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Original Article

Effects of concurrent strength and endurance training sequence order on physical fitness performance in adolescent students

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Abstract:

The aim of the study was to examine the effect of the sequence order of concurrent training on physical performance in students. 31 subjects were recruited from a Portuguese public high school and were randomly divided in strength training followed by endurance exercise group (GSE, n=12) and endurance followed by strength training group (GAS, n=11). The training program was performed during physical education classes, 2 times per week during 10 weeks. Anthropometrics and physical variables were assessed before (M1), after 5 weeks of training (M2) and after the training period (M3). Training induced significant differences in both groups after the training program [1kg and 3kg medicine ball throw gains (GES: 4.6 to 6.3%, and 3.9 to 6.0%, GSE: 5.0 to 9.3% and 3.0 to 8.4%), VO2max (GES: 2.3 to 3.7%, GSE: 2.8 to 8.0%), push-ups (GES: 11.7 to 12.5%; GSE: 13.3 to 23.5%), standing long jump (GES: 5.1 to 4.3%, GSE: 2.9 to 5.3%), counter movement jump (GES: 5.1 to 4.3%, GES: 3.1 to 8.1%) and sprint running 20m (GES: -1.5 to -1.2%, GSE: -1.0 to -1.7%). Independently of the sequence order, concurrent training appear to change body composition and increase physical fitness in students during physical education classes.

Keywords: endurance training, strength training, physical condition, students.

Introduction

In the young population, benefits of physical activity and fitness capacity are well recognised in the literature (e.g. Faigenbaum & Mediate, 2006; Edouard, Gautheron, D'Anjou, Pupier, & Devillard, 2007; Fleck & Kraemer, 2004; Matton, Thomis, Wijndaele et al., 2006; Twisk, Kemper & Van Mechelen, 2000). The school's physical and social environment and particularly the physical education (PE) classes provide a key context for regular and structured physical activity participation. Although there is very little research about the characteristics of regular exercise training under the school curricula (Edouard et al., 2007; Hoehner et al., 2008; World Health Organization, 2006; Faigenbaum & Mediate, 2006), PE programs often aim to improve student's muscular strength and total fitness capacity (Faigenbaum & Myer, 2010).

The strength training induces physical and performance improvements in the health of children and youth, promoting improvements in terms of body composition, motor coordination, injury and diseases control and prevention (Blimkie, 1993; Kraemer & Ratamess, 2000; Faigenbaum & Myer, 2010). In turn, endurance training causes an increase in maximal oxygen uptake (VO_{2max}) and positive enzymatic and metabolic adaptations, which increases resistance to fatigue (Volpe, Walberg-Rankin, Rodman & Sebolt, 1993) and sets an upper limit for endurance performance in a wide variety of physical activities (Baquet, van Praagh & Berthoin, 2003).

Concurrent training has become one of the main research training areas (Gravelle & Blessing, 2000), nevertheless, a considerable number of studies have been only conducted specifically in adults and focused on the effects of concurrent training vs. resistance-training only for muscular hypertrophy, strength and power of the upper and lower body. A recent meta-analysis by Wilson (2012) reported that gains in muscular hypertrophy and strength seem to be similar in both training programs, being muscular power more sensitive to the interference effect. However, very few studies have focused on whether strength training should precede or follow endurance training when both are conducted in the same workout.

The increase in strength performance achieved only by strength training alone may be compromised (Kraemer et al., 1995), because it depends on the level of physical activity and the type of exercise (Izquierdo, Exposito, Garcia-Pallare, Medina & Villareal, 2010). Therefore, the aim of the present study was to compare the effects of different order of concurrent training on the development of physical performance during PE classes.

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Methods

Subjects

Twenty-three male Portuguese adolescents were recruited at a public high school to performed exercise training during 10 consecutive weeks. Subjects were randomly divided into two groups of intervention: the subjects in group 1 (GSE, n=12, 16.79±0.932 years, 61.65±12.56 kg, 166.79±9.94 cm and BMI 22.38±0.06 kg/m^2) performed strength training followed by endurance exercise; the subjects in group 2 (GES, n=11, 16.64±0.953 years, 61.28±10.36 kg, 169.64±7.99 cm and BMI 21.45±0.9 kg/m^2) performed endurance training followed by strength exercise. All subjects were regularly participating in PE classes conducted by the same professor and were asked to continue lifestyle and physical activity habits throughout the study duration. The exclusion criteria were used: students with educational or motor handicap/disease or participating in extra school sport activities. Prior to all testing procedures, ethical procedures as the Helsinki declaration and an informed consent was obtained from the student parents.

