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EFFICACY OF A SCHOOL-BASED PHYSICAL ACTIVITY PROGRAM WITH COGNITIVE INVOLVEMENT ON LEARNING ABILITY: A PILOT STUDY ON THE PREVENTION OF ACADEMIC FAILURE AMONG INCOMING FIRST-YEAR HIGH SCHOOL STUDENTS

EFFICACIA DI UN PROGRAMMA DI ATTIVITÀ FISICA CON COINVOLGIMENTO COGNITIVO SULLA CAPACITÀ DI APPRENDIMENTO: UNO STUDIO PILOTA SULLA PREVENZIONE DEL FALLIMENTO SCOLASTICO TRA GLI STUDENTI DEL PRIMO ANNO DI SCUOLA SECONDARIA DI SECONDO GRADO

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Abstract

This study aims to investigate the efficacy of a 16-week physical activity program with cognitive involvement (CIPA) on students' academic performance and physical fitness. 88 students (14±.33yrs) were randomly assigned to an experimental group (EG, n=44) who received 15 more minutes of CPA (with cognitive involvement) in addition to physical education (PE) classes, or a control group (CG, n=44) who received regular PE lessons.
Students' physical fitness were assessed through a battery of motor tests (20mSRT, Push-up, Curl-up, Sit and reach). Cognitive performance and academic achievement were assessed by the Amos 8-15. After the intervention, the EG showed a greater capacity to organize their study and to be more flexible, an anxiety-reduction, and an improvement in motivation, concentration and learning ability ($p<0.001$). The CG did not report significant changes. This study suggests that a CIPA program might be effective on cognition and academic success, as well as for improving students' physical fitness.

Scopo del presente studio era quello di verificare l'efficacia di un programma di attività fisica con coinvolgimento cognitivo (AFCC) di 16 settimane sul rendimento scolastico e sulla forma fisica degli studenti. 88 studenti (14±0,33 anni) sono stati assegnati in modo casuale a un gruppo sperimentale (GS, n=44) che ha ricevuto 15 minuti in più di CPA (con coinvolgimento cognitivo) oltre alle normali lezioni di educazione fisica (EF) o un gruppo di controllo (GC, n=44) che ha invece svolto regolari lezioni di educazione fisica.

Contributions: Author 1. Introduction, paragraphs 1 and 3. Author 2. collected data and wrote paragraph 2. Author 3. carried out statistical analysis and wrote paragraph 2. Author 4. Coordinated the study and revised the manuscript.

La forma fisica degli studenti è stata valutata attraverso una batteria di test motori (20mSRT, Push-up, Curl-up, Sit and reach). Il rendimento cognitivo e il rendimento scolastico sono stati valutati dalla

batteria di test Amos 8-15. Dopo l'intervento, il GS ha mostrato una maggiore capacità di organizzare lo studio e di essere più flessibile rispetto ai compiti da svolgere, una riduzione dell'ansia e un miglioramento della motivazione, della concentrazione e delle capacità di apprendimento ($p<0,001$). Il GC non ha riportato cambiamenti significativi. Questo studio suggerisce che un programma AFCC potrebbe essere un mezzo efficace di miglioramento delle funzioni cognitive e del rendimento scolastico, nonché per migliorare la forma fisica degli studenti.

Key words:

Academic performance, school-based physical activity, learning outcomes.

Prestazione scolastica, attività fisica, risultati di apprendimento.

Introduction

It is now widely accepted that Physical Activity (PA) is closely related with healthy children development, as well as it is essential to achieve good academic outcome and appropriate classroom behaviors (Donnelly, 2016; Latino, Cataldi, & Fischetti, 2021). As a confirmation of this, in the last decade a growing interest has emerged in investigating the contingent influence of physical activity on cognitive function, reporting a positive association between them (Sibley & Etnier, 2003; Hillman et al., 2008; Tomporowski, 2003; Trudeau & Shephard, 2010).

