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Original Article

Multilateral methods in Physical Education improve physical capacity and motor skills performance of the youth

FISCHETTI FRANCESCO, GIANPIERO GRECO
Department of Basic Medical Sciences, Neuroscience and Sense Organs, School of Medicine, University of Bari, ITALY

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Abstract:
Physical education may help young people make informed lifestyle choices, develop proficiency in movement skills, and encourage lifelong participation in physical activity. There is ample evidence that participating in moderate-to-vigorous physical activity can lead to a variety of benefits for children and adolescents. Unfortunately, their physical activity levels are currently insufficient to promote these benefits. Thus, this randomized controlled study investigated the effects of extracurricular multilateral training (MT) lasting for 12 weeks compared to a standard training (ST) program performed at school on physical capacity and motor skills in adolescents. 20 healthy volunteers between 13 and 14 years of age (11 boys and 9 girls, age 13.6 ± 0.5 years) were randomly assigned to an experimental group (EG, n = 10) or control group (CG, n = 10). At weeks 1 and 12, the times to run a 505 change of direction speed (CODS) test (505 COD time plus the first 10 m (speed, agility)) and 300 m test (anaerobic capacity) were assessed. Thereafter, the EG underwent MT (90 min, 2 times a week) plus ST, while the CG underwent only ST. Significant main effects of Time (pre vs. post) were observed for 505 COD time (-8.37% vs. 1.81%, $f = 0.27$). Significant Time x Group interactions were detected in favor of the EG for 505 COD time (-8.37%, $f = 0.50$), 10 m speed test (-6.51%, $f = 0.43$) and 300 m run test (-3.50%, $f = 0.29$). Our findings suggest that the extracurricular MT protocol was effective in improving physical capacity and motor skills competence after a period of 12 weeks. Thus, inclusion of an extracurricular physical activity performed using a multilateral approach might be more beneficial than having only standard programs at school.
Key Words: physical education; physical activity; adolescents; educational methods.

Introduction

Physical education is considered important for many reasons; it may help young people make informed lifestyle choices, develop proficiency in movement skills, and encourage lifelong participation in physical activity (Bailey, 2006; Kirk, 2005; Morgan, Kingston, & Sproule, 2005). The priority for physical education is seen as providing opportunities for students to engage in enjoyable physical activity, to become physically fit, and to learn generalizable motor and behavioral skills (McKenzie et al., 2003). Competence in the different motor skills is positively associated with increased physical activity engagement (Livonen et al., 2013; Lubans, Morgan, Cliff, Barnett, & Okely, 2010), and it appears that improved performance in motor skills among children is positively correlated with participation in organized sport (Van Beurden, Zask, Barnett, & Dietrich, 2002). In fact, research shows a positive relationship between physical activity and motor development (Fisher et al., 2005) and fitness (Barnett, Van Beurden, Morgan, Brooks, & Beard, 2009a; Lubans et al., 2010; Stodden, Langendorfer, Roberton, & Kelbley, 2007).

There is ample evidence that participating in moderate-to-vigorous physical activity can lead to a variety of benefits for children and adolescents. Compared with their inactive counterparts, youth who are sufficiently active enjoy better physical health (Catuzzo et al., 2016; Lubans et al., 2010), report more positive physical self-concept and global self-esteem (Dishman et al., 2006), perceive a better quality of life (Shoup, Gattshall, Dandamudi, & Estabrooks, 2008), and achieve higher academic results (Singh, Uijtdewilligen, Twisk, van Mechelen, & Chinapaw, 2012). Unfortunately, the physical activity levels of many children and adolescents are currently insufficient to promote these benefits (Hardy, King, Espinel, Cosgrove, & Bauman, 2010; Sallis, 2000), and low levels of activity seem to persist into adulthood (Telama et al., 2005). Moreover, several studies have shown that insufficient physical activity is an important risk factor for obesity (Brock et al., 2009; Lau et al., 2007). In response to this evidence, the importance of schools in physical activity promotion has been highlighted (Cox, Schofield, & Kolt, 2010; Pate et al., 2006; Sallis et al., 2012; Salmon, Booth, Phongsavan, Murphy, & Timperio, 2007; Van Sluijs, McMinn, & Griffin, 2007), and the central role of physical education programs in this effort has been emphasized.

