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Does Intrasession Concurrent Strength and Aerobic Training Order Influence Training-Induced Explosive Strength and $\dot{V}O_2$max in Prepubescent Children?

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Abstract

Alves, AR, Marta, C, Neiva, HP, Izquierdo, M, and Marques, MC. Does intrasession concurrent strength and aerobic training order influence training-induced explosive strength and $\dot{V}O_2$max in prepubescent children?. *J Strength Cond Res* 30(12): 3267–3277, 2016—The aim of this study was to analyze the interference of strength and aerobic training order over an 8-week period on explosive skills and maximal oxygen uptake ($\dot{V}O_2$max) in prepubescent children. One hundred twenty-eight prepubescent children aged 10–11 years (10.9 ± 0.5 years) were randomly selected and assigned to 1 of the 3 groups: intrasession concurrent aerobic before (GAS: $n = 39$) or after strength training (GSA: $n = 45$) or control group (GC: $n = 44$; no training program). The GC maintained their baseline level performance, and training-induced differences were found in the experimental groups. Increases were found in the 1-kg and 3-kg medicine ball throws: GAS: +3%, +5.5%, $p \leq 0.05$, $p < 0.001$; GSA: +5.7%, +8.7%, $p < 0.001$, respectively; in the counter movement jump height and standing long jump length: GAS: +6.5%, +3.4%, $p \leq 0.05$; GSA: +7%, +4.5%, $p < 0.001$, respectively; in the 20-m shuttle-run time: GAS: +2.3%; GSA: +4.6%, $p < 0.001$; and, in the $\dot{V}O_2$max: GAS: +7.3%, $p < 0.001$; GSA: +3.8%, $p < 0.001$ from pretraining to post-training. All programs were effective, but GSA produced better results than GAS for muscle strength variables, and GAS produced better results than GSA for aerobic capacity variables. The present study explored an unknown issue and added useful information to the literature in this area. These training methods should be taken into consideration to optimize explosive strength and cardiorespiratory fitness training in school-based programs and sports club programs.

Key Words youth, power, cardiorespiratory, muscular conditioning, sequence

Introduction

Concurrent training (i.e., a combination of strength and aerobic regimens) has become a recurrent topic for researchers because of the controversial results of different experiments (6,8,10,16,23). Several studies have shown that concurrent training can affect the development of muscle strength and/or power (16,20,24,29). In contrast, other experiments have indicated a positive effect of concurrent training on strength (3,12,13,18,19,28) and on maximal aerobic capacity (17,27,35,40).

Whereas multiple studies have investigated concurrent training in young, adult or even elderly populations (9,12,22,33,42), a limited number of studies have explored concurrent training in prepubescent (33) and pubescent children (39). The majority of the pediatric research has focused on activities that enhance cardiorespiratory fitness and recent findings indicate that strength training offer benefits to children and adolescents (15,26,39). Meanwhile, improvements in muscular fitness, speed and agility, rather than cardiorespiratory fitness, seem to have a positive effect on skeletal health (26,39). Concurrent aerobic training and strength training have the potential to bring about gains in cardiorespiratory and muscular fitness simultaneously (25). Moreover, children and adolescents involved in physical education classes often perform strength and aerobic training concurrently in an effort to achieve specific adaptations to both forms of training (24,39). Furthermore, Marta et al. (33) showed that concurrent training is equally effective on training-induced explosive strength as only strength training in prepubescent children. Moreover, this experiment only

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compared the effects of concurrent training on the same day vs. strength training alone. In fact, concurrent training order in prepubescent children is another important issue that still has not been investigated. According to Kang and Ratamess (25), most studies suggest that different intrasession training order produces no significant differences in training-induced adaptations because both combinations generate similar improvements in cardiorespiratory and muscular fitness. Furthermore, those studies also found that either training order can have its own advantages that could make concurrent training more effective. For example, Chtara et al. (9) observed that performing aerobic training before strength training could improve running performance and $\dot{V}O_2max$ to a greater extent than the reverse order. Nevertheless, Cadore et al. (6,7) suggested that for intrasession concurrent training protocols, the strength gains might be optimized with intrasession strength before aerobic training order. To the best of our knowledge, no research has been conducted concerning the effects of intrasession concurrent strength and aerobic training order on training-induced explosive strength in prepubescent populations; thus, research in this area seems useful and relevant.