Over the past few years, a substantial line of research has been focused on the study of relationship between physical activity, cognitive functions, and academic performance among children and adolescents. Most studies investigated these relationships considering the quantitative aspects of the PA (i.e., intensity and duration), without pay any real attention to the qualitative aspects (cognitive involvement) (Beck, et a., 2016). However, several authors suggest that physical activity with cognitively engaging tasks is the one that better than any other form of exercise affects cognitive functions, as well as academic performance (Pesce, Masci, Marchetti, Vazou, Sääkslahti, & Tomporowski, 2016). Specifically, cognitively demanding physical activity, namely all those activities which adhere to a qualitative approach and manipulate the exercise in terms of mental effort, implicating complex coordination processes and rapid decision-making response, is associated to objective measures of cognitive functions and academic performance. Tomporowsky and Pesce (2020) suggest that this plausibly happens because qualitative physical activity which intentionally include problem-solving demands and lead to the acquisition of declarative and procedural knowledge, as well as immediate response strategies, could lead to the long-term development of the ability to exert control over the thought and actions.

Nevertheless, little work has explored how a physical activity program with cognitive involvement (CIPA) may promote school readiness among schoolers. Therefore, based on the assumption that high-quality education strategies play a key role in preparing adolescent to achieve their academic attainment, this study aims to investigate the efficacy of a 16-week physical activity program with cognitive involvement on students' academic performance. The purpose was to explore the changes in student’s physical fitness and learning outcomes relating to motivational/strategical profile as aspects of their school readiness. Hence, based on an in-depth analysis of the previous evidence of the positive effects of integrated physical activity with cognitive involvement, it was hypothesized that adolescents who carried out the experimental intervention would have outperformed the control group, reporting a significant effect on cognition and academic success, as well as an improved physical fitness.

1. Method

1.1 Study design

To investigate the effects of a 16-week CIPA program on student's learning outcome a randomized controlled study design was employed.
88 students attending the first class of a high-school placed in a municipality of southern Italy were randomly assigned to an experimental group (n = 44) who were given an intervention known as Action Class! This model adds 15 more minutes of physical activity with cognitive involvement within the physical education (PE) lesson (60 min., twice a week), or a control group (n = 44) who received non-specific regular physical education lessons with activities mainly focused on simple physical training (60 min., twice a week). Both the interventions were performed 2 days per week. Measurements were administered 1 week before training (pre-test) and directly after training (post-test).

1.2 Participants

The subjects of this study were 88 high-school students (14±.33yrs), from 4 classes of the same high-school. Participation was on voluntary basis and all first-class students were eligible to participate in this study. To respond to the study needs, the following inclusion criteria were identified: students attending the chosen high-school, relatively healthy, capable of completing an exercise session, and able to abstain from other physical activities otherwise the study. A priori power analyses revealed that an n = 27 in each group was sufficient to power the study, detect a medium effect size (f= 0.25 or 0.4) given a coefficient of correlation p=0.80 with 95% power and the .05 level of significance (α error). However, a larger sample were recruited to account for possible drop-out.

At the end of the identification of the sample, 90 subjects were invited to participate in the study, but 2 declined to participate due to personal reasons. Thus, the final sample involved 88 participants. Specifically, the EG (n = 44) was composed of 22 males and 22 females, and the CG (n = 44) involved 23 males and 21 females. All parents' students provided written informed consents and they were informed that their children could withdraw the intervention at any time. The researchers performed the study in compliance with the Declaration of Helsinki and all data were collected anonymously.

1.3 Procedures

The intervention program was performed in the school gym during the regular PE classes. Participants completed each test (motor and cognitive tests) individually, before and after the intervention period. The intent was to determine participant's starting level and to detect if any changes occurred compared to baseline. Moreover, they performed the tests at the same time of the day and under the same experimental conditions to avoid any possible affect which may alter the truthfulness of the data. Both the intervention programs were instructed, supervised and performed by the same experienced Physical Education teacher, certified by Italian Ministry of Education. Participants was instructed to avoid ingested stimulating food or soft drink before motor tests, but otherwise maintained their normal food intake. In addition, they were invited to wear suitable sportswear to limit possible variability within the testing procedure and were instructed to avoid excessive physical exertion 24 hours before each testing session. Each task of the tests was explained and demonstrated to participants, and verbal encouragement was given to them in order to support their actions.

