Acute effect of different classes of Physical Education on memory in children school-age

Abstract

Aim. The purpose of this study was to evaluate the effectiveness of an aerobics games vs. team game class on the memory in elementary school-aged children during the school day. **Method.** The data were collected from primary school in southern Spain. A total of 236 children aged 6 to 12 years participated in this study (age 9.84±1.16 years old, age range = 8-12 years old). The students were randomly assigned to the two experimental groups (EGs): team game group, n=79, aerobic exercise group, n=79 and control group (CG) n= 78. The Rey Auditory Verbal Learning test to analyse memory was employed. **Results**. In the pretest, there were no significant differences in any memory variables. In post-test conditions, the EGs displayed higher scores than the CG in deferred memory and recognition. As for group x time interaction (within-group), the EGs showed significant improvements in all memory variables except in learning curve. However, the CG only improve trial 1and displayed a worsening in learning curve. **Conclusion.** The findings suggest that acute aerobic exercise and team games exercises enhances student' memory, which could be important for academic achievement.

Key words: memory, elementary school, physical education, acute effects.

Introduction

The importance of physical activity (PA) for health is well known and research has noted both physical and psychological benefits when children participate in physical activities (Ahn & Fedewa, 2011; Janssen & Leblanc, 2010). In recent years, there has been a growing interest due to the benefits of physical activities for academic and cognitive performances and executive functions (EFs) (Ellemberg & St-Louis-Deschênes, 2010; Gallotta et al., 2014; Janssen et al., 2014; Soga, Shishido, & Nagatomi, 2015). In this regard, both acute and chronic exercise may facilitate EFs (Best, 2010).

This relationship between physical activity and cognition take place in the cerebellum and prefrontal cortex (Diamond, 2000) since there is a causal relationship between physical fitness and the vitality of the brain (Tomporowski, Davis, Miller, & Naglieri, 2008). Children who are fit exhibit greater cortical activation and correspondingly better cognitive performance than less fit children (Tomporowski et al., 2008). Previous studies have showed a relationship between physical fitness and cognitive performance (Latorre Román, García Pinillos, Pantoja Vallejo, & Berrios Aguayo, 2017; Latorre-Román, Mora-López, & García-Pinillos, 2016)

The preadolescent stage is a period in which children develop many of their physical and cognitive skills therefore, an suitable stimulation of them lead to an excellent physical and cognitive potential (Buck, Hillman, & Castelli, 2008). In this sense, physical fitness may benefit cognition during early periods of the lifespan, characterized by development and neural organization (Charles H Hillman, Buck, Themanson, Pontifex, & Castelli, 2009a).

Some research studies have analyzed the chronic and acute effect of the physical exercise on cognition (Jäger et al., 2015; Ma, Le Mare and Gurd, 2015; Mullender-Wijnsma et al., 2015;

Erwin, Fedewa and Ahn, 2012). The acute effect produces transient changes in arousal level and in cognitive processes that are responsible for mental resource allocation (Pesce, Crova, Cereatti, Casella, & Bellucci, 2009). Accordingly, PA has an acute effect on different executive functions in primary school children (Jäger et al., 2015; Gallotta et al., 2015). Moreover, previous studies showed how different physical education (PE) classes have an acute effect on cognitive variables (updating, inhibition, shifting, attention, memory) and academic performance. Schmidt, Jäger, Egger, Roebers and Conzelmann (2015) observed how children who performed a physical games class, an aerobic exercises classes, or a cognitive games class improved significantly their academic achievement in comparison with children in the control group who did not do physical classes. Ou, Wegner, Niemann and Budde (2016) examine the influence of different types of exercise exertion on primary school children's working memory. Working memory performance of the 9-10 years old children benefited from both the cardiovascular and the motor exercise programs, but not from the control group. The increase in working memory performance was significantly larger for children in the motor exercise compared with the cardiovascular exercise or control group. Howie, Schatz, & Pate (2015) showed that a 10-min and 20-min classroom exercise break moderately improves math performance in students compared with a seated classroom lesson. Other authors analysed the combination of different intensities of acute exercise in an environment of a physical education class, in relation to adolescents' cognitive function, yours results showed that the intensity is related to improvement in inhibitory control, in this regard, vigorous intensity seems to be better to increase cognition (Peruyero, Zapata, Pastor, & Cervelló, 2017).