Therefore, the purpose of the current study was to analyze the interference of intrasession concurrent strength and aerobic training order over an 8-week period on explosive skills and maximal oxygen uptake ($\dot{V}O_2max$) in a large sample of prepubescent children. We hypothesized that the prepubescent children would show increased explosive strength following the 8-week intrasession concurrent strength before aerobic training order, and that the prepubescent children would show increases $\dot{V}O_2max$ independent of the training approach.

Methods

Experimental Approach to the Problem

The aim of the current study was to analyze the interference of intrasession concurrent strength and aerobic training order (strength before aerobic training [GSA] or aerobic before strength training [GAS]) over an 8-week period on explosive strength and maximal oxygen uptake ($\dot{V}O_2max$) in prepubescent children. The study followed a repeated measures design, with each participant randomly assigned to a specific training program (concurrent strength and aerobic training or concurrent aerobic and strength training) or the control group (no training regimen). The 8-week period and study design were developed based on specific studies conducted in prepubescent children, which performed in similar periods (32,33). Based on those studies, and the knowledge of an experienced coach and researcher, a training program composed of specific sets, repetitions, and exercises was designed. The children were evaluated for changes in strength (1-kg and 3-kg medicine ball throw, standing long jump, counter movement jump, and a 20-m sprint running) and cardiovascular parameters ($\dot{V}O_2max$) before and after 8 weeks of training.

Subjects

The sample consisted of 128 healthy prepubescent children (aged 10.91 ± 0.51 years) from the Santa Clara school cluster (Guarda, Portugal) who were randomly assigned to the different training programs or the control group. The average height and body mass of the entire sample were 1.43 ± 7.53 m and 39.12 ± 8.60 kg, respectively. The inclusion criteria were children aged 10–12 years (in fifth or sixth grade) without a chronic pediatric disease or orthopedic limitation and without regular extracurricular physical activity (i.e., practice of a sport at an academy).

Before data collection and the beginning of training, each participant reported any health problems, physical limitations, physical activity habits, and training experiences within the last 6 months. Thereafter, maturity level was determined based on Tanner stage (14) through self-assessment; to minimize the effects of growth, only children that were self-assessed as Tanner stage I–II were selected. No subject had regularly participated in any training program before this experiment. Efforts were made to collect participants that would form comparable groups. Before the start of the study, all participants and their parents/guardians were informed about study procedures and possible benefits and risks. The written informed consent was obtained from parents/guardians of all participants. The study was approved by the Institutional Review Board of the University of Beira Interior, and procedures were in accordance with the latest version of the Declaration of Helsinki. There were no injuries resulting from the implementation of the training programs.

Procedures

Sample Procedures. Children were recruited from a Portuguese public high school and randomly assigned to 2 experimental groups (8-week training, twice a week, from January 14 to March 15, 2015) and 1 control group. The groups were intrasession concurrent strength before aerobic training group (GSA: $n = 45$, 24 girls, 21 boys), intrasession concurrent aerobic before strength training group (GAS: $n = 39$, 16 girls, 23 boys), and a control group (GC: $n = 44$, 23 girls, 21 boys) with no training protocol. This last group followed the physical education class curriculum and did not undergo a specific training program. The assigned groups were determined randomly using a random number generator on a computer and could not be predicted. This procedure was established according to the "CONSORT" statement, which can be found at http://www.consort-statement.org/. The participants were randomly assigned to 1 of 3 intervention arms. Randomization was performed using R software version 2.14 (R Foundation for Statistical Computing and developed by Bell Laboratories, Lucent Technologies, Vienna, Austria). Before the start of training, all subjects attended physical education classes twice a week, with one class lasting 45 minutes and the other lasting 90 minutes. Typical physical education classes have low-to-moderate intensity and involve the performance of various sports (team sports, gymnastics, dance, adventure sports, etc.) with an evident pedagogical focus.