1.4 Measures

Motor tests

Students' physical fitness, at baseline and after intervention, were measured through a battery of standardized assessment motor tests (20m shuttle run Test, Push-up test, Curl-up test, Sit and reach). To estimate aerobic fitness was used the 20-m shuttle run test (Léger, Mercier, Gadoury, & Lambert, 1988) which foresaw a gradually increase with 1-minute intervals until maximal voluntary exhaustion. the number of laps run provided the score of the test. Each participant performed three trials. Curl-up test (Knudson, 2001) and push-up test (Jackson, Fromme, Plitt, & Mercer, 1994) was used to determined Muscular fitness for the abdominal and upper-body muscle strength, respectively. The score was determined by the maximal number of repetitions for the first test, and the number of push-ups performed during 1-min in the second case. Each participant performed three trials for both tests. Lastly, sit and reach test (Castro-Piñero, et al., 2009) allowed to evaluate the flexibility of the lower back and hamstring muscles. It required the collection of three measure, and the score was the average reached by the three distances. Each participant performed three trials. All tests were standardized according to gender and age group.

Amos 8-15 Questionnaire

Students' study skills and motivational aspects were assessed by the Study approach questionnaire (QAS) and Objective study test, two subtests of the Amos 8-15 (Cornoldi, De Beni, Zamperlin, & Meneghetti, 2005). It is a test battery designed for the Italian cultural context that includes the following subtests: (i) Study approach questionnaire (QAS); (ii) Study strategies questionnaire (QS1 e QS2); (iii) Convictions questionnaire (QC1I, QC2F, QC3O) and attributions questionnaire (QCA); (iv) Objective study tests. The operator can choose to use all of them, some specific or just one. In this study, Authors decided to use the Study approach questionnaire (QAS), and the Objective study tests.

Study Approach Questionnaire (QAS)

It assesses the different components of the student's study approach and consists of 49 items divided into 7 areas: (i) Motivation; (ii) Organization; (iii) Didactic material development; (iv) Study flexibility; (v) Concentration; (vi) Anxiety; (vii) Attitude towards school. The response scale involves 3 points "Likert-type", ranging from 1 (disagree) to 3 (strongly agree), and the score is calculated for each area separately. Testing time was between 15 and 20 minutes, including the instruction and practice phase.

Objective Study Tests

It allows to check the student's ability to understand and memorize. This test requires student to learn a text for 30 minutes. At the end of the study phase, they carry out 3 different tests: (i) Choice of titles: it measures the student's ability to identify the most important events, by choosing from an 8-title list the 3 most meaningful. The score provided 1 point for each valid title; (ii) Open questions: the student is asked to answer 6 open questions about the text studied. The score provided from 1 to 3 points to assess the accuracy of the response; (iii) True/False questions: the student is asked to answer true or false to 12 questions, in order to evaluate the student's ability to understand and remember specific information. The score provided 1 point for each correct answer, 0 points for the answer not given, and -1 for each incorrect answer. The sum of the scores obtained for each test determines the overall final score. Testing time was between 75 and 90 minutes, including the instruction and practice phase.

Training intervention

The intervention program proposed to the EG consisted of different series of complex motor movements in which rapid decision-making response and problem-solving strategies were the core of the training. Thus, the exercises involved various coordinative abilities such us the ability to maintain balance, react to stimuli, adjust and to differentiate movements.

The activities proposed were organized in different types of circuit designed to ensure the stimulation of motor skills through the combination of running, obstacle courses, visual-spatial coordination, hopping and jumping, throwing and catching, and the use of unstable playground equipment. These activities were varied at each session in order to avoid boredom in students. To the control group were offered an equal amount of simple, and easy-to-perform activity program during the regular PE classes. Each session started with 10 minutes of full-body dynamic warm-up, followed by 45 minutes of core training, and ended with cool-down exercises, for both groups. A model of CPA circuit is illustrated in Table 1.