The relationship between memory and physical exercise has been poor studied. Memory is a cognitive ability used in various daily functions. Memory can be training in order to obtain better result in its functioning (Holmes, Gathercole, & Dunning, 2009; Melby-Lervåg & Hulme, 2013). It exists much way to trainer memory, being one of them the physical exercise. Therefore, a physical interventional programme could improve the memory capacity (Fisher et al., 2011). Physical activity training increase the hippocampal perfusion enhancing this way the memory working (Erickson et al., 2011). In additions, it is relevant in the study of memory to mention that some investigations have shown that children who have a better physical fitness have higher level of memory (Syväoja, Tammelin, Ahonen, Kankaanpää and Kantomaa, 2014; van der Niet et al., 2015). However, it exist different types of memory and different ways to activate it.

Moreover, the type of exercise that affects cognitive performance is poor understood. In this regard, the repetitive aerobic exercises, likely require less cognitive engagement, particularly of EF, since there is little need to guide cognition to accomplish a challenging goal or coordinate the body to execute complex movements (Best, 2010). These differences in EF demands may lead complex exercise, to have a stronger effect on EF than simpler exercise. Taking into consideration all aforementioned information, the purpose of this study was to evaluate the effectiveness of an aerobics games vs. team game class on the memory in elementary school-aged children during the school day. The authors hypothesize that memory capacity might be influenced by physical exercises and might already be visible after acute bouts of exercise, additionally; we hypothesize that complex exercise such as team games could to have a greater effects on memory capacity than aerobic exercise.

Method

Participants

A total of 236 children participated in this study (age 9.83±1.197 years old, age range = 8-12 years old). Demographic characteristics revealed that 116 children were male and 120 were female, and they were selected from a primary school in southern Spain. Inclusion criteria considered schooling in primary school and being free from physical and/or intellectual disabilities. The students were randomly assigned to the two experimental group: team game group (TGG), n=79, aerobic exercise group (AEG), n=79 and control group (CG) n= 78. Randomization was conducted independently by a research assistant who was not involved in the data collection, using the random numbers generated in Microsoft Excel 2010. Parents voluntarily signed an informed consent form for the participation of their children in this study. The study was completed in accordance with the norms of the Declaration of Helsinki (2013 version) and the study was approved by the Ethics Committee of the University of Jaen (Spain).

Material and testing

Memory

Memory was measured by The Rey Auditory Verbal Learning test (RAVLT) (Rey, 1964) dealing with its different revised editions (Schmidt, 1996; Spreen & Strauss, 1998). A Spanish validated version called *Prueba de Aprendizaje Auditiva-Verbal de Rey* was used (Ladera, 1992). . Uchiyama et al., (1995) revealed that RAVLT has a moderate but significant test–retest reliability. Research on the factor structure of the RAVLT is supportive of its validity as a measure of verbal learning, and scores correlate significantly with those for the

California Verbal Learning Test (Crossen & Wiens, 1994). Excellent normative data is available in Baron (2004) in relation to children population.

The RAVLT test evaluates short-term and long-term auditory-verbal memory, rate of learning and interference. Regarding the procedure of the test, firstly verbal learning is carried out through the reading of a list of 15 unrelated words (list A). A free memory is required from the child after each reading of the 15 words repeating 5 times the same procedure. Once the 5 trials are done, the learning curve that is the result of the difference between trial 5 and trial 1 is analyzed. Then a new list (list B) of other 15 words (list of interference) is read and asked for the free memory of the same. The list A is then re-read, which allows the impact of the interference to be evaluated. After 30 minutes again, List A is read to analyze the long-term memory. Finally, the items in the list are recognized with a list of words from list A and B that must be recognized.