However, Italian schools institute only 2 hours per week of physical education, which is not sufficient to promote the development of motor skills in youth and to develop competence in a range of fundamental and

Corresponding Author GIANPIERO GRECO, E-mail: gianpiero.greco@uniba.it

specialized movement skills that are necessary for participation in various games and sports (Lubans et al., 2010). Several factors can influence motor skill performance, such as the time spent in practice, intensity of exercise, quality of instructions and learning method, and it is difficult to identify specific intervention components that may contribute to success (Rietmuller, Jones, & Okely, 2009). Therefore, it becomes very important to recommend extracurricular physical activities (Crouter, Salas, & Wiecha 2016; Li et al. 2014), under the guidance of an expert physical education teacher (Hattie, 2003). To this end, we recommend a multilateral training (MT) program that aims to develop basic motor skills and motor qualities such as strength, speed, endurance, agility and flexibility. This multilateral approach respects the physiologic age and psychological maturation of youth and is a means to improve fitness and conditioning (Bompa, 1999).

Despite numerous publications on physical activity in students, there are few studies available that have assessed objectively, and with a rigorous design, extracurricular physical activity interventions (Mears & Jago, 2016). Consequently, we focused our research on filling the gaps identified in the literature, such as the lack of studies of adolescents and interventions performed outside of the school setting (Van Sluijs et al., 2007). Thus, the purpose of this study was to investigate the effects of an extracurricular MT program lasting 12 weeks compared to the standard training (ST) program at school as required by the ministerial program, on physical capacity and motor skills in adolescents. We hypothesized that participants who underwent extracurricular MT compared to only ST would show larger improvements in physical capacity performance tests.

Material & Methods

Experimental approach to the problem

To test our hypothesis, adaptations following extracurricular MT compared to only ST were assessed using a randomized controlled study design that included pre- and post-testing at weeks 1 and 12, respectively. This research was designed to obtain baseline data of some physical capacity tests in young students, in order to evaluate whether a supervised 12-week MT program can produce improvements. This outcome was defined as statistically significant improvements in physical capacity evaluation tests (i.e., a 505 change of direction speed (CODS) test, 10 m speed test and 300 meter run test)

Participants

Twenty healthy subjects between 13 and 14 years of age (11 boys and 9 girls, age 13.6 ± 0.5 years, body height 166 ± 4.7 cm, body mass 73.8 ± 4.3 kg, mean ± SD) volunteered to participate in this study. An a priori power analysis (Faul, Erdfelder, Lang, & Buchner, 2007) with an assumed type I error of 0.05 and a type II error rate of 0.20 (80% statistical power) was calculated for measures of physical capacity and revealed that 8 participants per group would be sufficient to observe medium 'Time x Group' interaction effects.

The subjects were recruited from a junior high school in Puglia (Italy) between January and February 2016. The characteristics of the study population are described in Table 1. The exclusion criteria were (a) children with a chronic pediatric disease, (b) children with an orthopedic limitation, and (c) children older than 14 years of age. All volunteers were accepted for participation.

Table 1. Characteristics of the study participants.

Characteristic	**CG (n = 10)**		**EG (n = 10)**		
	M	**SD**	**M**	**SD**	***p*-value**
Age (years)	13.6	0.5	13.7	0.5	0.660
Body height (cm)	165.1	4.4	166.5	5.1	0.519
Body mass (kg)	72.9	3.5	74.8	4.9	0.333
Sex (m/f)	5/5		6/4		

Note: m = male; f = female; M = mean; SD = standard deviation; CG = control group; EG = experimental group.

The participants were randomly assigned to two groups: an experimental group (EG), which underwent extracurricular MT, and a control group (CG), which underwent only ST during school. For randomization, we used the method of randomly permuted blocks using Research Randomizer, a program published on a publicly accessible official website (www.randomizer.org).

All participants and their parents received a complete explanation in advance about the purpose of the experiment, its contents, and safety issues based on the Declaration of Helsinki, and provided their informed consent. The study was conducted from February to May 2016.