Training Procedures. The training programs were implemented in addition to the physical education classes. Before training, the subjects warmed up for approximately 10 minutes with low-to-moderate intensity exercises (e.g., running, sprints, stretching, and joint specific warm-up). Joint rotations, slow circular movements in the clockwise and counter-clockwise direction, were performed until the entire joint moved smoothly. Stretching exercises, including back and chest stretches, shoulder and side stretches, and wrist, waist, quadriceps, groin, and hamstring stretches, were performed. At the end of the training sessions, all subjects performed 5 minutes of static stretching exercises, such as kneeling lunges, the ankle-over-knee stretch, rotation, and hamstring stretches. After the warm-up period, the GSA group performed strength training and then a 20-m shuttle-run exercise, whereas the GAS group performed a 20-m shuttle-run exercise and then strength training. The aerobic training task was based on individual training volume that was set to approximately 75% of the established maximum aerobic volume achieved on a previous test. After 4 weeks of training, both experimental groups were reassessed by a 20-m shuttle-run test to readjust the volume and intensity of the 20-m shuttle-run exercise.

Before the start of training, subjects completed 2 familiarization sessions to practice the exercises and routines that they would perform during the training period (i.e., power training exercises and 20-m shuttle-run test). During this time, the children were taught the proper technique for each training exercise, and all of their questions were properly answered to remove any doubts regarding the exercise techniques. During training, the safety of the children, including the maintenance of safe hydration levels, was ensured, and all children were encouraged to do their best to achieve the best results. Clear instructions about the

TABLE 1. Training program design (sets × repetitions/distances).*

	Sessions					
Exercise	1	2	3	4	5	6
1-kg ball throw	2 × 8	2 × 8	2 × 8	2 × 8	2 × 8	2 × 8
3-kg ball throw	2 × 8	2 × 8	2 × 8	2 × 8	2 × 8	2 × 8
SL jump	2 × 4	2 × 4	2 × 4	2 × 4	2 × 4	2 × 4
CM jump	1 × 5	1 × 5	1 × 5	1 × 5	2 × 5	2 × 5
20-m sprint (m)	2 × 20	2 × 20	2 × 20	2 × 20	3 × 20	3 × 20
20-m shuttle run (MAV, %)	70	70	70	70	75	75

	Sessions					
Exercise	7	8	9	10	11	12
1-kg ball throw	2 × 8	2 × 8	3 × 8	3 × 8	3 × 8	3 × 8
3-kg ball throw	2 × 8	2 × 8	2 × 8	2 × 8	3 × 6	3 × 6
SL jump	2 × 4	2 × 4	3 × 4	3 × 4	3 × 4	3 × 4
CM jump	2 × 5	2 × 5	2 × 5	2 × 5	3 × 5	3 × 5
20-m sprint (m)	3 × 20	3 × 20	3 × 20	3 × 20	3 × 30	3 × 30
20-m shuttle run (MAV, %)	75	75	75	75	80	80

	Sessions			
Exercise	13	14	15	16
1-kg ball throw	3 × 8	3 × 8	3 × 8	3 × 8
3-kg ball throw	3 × 6	3 × 6	3 × 6	3 × 6
SL jump	4 × 4	4 × 4	4 × 4	4 × 4
CM jump	3 × 5	3 × 5	3 × 5	3 × 5
20-m sprint (m)	3 × 30	3 × 30	3 × 30	3 × 30
20-m shuttle run (MAV, %)	80	80	80	80

*1-kg Ball Throw = chest 1-kg medicine ball throwing (m); 3-kg Ball Throw = chest 3-kg medicine ball throwing (m); SL Jump = standing long jump (m); CM Jump = counter movement jump onto a box (m); 20-m Sprint = 20-m sprint running (s); MAV = maximal individual aerobic volume.

importance of adequate nutrition were also delivered. The instructions for the 20-m shuttle run were given with the aid of a multistage fitness test audio CD of the FITNESSGRAM test battery. During this time, all children were taught the proper technique for each training exercise, and all of their questions were properly answered to remove any doubts regarding the exercise techniques. Throughout the pre-experimental and experimental periods, the subjects reported that they were not involved in regular exercise programs for developing or maintaining strength and endurance performance other than institutional regular physical education classes. A more detailed analysis of the program can be found in Table 1.