Phase	Activities	Duration
CPA training	- Walking in Balance on the beam - Jumping down - Running into hoops - Facing the stakes with sides slipping - Jumping hurdles - Running with high knee raises - Passing the cones with changes of direction - Facing the mini hurdles with elongated steps - Running and control a soccer-ball with the foot - Throwing a handball alternating with the left and right hand - Hitting with the head the ball launched by the teacher	**15'**

Table 1 - A model of CPA circuit.

Statistical analysis

Statistical analyses were carried out using IBM SPSS Statistics, version 26.0 (2019 SPSS Inc., IBM Company). Data were presented as group mean (*M*) values and standard deviations (*SD*) and checked for assumptions of normality (i.e. Shapiro-Wilk test) and homogeneity of variances (i.e. Levene test) in the data distributions. An independent sample *t*-test was used to evaluate group differences at baseline and a two-way ANOVA (group (experimental/control) × time (pre/post-intervention), with repeated measures on the time dimension, was conducted to examine the effect of the Multilateral Training on all dependent variables. When 'Group x Time' interactions reached significance, group-specific post hoc tests (i.e., paired *t*-tests) were conducted to identify the significant comparisons. Partial eta squared (η^2_p) was used to estimate the magnitude of the significant 'Time x Group' interaction and interpreted using the following criteria: small ($\eta^2_p < 0.06$), medium ($0.06 \leq \eta^2_p < 0.14$), large ($\eta^2_p \geq 0.14$). Effect sizes for the pairwise comparisons were determined by Cohen's *d* and interpreted as small ($0.20 \leq d < 0.50$), moderate ($0.50 \leq d < 0.79$) and large ($d \geq 0.80$) (Cohen, 1992). Statistical significance was set at $p < 0.05$.

2. Results

Both the experimental and control groups received the treatment conditions as allocated and their average adherence (attendance) to intervention sessions was 99,00 % (31.6 of 32 actual sessions). Furthermore, they did not differ significantly at baseline in age,

anthropometric characteristics, as well as in scholastic level ($p > 0.05$). Descriptive statistics for the whole sample are provided in Table 2.

Table 1 - Changes in physical fitness and study skills after 16-week of intervention.

	Experimental Group (n = 44)			Control Group (n = 44)		
	Baseline	**Post-test**	**Δ**	**Baseline**	**Post-test**	**Δ**
Motor Tests						
20m Shuttle run test	6.43 (1.51)	8.29 (1.97)†*	1.86 (1.73)	6.63 (1.51)	5.27 (1.63)	- 1.36 (0.86)
Push-up test	8.22 (2.25)	12 (3.27)†*	3.77 (1.87)	8.22 (2.25)	6.79 (2.23)	-1.43 (1.46)
Sit and reach test	18.77 (2.32)	20.79 (2.81)†*	2.02 (0.82)	18.77 (2.32)	17.38 (2.87)	-1.38 (1.67)
Curl-up test	28.90 (2.32)	31.27 (2.59)†*	2.36 (0.61)	28.90 (2.32)	27.22 (2.10)	-1.68 (0.85)
Amos 8-15 - QAS						
Motivation	13.88 (2.22)	15.72 (2.52) †*	1.84 (1.27)	13.88 (2.22)	12.70 (2.08)	-1.18 (1.04)
Organisation	15.00 (2.02)	16.88 (2.03) †*	1.88 (1.46)	14.68 (2.51)	13.40 (2.13)	-1.27 (0.89)
Didactic material development	15.40 (1.51)	15.13 (1.69)	-0.27 (0.72)	14.52 (1.56)	13.56 (1.46)	-0.95 (1.05)
Study flexibility	15.75 (2.00)	17.29 (2.14) †*	1.54 (0.84)	15.61 (1.67)	14.04 (1.89)	-1.56 (0.92)
Concentration	17.11 (2.10)	18.47 (1.87) †*	1.36 (0.94)	17.04 (2.18)	15.45 (2.29)	-1.59 (1.18)
Anxiety	17.06 (1.77)	14.97 (1.75) †*	-2.09 (1.25)	15.61 (2.39)	16.68 (2.20)	1.06 (1.14)
Attitude towards school	15.90 (2.54)	15.84 (2.60)	-0.06 (0.58)	16.59 (1.90)	15.11 (2.10)	-1.47 (0.73)
Amos 8-15 - Objective Study	19.06 (3.00)	22.97 (3.89)†*	3.90 (2.72)	18.79 (3.02)	16.79 (3.13)	-2.00 (0.91)