Procedures

Physical capacity testing was performed at weeks 1 (baseline) and 12 (end of the study). All subjects participated in an introductory training session before the testing procedures. Prior to pre- and post-testing, all participants underwent a standardized 10-minute warm-up that consisted of low-to-moderate intensity aerobic exercise (gradually from 60 to 80 %HRmax) and stretching. After the testing procedures, the subjects performed approximately 5 minutes of stretching exercises that consisted of achilles' tendon/calf stretches, skier's stretches, quadriceps stretches, hurdler's stretches, straddle stretches, groin stretches, back stretches, and archers. The anthropometric measurements were conducted indoors in the school gym, and the physical capacity testing was performed on an outdoor track near the school. The students were tested at the same time of day (3 pm – 6 pm) after school for three days.

The order of tests went from speed and change of direction (505 CODS) and ended with an anaerobic capacity test (300 meter run). All measurements for testing were performed by the same operator, and the test procedures were supervised by a physical education graduate. All trials were performed using standardized test protocols, observing the same conditions. Upon completion of testing, the subjects were assigned randomly to groups. The reliability of the dependent measures was calculated using the intraclass correlation coefficient (ICC).

Physical capacity testing

505 change of direction speed (CODS) test. This test was used to measure a component of agility, which is defined as including perceptual and reactive decision-making factors, and the change of direction speed. CODS is determined by technical factors such as stride adjustments and by physical elements such as straight sprinting speed and leg muscle qualities, which include strength, power and reactive strength (Young & Farrow, 2006). In this study, the 505 CODS test involved a high-velocity 180° directional change, which was executed during the test. The subjects began by standing behind a set of timing gates (Microgate, Bolzano, Italy), then sprinted 10 m through a second set of timing gates, then sprinted a further 5 m, at which point they passed with both feet through a photocells system, turned 180°, and completed the test by sprinting 5 m back through the timing gates (Figure 1). The subjects completed 2 trials, planting and changing direction with their preferred leg only. Limb dominance or the 'preferred limb' was defined as the limb that a subject chooses and relies on to carry out a variety of functional activities. Each participant performed 2 trials (best time recorded to the nearest 0.01 s) with 3 minutes of rest in between. The 505 COD time(s) and approach speed(s) across the first 10 m were used as dependent variables. The test-retest reliability reported a moderate reliability for the 505 COD time (ICC = 0.84) and a high reliability for the 10 m speed test (ICC = 0.90) (Vincent, 2005).

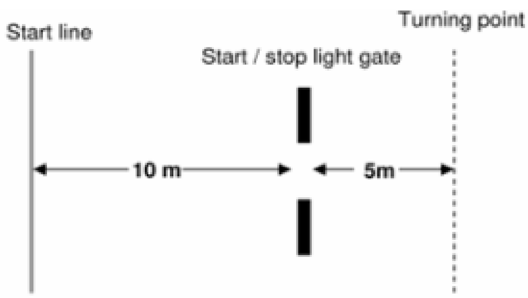

Fig. 1. Diagram of the 505 change of direction speed test. Participants perform the test as fast as possible from the start line to the stop light gate (10 m speed test) and from the start to the turning point and back to the stop light gate (505 COD time).

300 meter run test. This test assesses lower extremity anaerobic capacity via sprinting (Haff & Triplett, 2016). The students were instructed to run as fast as possible and to complete two trials separated by a 5-minute rest period. Two pairs of cones were used to delineate the 300 meters in the outdoor track. Upon completion, each participant's' time was recorded to the nearest 0.01 s on a hand-held stopwatch (Reiman & Manske, 2009). The minimum time (s) recorded in the trials was taken as a dependent variable. The test-retest reliability reported a moderate reliability for the 300 meter run test (ICC = 0.83) (Vincent, 2005).

Multilateral training (MT) protocol

The subjects allocated to the EG underwent an MT program for a period of 90 minutes, two days a week, with a total of 24 training sessions. The entire intervention program was implemented in 12 weeks from the beginning of February until the end of May 2016. The MT program was supervised and conducted by 2 experienced instructors who are graduates in physical education. Each training sessions started with a brief dynamic warm-up program mainly consisting of callisthenic-type exercises for 10 minutes and ended with a 10-minute cool-down program consisting of static stretching exercises. The targeted components of the MT program included cardiovascular endurance, agility, dynamic strength, flexibility, and team-building activities.