The experimental groups were assessed for upper and lower body explosive strength (ball throws 1–3 kg and jumps, respectively), running speed (20 m sprint), and $\dot{V}O_2max$ (20-m shuttle-run test) before and after the 8 weeks of the training program. The testing assessment procedures were always conducted in the same indoor environment and at the same time each week. Each subject was familiarized with the power training tests (ball throws, jumps, and sprints) and with the 20-m multistage shuttle-run test. The same researcher performed the training program, anthropometric and physical fitness assessments, and data collection.

Testing Procedures. ***Anthropometric Measurements.*** All anthropometric measurements were assessed according to international standards for anthropometric assessment (31) and were obtained before any physical performance test. The participants were barefoot and only wearing underwear. Body mass (in kg) was measured to the nearest 0.1 kg using a standard digital floor scale (model 841; Seca, Hamburg, Germany). A precision stadiometer with a scale range of 0.001 m was used to measure body height (in m) (Seca).

Medicine Ball Throwing. This test was performed according to the protocol described by Mayhew et al. (34). The subjects were seated with the backside of their trunk touching a wall. They were required to hold medicine balls (Bhalla International, Vinex Sports, Meerut, India) that weighed 1 kg (Vinex; model, VMB-001R; perimeter, 0.72 m) and 3 kg (Vinex; model, VMB-003R; perimeter, 0.78 m) with their hands (abreast of chest) and throw the ball forward for the maximum possible distance. Neither hip inflection nor withdrawal of the trunk away from the wall was allowed. Three trials were performed. The throws were measured (in m) from the wall to the first point at which the ball made contact with the floor, and the furthest throw was recorded. One minute of rest was provided between the 3 trials. The intraclass correlation coefficients (ICCs) for the data of the 1-kg and 3-kg medicine ball throwing exercises were both ≈ 0.98.

Standing Long Jump (SL Jump). This test was assessed using the EUROFIT test battery (1). The participants stood with their feet slightly apart (toes behind a starting line) and jumped as far forward as possible. Three trials were performed. The distance jumped was measured (in m) from the starting line to the heel of the foot nearest the starting line, and the furthest distance was recorded. The ICCs for the standing long jump data were 0.94.

Counter Movement Vertical Jump (CM Jump). This test was conducted on a contact mat connected to an electronic power timer, control box, and handset (Globus Ergojump, Italy). From a standing position, with their feet

Table 2. Univariate analysis.*†

	GSA	GAS	GC	*p*
Age (mean + *SD*)	10.8 ± 0.5	11.1 ± 0.5	10.9 ± 0.5	0.038‡
BMI (mean + *SD*)	19.3 ± 3.0	18.2 ± 3.1	19.2 ± 3.1	0.346
FAT (mean + *SD*)	22.6 ± 8.3	18.6 ± 8.8	21.6 ± 7.0	0.290
$\dot{V}O_2max$ ($ml\cdot kg^{-1}\cdot min^{-1}$)	44.4 ± 3.3	42.5 ± 3.1	44.8 ± 3.6	0.000§
1-kg ball throw (m)	3.6 ± 0.6	3.3 ± 0.7	3.6 ± 0.6	0.000§
3-kg ball throw (m)	2.2 ± 0.4	2.3 ± 0.4	2.2 ± 0.4	0.081
SL jump (m)	1.3 ± 0.2	1.3 ± 0.3	1.3 ± 0.2	0.659
CM jump (m)	0.2 ± 0.0	0.2 ± 0.1	0.2 ± 0.1	0.442
20-m sprint (s)	4.4 ± 0.3	4.3 ± 0.3	4.4 ± 0.3	0.013‡

*$\dot{V}O_2max$ = multistage shuttle run ($ml\cdot kg^{-1}\cdot min^{-1}$); 1-kg Ball Throw = chest 1-kg medicine ball throwing (m); 3-kg Ball Throw = chest 3-kg medicine ball throwing (m); SL Jump = standing long jump (m); CM Jump = counter movement jump onto a box (m); 20-m Sprint = 20-m sprint running (s).