Note: values are presented as mean (± SD); Δ: pre- to post-training changes; †Significant 'Group x Time' interaction: significant effect of the intervention ($p< 0.001$). *Significantly different from pre-test ($p< 0.001$).

Motor Tests

A two-factor repeated measures ANOVA found significant 'Time x Group' interaction for the all four Motor tests performed: 20m Multistage Fitness Test ($F_{1,86} = 122.12$, $p< 0.001$, $\eta^2_p = 0.58$, large effect size), Push-up test ($F_{1,86} = 209.58$, $p< 0.001$, $\eta^2_p = 0.70$, large effect size), Curl-up test ($F_{1,86} = 648.76$, $p< 0.001$, $\eta^2_p = 0.88$, large effect size) and Sit and Reach test ($F_{1,86} = 147.17$, $p< 0.001$, $\eta^2_p = 0.63$, large effect size). Post hoc analysis revealed that experimental group made significant increase from pre- to post-test in 20m Multistage Fitness Test ($t = 7.13$, $p< 0.001$, $d = 1.07$ large effect size), Push-up test ($t = 13.32$, $p< 0.001$, $d = 2.00$, large effect size), Curl-up test ($t = 25.55$, $p< 0.001$, $d = 3.85$, large effect size), and Sit and Reach test ($t = 16.34$, $p< 0.001$, $d = 2.46$, large effect size)test scores. No significant changes were found for the control group ($p > 0.05$).

Study approach questionnaire QAS

A significant 'Time x Group' interaction was also found for Motivation ($F_{1,86} = 148.47$, $p< 0.001$, $\eta^2_p = 0.63$, large effect size), Organization ($F_{1,86} = 148.49$, $p< 0.001$, $\eta^2_p = 0.63$, large effect size), Study flexibility ($F_{1,86} = 270.91$, $p< 0.001$, $\eta^2_p = 0.75$, large effect size), Concentration ($F_{1,86} = 167.13$, $p< 0.001$, $\eta^2_p = 0.66$, large effect size), and Anxiety ($F_{1,86} = 151.74$, $p< 0.001$, $\eta^2_p = 0.63$, large effect size). The post hoc analysis revealed that experimental group made significant increase from pre- to post-test in Motivation ($t = 9.57$, $p<0.001$, $d = 1.44$, large effect size), Organization ($t = 8.53$, $p< 0.001$, $d = 1.28$, large effect size), Study flexibility ($t = 12.09$, $p< 0.001$, $d = 1.82$, large effect size), and Concentration ($t = 9.59$, $p< 0.001$, $d = 1.44$, large effect size). In the same way, experimental group showed a significant decrease in Anxiety score ($t = -11.05$, $p< 0.001$, $d = 1.66$, large effect size). After 8 weeks of intervention program, there were no significant "Time x Group" interactions in

Didactic material development and Attitude towards school ($p > 0.05$). No significant changes were found for the control group ($p > 0.05$).

Objective Study Tests

A two factor repeated measure ANOVA found significant "Time x Group" interaction effects for Objective Study Tests ($F_{1,86} = 182.68$, $p < 0.001$, $\eta^2_p = 0.68$, large effect size). The post hoc analysis revealed that experimental group made significant increase in the score for Objective Study Tests ($t = 9.42$, $p < 0.001$, $d = 1.42$, large effect size) in the intervention group after 8 weeks, whereas no significant changes were found for the control group ($p > 0.05$).