The dynamic warm-up included arm swings, trunk twisting, high marching, stride jumping, high knees, side bending, side stretching, skipping leg swings, backward sprinting, and lateral shuffles.

The cool-down included traditional movements such calf stretches, quadriceps stretches, back stretches, straddle stretches and groin stretches.

Cardiovascular endurance consisted of a variety of training exercises, including running, walking, circuits, sprint intervals and agility (i.e., the ladder exercise), performed gradually from 20 to 30 minutes. This training program was incorporated into every training session.

Dynamic strength included resistance training and body weight plyometrics such as jump squats, lunges, push-ups, pull-ups, curl-ups, half squats, long jumps, planks and medicine ball tosses. This program began with 1-2 set of 8–15 repetitions with 45 sec of slow walking between each exercise and adequate exercises to include all major muscle groups. In addition, this training program was included into every session and lasted 10 to 20 minutes.

Flexibility was trained using both dynamic and static stretches, typically as a part of the warm-up or cool-down phase of each training session.

The team-building activities of the training program consisted of team games such as volleyball, basketball, handball and soccer. The adolescents also played modified forms of these sports. The activities were characterized by a predominantly playful approach to encourage enthusiasm, socialization and participation of the young students. These activities were performed at the end of the session, before the cool-down.

Statistical analyses

All analyses were performed using SAS Jmp Statistics (v. 12.1, Cary, NC, USA), and the data are presented as group mean values and standard deviations.

Because we could not detect significant differences between males and females ($p > 0.05$), the data were pooled for males and females.

A multivariate analysis of variance (MANOVA) was used to detect differences between the study groups in all baseline variables. A mixed between-within subjects analysis of variance (ANOVA) was used to determine the interaction between the two independent variables of training (pre/post; within-subjects factor) and group (EG and CG; between-subjects factors) on the dependent variables of physical capacity. When 'Time x Group' interactions reached the level of significance, group-specific post hoc tests (i.e., paired t-tests) were conducted to identify the significant comparisons.

Additionally, classification of the effect size (f) was used to estimate the magnitude of differences within each group by calculating the partial η2. According to Cohen (1988), $0.00 \leq f \leq 0.24$ indicates a small effect, $0.25 \leq f \leq 0.39$ indicates a medium effect, and $f \geq 0.4$ indicates a large effect. Statistical significance was set at $p < 0.05$.

Results

All subjects received the treatment conditions as allocated. Twenty participants completed the training program, and none reported any training-related injury. Table 2 describes the pre- and post-intervention results for all outcome variables. Overall, there were no significant differences in mean age, height, weight and baseline values between the two intervention groups ($p > 0.05$).

Table 2. Effects of the multilateral training program on measures of physical capacity.

	Control group (n = 10)					**Experimental group (n = 10)**					**p-value (effect size *f*)**		
Variables	**Pre**		**Post**		**Δ (%)**	**Pre**		**Post**		**Δ (%)**	**Main effect: Time**	**Main effect: Group**	**Interaction: Time x Group**
	M	**SD**	**M**	**SD**		**M**	**SD**	**M**	**SD**				
505 COD time (s)	3.87	0.23	3.94	0.19	1.81	3.94	0.27	3.61	0.26	-8.37	0.0006 (0.27)	0.2137 (0.29)	< 0.0001 (0.50)
10 m speed (s)	2.88	0.18	2.97	0.11	3.12	2.92	0.24	2.73	0.15	-6.51	0.3872 (0.15)	0.0854 (0.30)	0.0202 (0.43)
300 m run (s)	65.59	3.24	67.14	3.58	2.36	67.39	4.03	65.03	3.28	-3.50	0.2448 (0.06)	0.9215 (0.02)	< 0.0001 (0.29)

Note: M = mean; SD = standard deviation; COD = change of direction; Δ = mean difference.

