0.1)	0.001
Tanner, %: Stages I/II/III/IV/V									0.21
I	0		0		0		0		
II	16.4		0		23.1		21.7		
III	23.9		33.3		19.2		21.7		
IV	47.8		44.4		53.8		43.5		
V	11.9		22.2		3.8		13.0		
Weight, kg	54.8	(1.7)	59.3	(3.7)	54.6	(3.1)	51.6	(1.9)	0.22
Height, cm	156.5	(0.9)	157.5	(1.4)	156.4	(1.6)	156.0	(1.5)	0.80
Body mass index, kg/m^2	22.3	(0.6)	23.8	(1.4)	22.2	(1.1)	21.1	(0.6)	0.24

This study was conducted in South-East Spain, 2007.

Data are means and (standard errors), unless otherwise stated. CG, control group (two lessons Physical Education/week); EG1, experimental group 1 (four lessons/week); EG2, experimental group 2 (four lesson/week + high intensity).

Analysis variance one factor (group). Differences in sexual maturation between groups were analyzed using Chi-square test.

Table 2. Effects of the intervention on cognitive performance

	n	Pre		n	Post		n	Difference (post-pre)*	
Non-verbal ability									
CG	18	48.9	(7.2)	17	38.1[a]	(7.5)	17	−10.7[a]	(5.4)
EG1	24	54.8	(8.2)	20	57.7[b]	(6.8)	20	−6.4[b]	(4.8)
EG2	23	55.8	(7.5)	18	82.4[a,b]	(6.7)	18	21.9[a,b]	(5.0)
F-value		0.206			9.652			12.342	
P (groups)		0.815			<0.001			<0.001	
Verbal ability									
CG	18	47.9[a]	(5.9)	17	42.9[a]	(5.6)	17	−12.0[a]	(5.5)
EG1	24	60.9	(4.8)	20	51.0[b]	(6.4)	20	−12.8[b]	(4.8)
EG2	23	68.1[a]	(5.5)	18	83.5[a,b]	(4.5)	18	18.8[a,b]	(5.1)
F-value		3.328			14.15			12.664	
P (groups)		0.042			<0.001			<0.001	
Abstract reasoning									
CG	18	46.9	(6.3)	17	36.1[a]	(8.6)	17	−12.0[a]	(6.1)
EG1	24	54.0	(7.7)	20	56.9	(6.9)	20	−6.2[b]	(5.4)
EG2	23	55.5	(7.4)	18	80.2[a]	(6.7)	18	20.7[a,b]	(5.5)
F-value		0.349			8.476			9.621	
P (groups)		0.706			0.001			<0.001	
Spatial ability									
CG	18	58.7	(7.7)	17	47.1[a]	(6.4)	17	−11.3[a]	(6.3)
EG1	24	61.0	(6.5)	20	57.0	(5.9)	20	−7.9	(5.6)
EG2	23	60.4	(6.6)	18	74.2[a]	(5.8)	18	10.6[a]	(5.8)
F-value		0.027			4.959			4.075	
P (groups)		0.973			0.011			0.023	
Verbal reasoning									
CG	18	56.6	(6.9)	17	54.8[a]	(6.0)	17	−5.8	(5.4)
EG1	24	67.7	(4.5)	20	53.4[b]	(6.0)	20	−17.2[a]	(4.7)
EG2	23	71.9	(4.3)	18	83.2[a,b]	(4.6)	18	12.7[a]	(4.8)
F-value		2.176			8.979			10.44	
P (groups)		0.122			<0.001			<0.001	
Numerical ability									
CG	18	45.8[a]	(5.9)	17	32.1[a]	(5.9)	17	−23.4[a]	(6.3)
EG1	24	61.7	(5.3)	20	50.2[b]	(6.6)	20	−13.7[b]	(5.5)
EG2	23	68.8[a]	(6.1)	18	74.5[a,b]	(6.0)	18	9.1[a,b]	(5.8)
F-value		3.801			11.058			7.585	
P (groups)		0.028			<0.001			0.001	
Overall cognitive performance†									
CG	18	47.4	(6.4)	17	39.4[a]	(6.3)	17	−11.8[a]	(4.6)
EG1	24	54.9	(6.8)	20	53.9[b]	(6.3)	20	−8.4[b]	(4.0)
EG2	23	62.7	(6.5)	18	84.9[a,b]	(4.5)	18	21.2[a,b]	(4.2)
F-value		1.234			15.422			18.105	
P (groups)		0.298			<0.001			<0.001	

This study was conducted in South-East Spain, 2007.