Physical performance

For the assessment of perceived exertion (RPE) after the completion of the aerobic games session the Borg Scale (Borg, 1982) was used for scoring items from 0 to 10 (low intensity to high intensity).

Procedure

After obtaining the appropriate permits from the school and informed parental consents, we proceeded to the application of the questionnaires. In two separate sessions, a team of previously trained researchers performed the evaluation. The RAVLT test was assessed during the first testing session; the children´s answers were individually marked. The requirements for passing the test were explained to the students.

A week later, the participants were newly assessed. Twenty minutes after the end of the PE class, the RAVLT test was performed in the classroom by EGs, in accordance with prior research (Hillman et al., 2009), while the CG did not take part in a PE class on that school day and remained sitting in the classroom working on other school subjects (e.g. mathematics and language). The intensity of the aerobic games was monitored through the RPE. In this study, TGG performed aerobic games such as those employed by Pesce et al. (2009) were used (team games, small-sided games), which require cooperation with other children, strategic behaviour, coordination and adaptation to continually changing task demands. These aerobic games also require skilled and complex movement, which directly relies on the prefrontal neural circuitry supporting EFs; however, repetitive aerobic exercises, which were performed by AEG such as running (chase games) probably requires less cognitive engagement (Best, 2010). Each child was individually assessed. The children were encouraged to reach the best score possible in every test.

Statistical analysis

The data were analysed using the statistical program SPSS v.19.0 for Windows (SPSS Inc, Chicago, USA) and the significance level was set at $p \leq 0.05$. Descriptive statistics are represented as mean and standard deviation (*SD*). Tests of normal distribution and homogeneity (Kolmogorov-Smirnov and Levene's, respectively) were conducted on all data before analysis. Moreover, a 2x2 analysis of variance (ANOVA) with repeated measures (group x measurement) was conducted for the dependent variables. Additionally, effect sizes for group differences were expressed as Cohen's *d* (Cohen, 1988); effect sizes of less than 0.4 represented a small difference, whereas effect sizes of 0.41–0.7 and greater than 0.7 represented moderate and large differences, respectively (Thomas, Silverman, & Nelson, 2015). An ANOVA and chi-squared test were used to compare demographic variables between groups.

Results

No significant differences were found between the EGs and CG, either in age (TGG = 9.84±1.17 y, AEG =9.77 ± 1.15 y and CG=9.92 ± 1.19 y, p = 0.721), sex distribution (% girls, TGG =54.4%, AEG=53.2 % and CG = 44.9%, p = 0.430), parents' socio-economic status (% medium level , TGG = 91.1%, AEG=97.5 and CG = 89.7%, p = 0.374) or parents' academic level (% university studies, TGG = 34.2 %, AEG=38.0 and. CG = 38.5%, p = 0.192). Significant differences in RPE between EGs were find, AEG showed greater RPE than TGG (6.94 ± 2.18 vs. 4.24 ± 2.07, p <0.001).

Table 1 shows performance in the RAVLT test for both the EGs and the CG in both conditions (pretest/post-test). In the pretest, there were no significant differences in any memory variables. In post-test conditions, the EGs displayed higher scores than the CG in deferred memory and recognition. As for group x time interaction (within-group), the EGs showed significant improvements in all memory variables except in learning curve. However, the CG only improve trial 1and displayed a worsening in learning curve.

Insert table 1

Discussion

The purpose of this study was to evaluate the effectiveness of an aerobics games vs. team game class on the memory in elementary school-aged children during the school day. The main finding was that memory might be influenced by PE classes and might already be visible after acute bouts of physical exercise both with team game and aerobic exercise. In addition, there were no significant differences between EGs (with different intensities of PA) in RAVLT scores after PE classes. Therefore, the findings of the current study are according to the previous research, which suggested that vigorous-intensity exercise improves cognitive function (Peruyero et al., 2017).