Training Design

The intervention program was executed at school additionally to PE classes. The intensity and the volume of training were set according to the latest guidelines of the American College of Sports Medicine (ACSM, 2013). The application mode of exercise was based on the recommendations of several authors who have developed similar studies (Table 1) (Faigenbaum et al., 2001; Faigenbaum et al., 2002; Faigenbaum & Mediate, 2006; Faigenbaum et al., 2007). During warm-up, both groups completed 5 minutes of constant running. After, they were submitted to one of the concurrent protocols order for about 20 minutes. As can be seen in table 1, GES group performed a shuttle running cutting task (sets of 30 repetitions of 20 m) before four strength training exercises (circuit): sit-ups, vertical and horizontal jump and medicine ball throw (1 kg and 3 kg). The GSE group performed exactly the same type of workout but with a reverse sequence order, i.e. the circuit strength training was conducted before the shuttle running cutting task. Students only had 15 seconds to change between exercises (Santos et al., 2011).

Experimental groups underwent training in the same conditions (day and hour). All participants were previously familiarized with data collection and testing procedures.

Table 1. Training program design.

Exercises	**Session 1**	**Session 2**	**Session 3**	**Session 4**	**Session 5**
Overhead 1 kg Medicine Ball Throw	2×8	2×8	2×8	6x8	TestM
Overhead 3 kg Medicine Ball Throw	2×8	2×8	2×8	6x8	TestM
CMJ	1x5	1x5	1x5	3x5	TestM
Sprint Running (m)	4×20m	4×20m	3×20m	3×20m	TestM
20m Shuttle Run (MAV)	75%	75%	75%	75%	TestM
Exercises	**Session 6**	**Session 7**	**Session 8**	**Session 9**	**Session 10**
Overhead 1 kg Medicine Ball Throw	3x5	2x5	2x5	1x5	1x5
Overhead 3 kg Medicine Ball Throw	3x5	2x5	2x5	1x5	1x5
CMJ	4x5	4x5	2x5	2x4	2x4
Sprint Running (m)	4x30m	4x30	3x40	2x30m	2x30m
20m Shuttle Run (MAV)	75%	75%	75%	75%	75%

Legend: Medicine Ball Throwing and Jump onto box: 1st number corresponds to sets and 2nd corresponds to repetitions; Sprint Running: 1st number corresponds to sets and 2nd corresponds to the distance to run; 20m Shuttle Run: each subject ran each session (until test M) 75% of maximum individual aerobic velocity performed on pre-test and after this test M moment until program end, ran 75% of maximum individual aerobic volume performed on test M; CMJ – Counter movement jump. MAV - maximum individual aerobic velocity

Testing Procedures

The following battery of tests was applied in both experimental and control groups and repeated in three different moments (pre, middle and posttest measurements).

Anthropometric assessment

Total height and body weight were measured according to international standards for anthropometric assessment (Marfell-Jones et al., 2006). Body mass index (BMI) was mathematically estimated according with the equation BMI = weight/height^2 (kg/m^2). Body composition was assessed using a Tanita body at analyzer (model TBF-300; Tanita Corporation of America, Inc., Arlington Heights, IL. USA). Subjects were measured only wearing shorts and t-shirts.

20 Meter Shuttle Run (VO_{2max})

The maximal multistage 20 m shuttle run test was conducted to determine the maximal aerobic power of all participants using the Léger's equation (Léger, Mercier, Gadoury, Lambert, 1988). The test starts by an initial running velocity (8.5 km/h) between two lines (20m apart), which increases by 0.5 km/h each minute. Beep sounds were used to indicate and increase in speed. The final score was based on the level and number of shuttles reached before failing (for two consecutive ends) to keep up with the audio recording. The 20 m Shuttle Run test has shown an ICC of 0.90.

Push-ups

Push-ups (flexion / extension of the upper limbs to the elbow joint reaches a 90-degree angle) are common and recommended field tests to accesses strength and endurance of the upper body (FITNESSGRAM, 1987). The purpose of the test is to complete the largest possible number of push-ups with a certain cadence (20 per minute). The teacher emphasized the students hand placement under the shoulders, arms straight, fingers stretched out, and legs together and straight with the toe tucked downward. Participants would then lower the body by bending their elbows to a 90° angle and continue the movement until the arms were straight again (the back and legs were kept in a straight line throughout the execution). Completion of this movement was counted as one successful push-up. The entire process was performed as many times as possible.