Data are adjusted means and (standard errors). Each category is expressed in the questionnaire score which ranges from 0 to 100. CG, control group (two lessons Physical Education/week); EG1, experimental group 1 (four lessons/week); EG2, experimental group 2 (four lessons/week + high intensity).

One-way analysis of covariance (dependent variable = post-pre differences, fixed factor = group). Pairwise comparisons were performed using Bonferroni adjustment of the confidence interval. Common superscripts ([a,b] in vertical direction) indicate significant differences between groups ($P < 0.05$).

* Descriptive values for the differences and *P*-values are adjusted by sex, sexual maturation, attendance and the corresponding baseline cognitive performance variable.

† This is an average score computed from all cognitive variables studied.

the ANCOVA model) was change (pre-post difference) in overall cognitive performance, then baseline overall cognitive performance was entered into the models as a covariate, together with the rest of potential confounders. All cognitive performance indicators improved significantly in the adolescents from the EG2, compared with those from the CG and EG1 (all $P \leq 0.001$, and verbal reasoning $P = 0.02$). We did not find any significant difference between CG and EG1 in the cognitive performance variables studied (Table 2). Cognitive performance indicators improved in most of adolescents belonging to EG2 (average = 75%). We tested the pre-post differences for EG1 and CG separately by using repeated measures ANCOVA (adjusting for the same set of confounders) and observed no significant differences in any of the cognitive performance indicators (all $P \geq 0.2$).

Baseline values for academic achievement were lower in the EG1, compared with the CG or the EG2 ($P \leq 0.01$); consequently, all the models were

Table 3. Effects of the intervention on academic achievement

	n	Pre		n	Post		n	Difference (post-pre)*	
Language									
CG	18	6.8[a]	(0.3)	18	6.3[a]	(0.3)	18	–0.3	(0.2)
EG1	26	4.3[a,b]	(0.4)	26	4.5[a,b]	(0.4)	26	0.1	(0.2)
EG2	23	5.9[b]	(0.4)	23	6.0[b]	(0.4)	23	0.2	(0.2)
F-value		10.626			5.67			1.273	
P (groups)		<0.001			0.005			0.287	
Mathematics									
CG	18	6.4[a]	(0.3)	18	6.1[a]	(0.3)	18	–0.5	(0.2)
EG1	26	4.6[a,b]	(0.4)	26	3.9[a,b]	(0.4)	26	–0.6[a]	(0.2)
EG2	23	6.3[b]	(0.5)	23	6.3[b]	(0.5)	23	0.0[a]	(0.2)
F-value		6.418			9.975			3.968	
P (groups)		0.003			<0.001			0.024	
Other subjects†									
CG	18	6.1[a]	(0.4)	18	6.1	(0.4)	18	–0.1[a]	(0.1)
EG1	26	4.9[a,b]	(0.3)	26	4.9[a]	(0.3)	26	0.0[b]	(0.1)
EG2	23	6.1[b]	(0.3)	23	6.7[a]	(0.3)	23	0.6[a,b]	(0.1)
F-value		4.578			7.041			8.368	
P (groups)		0.014			0.002			0.001	
Average of all subjects‡									
CG	18	6.0	(0.2)	18	6.1	(0.1)	18	0.0[a]	(0.1)
EG1	26	5.0[a]	(0.3)	26	5.2[a]	(0.4)	26	0.3[b]	(0.1)
EG2	23	6.2[a]	(0.4)	23	6.9[a]	(0.4)	23	0.7[a,b]	(0.1)
F-value		4.670			6.479			8.435	
P (groups)		0.013			0.003			0.001	
Average of all subjects excluding Physical Education									
CG	18	6.1	(0.2)	18	6.0	(0.1)	18	–0.2[a]	(0.1)
EG1	26	5.0[a]	(0.3)	26	4.9[a]	(0.4)	26	–0.1[b]	(0.1)
EG2	23	6.2[a]	(0.4)	23	6.6[a]	(0.4)	23	0.5[a,b]	(0.1)
F-value		4.576			6.802			8.175	
P (groups)		0.014			0.002			0.001	

This study was conducted in South-East Spain, 2007.

Data are adjusted means and (standard errors). Each category refers to the school grades which range from 0 to 10. CG, control group (two lessons Physical Education/week); EG1, experimental group 1 (four lessons/week); EG2, experimental group 2 (four lessons/week + high intensity).

One-way analysis of covariance (dependent variable = post-pre differences, fixed factor = group). Pairwise comparisons were performed using Bonferroni adjustment of the confidence interval. Common superscripts ([a,b] in vertical direction) indicate significant differences between groups ($P < 0.05$).