In a similar study, Pesce, Crova, Cereatti, Casella and Bellucci (2009) investigated the effects of physical exercise on memory performance in children through two sessions directly followed physical education lessons (aerobic circuit training or team games) characterized by similar exercise intensities, but different cognitive and social interaction demands. Your results suggest that an acute bout of submaximal exercise, not only by exercise-induced increases in physiological arousal, but also by the cognitive activation induced by cognitive exercise demands may facilitate memory storage.

Other studies have shown that acute exercise improves certain aspects of cognitive processing. Hillman, Buck, Themanson, Pontifex, & Castelli (2009) showed that single bouts of moderately intense aerobic exercise (i.e. walking) may improve the cognitive control of attention in preadolescent children. Moreover, Pontifex et al. (2013) demonstrated greater performance in the areas of reading and arithmetic following a single 20-minute bout of exercise in children between the ages of 8 and 10.

However, in contrast to our results, previous research findings have been contradictory and inconsistent.(Benzing & Schmidt, 2017) showed that acute physical activity with high cognitive engagement could be more efficient than physical activity of the same intensity with low cognitive engagement for the improvement of EFs. In addition, (van den Berg et al., 2016) indicated that exercising at low to moderate intensity does not have an effect on the cognitive parameters tested in young adolescents, moreover, there were no differential effects of exercise type (12-min classroom-based with aerobic, coordination, and strength exercises).

The basis for the results found in the current study is the fact that physical exercise produces not only general but also specific physiological changes in the brain, besides causing an immediate neurochemical response that may enhance cognitive performance (Best, 2010). Moreover, exercise has been shown to positively affect cognitive performance, due to the neuronal connection between the cerebellum and the frontal cortex (Budde, Voelcker-Rehage, Pietraßyk-Kendziorra, Ribeiro, & Tidow, 2008) and an exercise-induced increase in cerebral blood flow (Querido & Sheel, 2007)

Additionally, Colzato et al., (2013) indicate that the nature and the consequences of this link depend on the particular task and the individual physical fitness. In this regard,the type of physical activity, intensity and activity length may have influence on the acute effect of a physical activity bout on attention (Janssen et al., 2014; Gallotta et al., 2015a). As well, an important aspect to consider is the timing of the cognitive testing. In the current study, cognitive tests were conducted a week before and 20 minutes after the exercise session. In this line, Cooper, Bandelow, Nute, Morris, & Nevill, (2013) found significant differences in cognitive function between the 10 min post exercise and resting trials, however, after 10 min post exercise, there was no significant changes.

Therefore, the available information about the impact of PA on cognitive processes is highly controversial and that is why more research is needed. Different forms of physical activity need to be compared to test whether these have important effects on cognitive performance. More experimental studies with a comparable methodology, especially in the school setting, are needed to strengthen this evidence (Janssen et al., 2014). Although, in accordance with Schmidt, Jäger, Egger, Roebers and Conzelmann (2015), overall, the current results showed that there seems to be some evidence to indicate that for the improvement of cognitive performance through PE or PA during a school day, it is important taking into account not only the PA intensity, but also high-quality PA which integrates games and activities requiring cognitive engagement.

Conversely, the CG did not improve in any memory variables; indeed, the CG displayed a worsening in trial 1 and learning curve. One possible explanation for this might be that long sedentary periods in school affect the cognitive processes such as memory. In this regard, Mahar et al. (2006) indicate that long periods of instructional time without a break might be counterproductive in terms of academic performance. Some previous papers (Jarrett & Maxwell, 1998; Pellegrini, Huberty, & Jones, 1995) pointed out that elementary school-aged children who undergo prolonged periods of academic instruction often become more fidgety or restless and experience reduced concentration and attention.