The test ended when the participant stopped or rested, did not maintain correct body position, did not extend the arms fully, or did not achieve a 90° bend at the elbow on at least two push-ups. The number of the push-ups correctly completed was considered for analysis.

Overhead Medicine Ball Throwing 1kg and 3kg

Maximal throwing velocity (BTd) was performed using medicine balls (Bhalla International - Vinex Sports, Meerut - India) weighing 1 kg and 3 kg (Vinex, model VMB-001R and VMB-003, perimeter 0.72m and 0.78m). The best distance was considered for analysis. The ICC for 1 kg and 3 kg BTd was 0.91 and 0.93, respectively.

Standing Long Jump (SLJ)

A fiberglass tape measure (Vinex, MST-50M, Meerut, India) was extended across the floor and used to measure horizontal distance. Each participant completed three trials with a 1-min recovery between trials using a standardized jumping protocol to reduce inter-individual variability. The greatest distance (cm) of the two jumps was taken as the test score. The SLJ has shown an ICC of 0.90.

Counter movement Jump (CMJ)

The vertical jump test was conducted on a contact mat connected to an electronic power timer, control box and handset (Globus Ergojump, Codognè, Italy). Each participant performed three jumps with a 1-min recovery between attempts. The highest jump (cm) was recorded. The CMJ has shown an ICC of 0.94.

Sprint Running 20m

Time to run 20 m was obtained using photocells (Brower Timing System, Fairlee, Vermont, USA). Each subject repeated the procedure for 3 attempts and only the best time was used in data analysis. A rest period of 10 min among attempts was accomplished. The sprint running (time) has shown an ICC of 0.92.

Statistical analysis

Means and standard deviations ($\bar{x}$±sd) were measured by standard statistical methods. Friedman followed by Wilcoxon's signed-rank test was used as appropriate to determine the intra-group difference between assessment moments. The analyses were adjusted using the Holm's sequential Bonferroni correction (Holm, 1979). To verify whether there were significant differences among the three groups in each of the moments of evaluation, we used Kruskal-Wallis test. The differences in both cohort groups were analyzed computing the Mann–Whitney U test. The statistical significance was set at $P \leq 0.05$.

Results

In the pre-training, no significant differences were observed between groups in anthropometrics measures and performance variables (p>0.05). Significant training□induced differences (p<0.05) were observed in both groups after 10 weeks of training in all assessed parameters.

Between pre-training to the post-training period GES and GSE increased significantly in ball throw distance (1kg and 3kg: p<0.05) (GES: 4.6 to 6.3%, and 3.9 to 6.0%, GSE: 5.0 to 9.3% and 3.0 to 8.4%). The VO2max enlarged significantly in GES (2.3 to 3.7 %,) and GSE (2.8 to 8.0%). The push-ups remained unchanging in GES (11.7 to 12.5%) whereas in GSE significantly increased (13.3 to 23.5%). In the standing long jump and CMJ both groups significantly improved their performance (GES: 5.1 to 4.3%, GSE: 2.9 to 5.3% and GES: 5.1 to 4.3%, GES: 3.1 to 8.1%, respectively). Finally, the time to run 20m decreased in both groups (GES: -1.5 to -1.2%, GSE: -1.0 to -1.7%, p<0.05).

Table2.Mean±standard deviation values regarding the subject's physical fitness performance

	Group	M1 ($\bar{x}$±sd)	M2 ($\bar{x}$±sd)	M3 ($\bar{x}$±sd)
VO_{2Max} ($mL.kg^{-1}.min^{-1}$)	GES (n=11)	34.360±9.4100$^{□,¥}$	35.146±9.379$^{□,‡}$	36.413±9.474$^{‡,¥}$
	GSE (n=12)	33.182±7.980$^{□,¥}$	33.977±7.904$^{□,‡}$	36.682±8.101$^{‡,¥}$
	P-value	0.648	0.649	0.905
Push-ups (rep.)	GES	16.120±7.887$^{□,¥}$	18.000±8.314$^{□,‡}$	20.250±8.853$^{‡,¥}$
	GSE	14.360±6.05$^{□,¥}$	16.270±5.684$^{□,‡}$	20.090±6.369$^{‡,¥}$
	P-value	0.398	0.412	0.918
Overhead 1kg Medicine Ball Throw (m)	GES	8.183±1.905$^{□,¥}$	8.556±2.216$^{□,‡}$	9.095±2.669$^{‡,¥}$
	GSE	8.00±1.989$^{□,¥}$	8.401±2.019$^{□,‡}$	9.186±2.289$^{‡,¥}$
	P-value	0.752	0.815	0.944
Overhead 3kg Medicine Ball Throw (m)	GES	5.190±1.457$^{□,¥}$	5.395±1.477$^{□,‡}$	5.719±1.422$^{‡,¥}$
	GSE	5.219±1.343$^{□,¥}$	5.373±1.377$^{□,‡}$	5.827±1.427$^{‡,¥}$
	P-value	0.944	0.957	0.902