3. Discussion

This research aimed to investigate the effectiveness of a CIPA program on students' physical fitness and learning outcomes relating to motivational/strategical profile as aspects of their school readiness.

Results showed that performing a CIPA program integrated into the curriculum, had a positive effect on academic performance among first-year high school students. Specifically, this research has found improvements on six of the eight considered variables, namely motivation, concentration, anxiety, capacity to organize the study and to be more flexible.

Regarding positive effect on learning motivation, it was consistent with previous studies that document a positive relationship between physical activity, learning motivation and attention to the subject matter (Hillman et al., 2009; Buddle et al., 2008, Latino, Fischetti, Cataldi, monacis, & Colella, 2021). Indeed, has been shown that students who experience significant experiences arising from physical activity with cognitively engaging tasks are able to maintain a successful motivation toward learning. Several research evidence suggests the existence of positive a relationship between students' high-qualitative physical activity experience and intrinsic learning (Pesce, 2012).

The CIPA program was also able to enhance concentration and anxiety. This supports the idea that physical activity with cognitively engaging tasks may reduce anxiety and boredom and, at the same time, can lead to an increased attention span and concentration, which would improve classroom behavior as well as academic performance. Different studies have shown a very strong correlation between sedentary lifestyle and the development of anxiety. Several researchers have provided some evidence that physically active adolescent have lower levels of anxiety than sedentary people (Kandola, et. Al, 2018). Physical activity may improve mental health by helping the brain cope better with stress. In a 2014 study, Wang et al. found that those who got regular vigorous exercise were 25% less likely to develop an anxiety disorder over the next five years.

Moreover, was observed from students an increase in the capacity to organize the study and to be more flexible, probably since CIPA program was able to induce greater problem solving and decision-making capabilities. Problem-solving ability involves the higher-level cognitive processes needed to cope appropriately with various problems experienced in life. Cognitively demanding physical activity, namely all those activities which adhere to a qualitative approach which intentionally include problem-solving demands and lead to the acquisition of declarative and procedural knowledge, as well as immediate response strategies, would seem to have a favorable influence on these variables (Tomporowski, & Pesce, 2021).

Lastly, the most significant finding of the present study was the evidence of the CIPA program to improve learning ability. We believe that it was a consequence of the improvement of concentration and attention span (Hillman, Erickson, & Kramer, 2008; Pontifex, Saliba, Raine, Picchietti, & Hillman, 2013), reduction of anxiety, greater motivation, higher capacity

to organize the study and reduced off-task behaviors. Indeed, it was widely acknowledged that they are all factors that physical activity is able to mediates because it allows the allocation of neural resources underlying physical performance (Vazou, & Smiley-Oyen, 2014).

However, the CIPA program has not been able to improve Didactic material development and Attitude towards school variables. The lack of influence of the CIPA program on these domains may be due to the fact that they are mostly affected by social and cultural factors, personal habits and study methods which gradually have been consolidated over time (Khan, 2016).

Although the significant relationship between CIPA program and learning abilities, some limitations were present within this study. First was related to the small sample size (n=88). It was since students were unable to abstain from other physical activity outside the intervention protocol. The second limitation was that students attended the same school. Therefore, the results may not be generalizable to adolescent at other institutions or with other demographics. Lastly, we did not evaluate the long-term effects of CIPA on cognitive skills, and the impact of other variables that might also affect learning performance, such as interest, socio-economic status, and IQ. To the other hand, the strengths of this study were represented by the potential contribution that physical activity with cognitive involvement may bring to academic performance, and as well as physical and cognitive health among students.

Conclusion

This study contributes to the current knowledge by suggesting that a physical activity with cognitively engaging tasks might play a crucial role in the positive effect on cognition and academic success, as well as for improving students' physical fitness. This approach may be an effective strategy to intervene in a conscious, targeted and timely way on development and enhancement of the cognitive abilities in order to prevent academic failure while fostering a virtuous circle which would lead to achieve better academic outcomes.

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