This current study had some limitations that will motivate future work. One limitation of this study was its repeated study design which only showed the acute effect of different PE classes. Longitudinal randomised controlled trials are necessary to provide adequate evidence of causality between, PA and cognitive process. Moreover, in this study, the previous physical fitness levels of the participants not were registered and because the previous fitness level may influence executive control during low- and moderate-intensity exercise (Wang, Chu, Chu, Chan, & Chang, 2013). However, the strength of this study was that this was a field-study carried out in a school context, away from laboratories where, to date, most of studies had been performed (Hillman et al., 2009; Pontifex et al., 2013).

The pre-pubertal period offers many opportunities to stimulate cognitive function. However, the relationship between participation in PA and cognitive performance has been a subject of discussion between advocates and sceptics of physical activity, as well as parents concerned about decreases in study and homework time. Additionally, opportunities to be physically active at school are limited because of pressure to perform well academically (Mahar et al., 2006). However, participation in physical activity is not associated with less time dedicated to study (Ruiz et al., 2010). An additional curricular emphasis on PE may result in significant gains in cognitive performance. In this regard, the literature suggests that academic achievement, physical fitness and health of children will not be improved by limiting the time allocated to PE and physical activity (Trudeau & Shephard, 2008) In conclusion, the findings suggest that acute aerobic exercise and team games exercises enhances student' memory, which could be important for academic achievement.

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Tabla 1

Results of memory variables (pretest-post-test) in experimental groups and control group

		Pretest Mean (SD)	Postest Mean (SD)	P-value (group x time)	Cohen's d
Trial 1	EG 1	5.84 (1.62)	6.76 (1.79)	<0.001	-0,542
	EG 2	5.89 (1.50)	6.66 (2.03)	0.001	-0,434
	CG	5.49 (1.96)	6.59 (2.15)	<0.001	-0,538
p-value (time x group)		0.284	0.867		
Trial 5	EG 1	12.94 (1.75)	14.11 (1.23)a	<0.001	-0,778
	EG 2	12.25 (2.36)	13.68 (1.70)ab	<0.001	-0,699
	CG	12.86 (2.94)	13.06 (2.51)b	0.431	-0,073
p-value (time x group)		0.149	0.003		
trials summation	EG 1	48.01 (8.46)	53.58 (7.99)a	<0.001	-0,681
	EG 2	47.85 (9.57)	51.91 (8.76)ab	<0.001	-0,445
	CG	49.77 (9.79)	48.81 (10.18)b	0.053	0,096
p-value (time x group)		0.359	0.004		
learning curve	EG 1	7.09 (2.00)	7.25 (1.70)a	0.669	-0,086
	EG 2	6.37 (2.84)	6.99 (1.99)a,b	0.108	-0,254
	CG	7.38 (3.31)	6.38 (2.77)b	0.010	0,329
p-value (time x group)		0.063	0.043		
deferred memory	EG 1	12.19 (2.35)	13.28 (1.53)a	<0.001	-0,553
	EG 2	11.30 (2.57)	12.94 (1.76)a	<0.001	-0,749
	CG	12.10 (3.50)	12.15 (2.21)b	0.516	-0,017
p-value (time x group)		0.102	0.001		
recognition	EG 1	11.80 (1.77)	12.97 (1.26)a	<0.001	-0,766
	EG 2	11.70 (1.84)	12.70 (1.34)a	<0.001	-0,625
	CG	12.21 (1.36)	11.90 (1.44)b	0.082	0,222
p-value (time x group)		0.133	<0.001		
interference	EG 1	1.43 (1.45)	0.73 (0.91)	0.001	0,581
	EG 2	1.48 (1.72)	0.72 (0.90)	<0.001	0,557
	CG	1.26 (1.75)	1.03 (1.55)	0.282	0,140
p-value (time x group)		0.671	0.182		

Nota: Experimental group (EG); Control group (CG)