* Descriptive values for the differences and *P*-values are adjusted by sex, sexual maturation, attendance and the corresponding baseline academic achievement variable.

† Includes Foreign Language (English), Social Sciences, Natural Sciences, Technology, Plastic-Visual Education and Music.

‡ Includes "other subjects" plus Language, Mathematics, Physical Education.

additionally adjusted for baseline levels of the outcome studied. Adolescents from the EG2 had an improved average academic achievement (a score including all the subjects) compared with the CG and the EG1 ($P < 0.001$). The exclusion of PE from this score did not alter the results ($P < 0.001$). The differences were significant for Mathematics ($P = 0.02$) and other subjects ($P = 0.001$), including Technology ($P < 0.001$), Natural Sciences ($P < 0.001$), and as expected, PE ($P < 0.001$). Academic achievement indicators improved in most of adolescents belonging to EG2 (average for all school subjects = 96% and = 78% when excluding PE).

Additional analyses

Partial correlation analysis in full sample (data not shown), adjusted for sex, sexual maturation, attendance and baseline values of the study outcome, showed that improvements in speed-agility were correlated with improvements in cognitive performance, i.e., overall cognitive performance ($r = –0.28$, $P = 0.04$; lower values in the speed-agility test mean higher performance) and non-verbal ability ($r = –0.30$, $P = 0.03$). Likewise, improvements in cardiorespiratory fitness were correlated with improvements in overall cognitive performance ($r = 0.37$, $P = 0.009$), non-verbal ability ($r = 0.33$, $P = 0.02$) and abstract reasoning ($r = 0.34$, $P = 0.02$). No associations were observed between changes in fitness and changes in academic achievement. Overall, the results did not differ when age was used in the models instead of sexual maturation status. No unintended effect was identified as a result of the intervention.

Discussion

The results of the present study suggest that increasing the number and intensity of PE sessions per week has a positive effect on both cognitive performance and academic achievement. Comparisons between the CG and the EG1 suggest that to double the number of PE sessions per week is not enough stimuli for improving cognitive or academic performance. Nevertheless, these results should be taken as preliminary due to the small sample size and consequent small statistical power. On the other hand, the comparison between the CG and the EG2 supports that increasing the "dose" of PE in terms of both volume and intensity has a clear and significant effect on cognitive performance and academic achievement. In addition, comparison between the EG1 and EG2 suggest a specific role for high intensity exercise in cognition.

Several PE-based intervention studies have explored the effect of physical activity on cognitive performance or academic achievement. Sallis et al. (1999) studied the effects of a 2-year health-related school PE program on standardized academic achievement scores (project SPARK). The program consisted of two intervention groups (based on who implemented the PE sessions, trained teachers vs specialists) receiving 27–44 min additional PE per week, compared to the CG. The primary finding was that spending more time in PE did not have harmful effects on standardized academic achievement test scores in elementary school children. In addition, there was some evidence that a 2-year health-related PE program had several significant favorable effects on academic achievements. Similarly, findings were observed by Ahamed et al. (2007), concluding that despite dedicating approximately 10 additional minutes of daily school physical activity (intervention group vs CG), children's academic performance was not compromised. Ericsson (2008) observed that increasing the frequency of PE per week (i.e., from 2 days per week to daily) had a positive effect on academic achievement. This study also reported a positive effect on attention. Dwyer et al. (1996) found no differences in academic achievement across the study groups. It is important to note that the children belonging to the intervention group had less classroom time, to compensate the increase in PE time. This fact not only did not have any negative effect on academic achievement, but had a positive effect on classroom behavior in the students belonging to the experimental group vs CG. Similarly, Pollatschek and O'Hagan (1989) did not observe any negative effect on academic achievement when comparing the intervention group (daily PE) vs CG (usual PE).

Our study findings are in agreement with the previous literature. We observed no significant differences between usual PE (CG) and doubling the number of PE sessions/week (EG1). However, large positive effects were observed on both cognitive performance indicators and academic achievement (school grades), when the amount plus intensity of PE was increased (EG2), suggesting a specific role for the intensity of PE. A cross-sectional study reported that the time spent in vigorous physical activity, but not moderate physical activity, was related to better academic performance (Coe et al., 2006). Accordingly, we have also observed in Swedish girls that vigorous physical activity (objectively measured), but not moderate physical activity, was positively associated with school grades (Kwak et al., 2009). To the best of our knowledge, no previous intervention study has explored the effect of increasing the intensity of the PE sessions on cognitive performance or academic achievement, which is a major contribution of the present study to the existing literature.