505 CODS test

505 COD time. The statistical analysis indicated a significant main effect of 'Time' ($F_{1,18} = 17.2$, $p = 0.0006$, $f = 0.27$), but not of 'Group', for the 505 COD time. Again, a significant 'Time x Group' interaction was found ($F_{1,18} = 45.79$, $p < 0.0001$, $f = 0.50$) (Figure 2a), and the post hoc analysis revealed a significant decrease in time to run the 505 CODS test from pre- to post-test in the EG (Δ -8.37%, $p < 0.0001$) (Table 2).

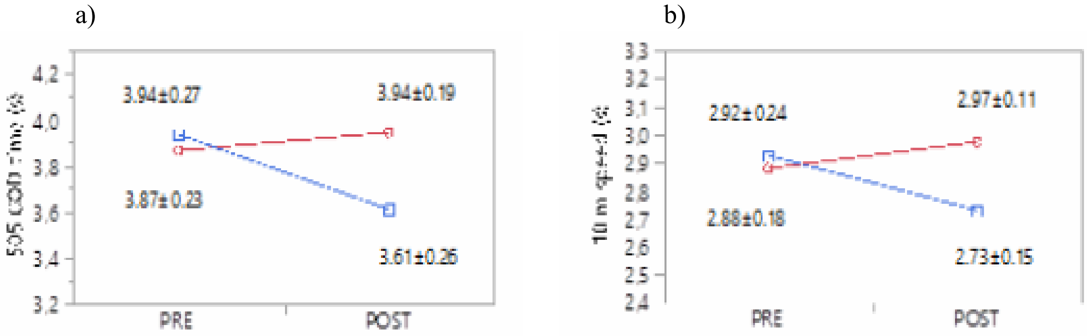

Fig. 2. Mean ± SD pre- and post-testing data for a) 505 COD time and b) 10 m speed test in the experimental group (EG, multilateral training program) and control group (CG, only standard program). Unfilled squares indicate mean data of the EG, and unfilled circles indicate mean data of the CG.

10 m speed test. In terms of the approach speed across the first 10 meters, the statistical analysis revealed a significant 'Time x Group' interaction ($F_{1,18} = 6.49$, $p = 0.0202$, $f = 0.43$) (Figure 2b). However, we could not detect a significant main effect of 'Group' or 'Time.' The post hoc analysis revealed a significant decrease in the run time from pre- to post-test in the EG (Δ -6.51%, p = 0.0268) (Table 2).

300 meter run test

A significant 'Time x Group' interaction was found ($F_{1,18} = 33.46$, $p < 0.0001$, $f = 0.29$) (Figure 3). However, no significant main effects of 'Group' and 'Time' were detected. The post hoc analysis revealed a significant decrease in run time from pre- to post-test in the EG (Δ -3.50%, $p = 0.0004$), whereas a significant increase was found in the CG (Δ 2.36%, $p = 0.0157$) (Table 2).

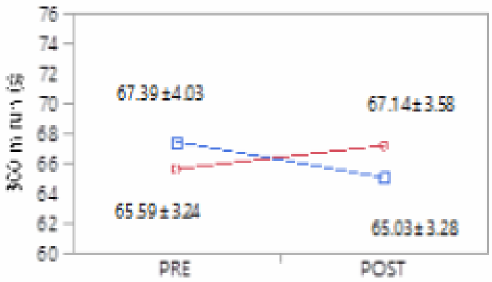

Fig. 3. Mean ± SD pre- and post-testing data for the 300 m run test in the experimental group (EG, multilateral training program) and control group (CG, only standard program). Unfilled squares indicate mean data of the EG, and unfilled circles indicate mean data of the CG.

Discussion

This study sought to fill some gaps identified in the literature about extracurricular physical activity interventions for adolescents outside the school setting. Thus, through a randomized and controlled research design, this study investigated the effects of an extracurricular MT compared to an ST program performed at school, on physical capacities and motor skills in adolescents. The main findings of this study were that performance in physical capacity tests (i.e., 505 CODS test, 10 m speed test and 300 meter run test) significantly improved in the EG after the same training period.