SLJ (m)	GES	1.732±0.359[□,¥]	1.797±0.3566[□,‡]	1.873±0.338[‡,¥]
	GSE	1.771±0.368[□,¥]	1.823±0.344[□,‡]	1.920±0.317[‡,¥]
	P-value	0.713	0.808	0.973
CMJ (cm)	GES	28.296±8.126[□,¥]	29.729±7.899[□,‡]	31.020±7.607[‡,¥]
	GSE	27.086±6.847[□,¥]	27.932±7.118[□,‡]	30.205±7.301[‡,¥]
	P-value	0.584	0.421	0.635
Sprint Running 20m (sec.)	GES	3.725±0.374[□,¥]	3.669±0.3643[□,‡]	3.624±0.371[‡,¥]
	GSE	3.660±0.294[□,¥]	3.623±0.274[□,‡]	3.560±0.252[‡,¥]
	P-value	0.512	0.626	0.709

Legend: $\bar{x}$ – mean; sd- standard deviation; M1–pre-training; M2 – Middle period training program; M3 – After training program; p (M2-M3) - GES – concurrent endurance and resistance training group, GSE - concurrent resistance and endurance training, □ - Significant changes between M1 and M2; ‡ - Significant changes between M2 and M3; ¥ - Significant changes between M1 and M3.

Discussion

The purpose of the present study was to examine the effects of different order of concurrent training protocols on physical fitness performance of students in PE classes. The main results after the program training showed that both protocols significantly induced an increase in overall fitness performance. Thus, it may suggest that concurrent training with different order seem to be an effective exercise program to increase strength performance and aerobic capacity in healthy school subjects.

There is evidence that strength training and aerobic training induce significant improvements in children and adolescents physical fitness (Chtara et al., 2005). Additionally, and according to several authors (Edouard et al., 2007; Aburto et al., 2011) children and youth of both genders show substantial improvements in muscle strength and aerobic capacity in response to different training protocols. This is consistent with our findings showing that a reduced period of concurrent training (10 weeks), during PE classes, seems to be enough to promote significant gains on youth physical fitness. Moreover, our study is particularly consistent with the results obtained by Cunha (1996) with in which the author evaluated the effects of 10 weeks of resistance training in 7^{th} grade students. In the present study, upper and lower strength performance executed at fast velocity has significantly increased in both groups. Although, concurrent training performed on separate or in the same day should induce different effects (Santos et al., 2011) and the order of different concurrent training in the same session, the mode of exercise in different days seems to produces different effects. The organisation of the program training, seems to interfere in the results and that needs to be investigated to recognize other possible mechanisms to decrease the improvement of better performance (Izquierdo et al., 2010; Sale et al., 1990).

In research about the concurrent training in school context the studies revealed that strength improvements are lower comparatively to subjects that only performed strength training (Dolezal & Potteiger, 1998; Bell et al., 2000), or that there is no interference (Häkkinen et al., 2003, Santos et al., 2011). Further, in endurance performance, achieved in VO_{2max} (ml.kg^{-1}.min^{-1}) the biggest increase seems to be more significant when resistance training is preceded by strength training (Chtara et al., 2005). In the present study the level of physical condition in the students was not high and it may suggest a large permeability for the purposes of training regardless of their order of application. Indeed, circuit training presents pedagogical advantages which make it an important method to be considered in the development of general and specific strength in youth age groups (Santos et al., 2011). Despite the importance of our results, some limitations should be addressed to the current study. No baseline information about the student's physical activity habits and patterns were available, which could allow us a better understanding of how physical activity affects training response. Indeed, we observe a significant enhancement in running speed and VO_{2max} (ml.kg^{-1}.min^{-1}) in all groups, however, students may had been performing physical activity at home, possibility which could have improved this variables. Also no control group was included, which could enable to isolate the independent variables' effects of concurrent training in relation to the expected effects of PE classes alone. Future studies should assess the detraining and others variables, as fatigue elements and physiologic measures.

Conclusion

Concurrent training applied twice a week at the beginning of the PE classes seems to be sufficient to significantly contribute to the improvement of the physical fitness condition of young students.

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