Plausible underlying mechanisms

There is increasing evidence supporting that beneficial effects of exercise on brain are mediated by the brain derived neurotrophic factor (BDNF) (Noakes & Spedding, 2012). The BDNF acts on certain neurons of the central nervous system and the peripheral nervous system, helping to support the survival of existing neurons and encourage the growth and differentiation of new neurons and synapses. The BDNF has shown to acts together with another important protein, the epidermal growth factor, activating neuronal m-calpain which plays a significant role in synaptic plasticity, cell motility, and neurodegeneration. Moreover, Rasberry et al. (2011) reported that regular physical activity seems to have a positive impact on academic performance through a variety of direct and indirect physiological, cognitive, emotional, and learning mechanisms. Current research on brain development indicates that cognitive development occurs in tandem with motor ability (Smith et al., 1999). Cognitive and motor skills appear to develop through a dynamic interaction. Research has shown that physical movement can affect the brain's physiology by increasing cerebral capillary growth, blood flow, oxygenation, production of neurotrophins, growth of nerve cells in the hippocampus (center of learning and memory), neurotransmitter levels, development of nerve connections, density of neural network, brain tissue volume, changes in hormone levels, and greater arousal (Rosenbaum et al., 2001; Sibley & Etnier, 2003; Hillman et al., 2005, 2009; Chaddock et al., 2010, 2011; Reed et al., 2010). It has been suggested that increases in physical activity and fitness, might also be associated with improved attention; improved information processing, storage, and retrieval; enhanced coping; and modulation of cognitive control processes to meet task demands (Shephard, 1996; Ericsson, 2008; Hillman et al., 2008, 2009; Pontifex et al., 2011). Hence, regular physical activity can improve cognitive function and increase levels of substances in the brain responsible for maintaining the health of neurons. Brain function may also indirectly benefit from physical activity due to increased energy expenditure as well as from time outside of the classroom/away from studying. The increased energy expenditure and time outside of the classroom may give relief from boredom resulting in higher attention levels during classroom instruction (Lindner, 1999).

Chaddock et al. (2010, 2011) found that in children a high cardiorespiratory fitness was associated with greater bilateral hippocampal volumes estimated by magnetic resonance. We have previously reported that our intervention had a positive effect on cardiorespiratory fitness and speed-agility (Ardoy et al., 2011). We have previously reported that higher cardiorespiratory fitness is associated with a better academic achievement (Kwak et al., 2009), in line with results from other studies (Castelli et al., 2007; Chomitz et al., 2009). Consequently, we tested the hypothesis that the participants in this trial that have improved more their fitness levels could have also improved more their cognitive performance and may be their academic achievement. Our results support an association between changes in fitness and changes in cognitive performance, but not between changes in fitness and changes in academic achievement.

Strengths and limitations

The main limitation of this study was its small sample size and consequent small statistical power. Our results are therefore preliminary and should be confirmed in future studies. As most of school-based intervention studies, we randomized groups instead of individuals what in addition to the small sample size used in our study increase the risk that the study groups are not identical at baseline. This was the case in our study and some baseline differences in cognitive performance and academic achievement were observed among groups. Nevertheless, we controlled all the analyzed for baseline values of the outcome being studied, which mathematically balanced possible baseline differences, reducing the error inherent to group-randomized controlled trials. Another limitation was the lack of information about classroom behaviors. It has been shown that increased physical activity during the school day may induce arousal and reduce boredom, which can lead to increased attention span and concentration (Shephard, 1996; Ericsson, 2008).

An important strength of the present study was that data were collected on measures of both cognitive performance and academic achievement. Likewise, an important contribution of EDUFIT to previous studies is the specific and combined analysis of volume and intensity with effects on cognitive performance and academic achievement in three different groups.

Public health implications

There are a number of policy implications stemming from this study. First, there is substantial evidence that physical activity can help improve academic achievement (including school grades). Second, the findings of the present study, together with those from previous literature, suggest that physical activity in school setting can have an impact on cognitive skills, attitudes and academic behavior, all of which are important components of improved academic performance. Third, increasing time dedicated to PE may help, and does not appear to adversely impact, academic performance, and can improve fitness and reduce other cardiovascular risk factor.

Perspectives

Our results support previous literature, indicating that increasing the number of PE sessions do not compromise cognitive performance and academic achievement, and contribute to the current knowledge by suggesting that the intensity of PE sessions might play a role in the positive effect of physical activity on cognition and academic success. Future studies involving larger sample sizes should confirm or contrast these preliminary findings. These data together with those from previous studies suggest that increasing the time devoted to PE on the school curriculum can lead to physical and mental health benefits in youth.

Key words: adolescent, school, intervention, fitness, physical activity, physical education, health, cognitive, academic achievement.

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