In effect, our results are in accordance with the literature regarding the efficacy of physical activity in improving performance in physical capacity, motor skills, and fitness among children and adolescents (Barnett et al., 2009a; Fisher et al., 2005; Lubans et al., 2010; Stodden et al., 2007; Van Beurden et al., 2002). These results are even more important if we consider that adolescents are also known to be less active than children (Fox & Riddoch, 2000; Riddoch et al., 2004). This confirms that physical education is a valuable source of physical activity for children and adolescents (Tudor-Locke, Lee, Morgan, Beighle, & Pangrazi, 2006), since it has been demonstrated that motor skill competence in childhood was associated with a greater likelihood of vigorous physical activity engagement in adolescence and that perceived sports competence was a mediator (Barnett, Van Beurden, Morgan, Brooks, & Beard, 2008; Barnett et al., 2009b). Besides, with reference to the literature (Barnett et al., 2009a; Fisher et al., 2005; Livonen et al., 2013; Lubans et al., 2010; Stodden et al., 2007; Van Beurden et al., 2002) and our own findings, the positive effects of the MT on improving performance in physical capacities and motor skills can most likely be explained by the role of increased physical activity performed outside of the school setting. Consequently, all this could encourage engagement in lifelong physical activity (Robinson et al., 2015; Stodden et al., 2008).

However, our findings extend the existing results because we additionally observed improvements in measures of agility, speed, and anaerobic capacity in adolescents following an extracurricular training program. In fact, we encourage this MT protocol because in addition to having obvious skill-related benefits, it helps reveal the natural development potential of adolescents. In particular, CODS and agility maneuvers are multidimensional skills requiring the control of individual components of body position, muscle activation, force production and cognitive interpretation (Young & Farrow 2006). Consequently, improvements in the 505 CODS test by the EG after 12 weeks of training could indicate the development of motor skills such as agility, balance, coordination, speed and power. In addition, improvements in the 10 m and 300 m sprint performances could indicate increases in speed and anaerobic power, respectively.

This study has some limitations that need to be acknowledged. A major limitation of the present study is related to the origin of the subjects; the Apulian students cannot be considered a representative sample of the Italian population, although this group is representative of Southern Italy. In addition, some Italian regions may have a different socio-economic status that has been identified as a possible determinant of physical inactivity (Gordon-Larsen, McMurray, & Popkin, 2000; Kristjansdottir & Vilhjalmsson, 2001). Moreover, due to the small sample size and because only three physical capacity performance tests were assessed, the results from the study should be interpreted with caution; therefore, further studies are also needed to measure muscular strength, cardiorespiratory endurance and flexibility in young students.

However, the present research study conducted with a rigorous design has objectively evaluated the effects of physical activity performed after school compared to that performed only during school hours. Moreover, the present research provides novel findings in the field of physical education. The findings indicate that a multilateral approach to training might play a key role in improving physical capacities and motor skills in adolescents while respecting the physiological and psychological maturation. In this light, motor skills proficiency in conjunction with physical activity participation and enjoyment should be part of a range of indicators of an effective Physical Education curriculum and Physical Education pedagogy. For this reason, promoting such activities after school would be beneficial for motor skills development and provide students with the knowledge, skills, abilities, and confidence to be active both now and throughout their lifetime.

Conclusions

In summary, our findings suggest that an extracurricular MT protocol was effective in improving physical capacity and motor skills competence after a period of 12 weeks. Thus, inclusion of an extracurricular physical activity performed using a multilateral approach might be more beneficial than having only standard programs at school. Physical education teachers should be encouraged to develop extracurricular activities with a multilateral approach consisting of cardiovascular endurance, agility, dynamic strength, flexibility, and team building, all characterized by a predominantly playful approach to encourage enthusiasm, socialization and participation of young students. Furthermore, these professionals should promote lifelong physical activity and plan social policies for help young people make informed lifestyle choices, develop proficiency in movement skills, and become physically fit.

Conflicts of interest - The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Authors' contribution

Francesco Fischetti and Gianpiero Greco contributed equally to the research conducting and design, statistical analysis, interpretation of data, critical review of draft manuscripts, and written the manuscript. Authors read and approved the final manuscript.

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