†Mean ± *SD* of age, body mass index (BMI), % fat mass (FAT), maximal oxygen uptake ($\dot{V}O_2max$), and muscle strength variables in intrasession strength before aerobic training (GSA), intrasession aerobic before strength training (GAS), and control group (GC).

‡$p \leq 0.05$.

§$p < 0.001$.

shoulder-width apart and hands placed on the pelvic girth, the subjects performed a counter movement with their legs before jumping. Such movement makes use of the stretch-shorten cycle in which the muscles are prestretched before shortening in the desired direction (30). The subjects were informed that they should try to jump vertically as high as possible. Each participant performed 3 jumps with a 1-minute recovery between attempts. The highest jump (in m) was recorded. The ICCs of the counter movement vertical jump data were 0.91.

20-Meter Sprint Running (20 m Sprint Running). The subjects were required to cover a 20-m distance on a track in the shortest time possible. The time (in s) to run 20 m was obtained using photocells (Brower Timing System, Fairlee, VT, USA). Three trials were performed, and the best time (seconds and hundredths) was recorded. The ICCs of the sprint running data were 0.97.

Statistical Analyses

Standard statistical methods were used to calculate means and standard deviations. The normality of the data distribution was evaluated by applying the Kolmogorov–Smirnov test. The within-subject reliabilities of the endurance and strength tests were determined by calculating ICCs and 95% confidence intervals (CIs). We performed univariate analyses (one-way ANOVA and Qui-Squared test) to compare physical performance variables, age, BMI, and body fat at baseline between the groups. To evaluate the changes from pretreatment to post-treatment, we used a paired *t*-test for each group, and we performed a multivariate analysis of covariance (MANCOVA) with group as fixed-effect and physical performances variables as covariates. The normality of the residuals was examined by the Kolmogorov–Smirnov test, and the homogeneity of the variance–covariance matrix was examined by the Box's M test. This assumption was not verified, so we used Pillai's trace test statistics ($M = 81.70$, $F_{(2,125)} = 1.81$, $p \leq 0.05$). When statistically significant differences were observed between groups, an analysis of covariance (ANCOVA) was performed for each dependent variable, followed by the Bonferroni post hoc comparison test. Using the ANCOVA results, it was also possible to analyze the effect size of the intervention on the physical performance variables. The data were analyzed using SPSS 22.0 (International Business Machines Corporation-IBM, Armonk, NY, USA), and statistical significance was set at $p \leq 0.05$.

TABLE 3. Mean ± *SD* and paired *t*-test analysis.*†

	Pre	Post	Difference (Pre − post)	*p*
GAS				
$\dot{V}O_2max$ (ml·kg^{-1}·min^{-1})	42.5 ± 3.1	45.6 ± 3.2	−3.1 ± 1.7	0.000‡
1-kg ball throw (m)	3.3 ± 0.7	3.4 ± 0.7	−0.1 ± 0.2	0.033§
3-kg ball throw (m)	2.3 ± 0.4	2.4 ± 0.5	−0.1 ± 0.1	0.000‡
SL jump (m)	1.3 ± 0.3	1.4 ± 0.3	−0.1 ± 0.2	0.025§
CM jump (m)	0.2 ± 0.1	0.2 ± 0.1	0.0 ± 0.0	0.001§
20-m sprint (s)	4.3 ± 0.3	4.2 ± 0.3	−0.1 ± 0.0	0.000‡
GSA				
$\dot{V}O_2max$ (ml·kg^{-1}·min^{-1})	44.4 ± 3.3	46.1 ± 4.1	−1.7 ± 1.9	0.000‡
1-kg ball throw (m)	3.6 ± 0.6	3.8 ± 0.6	−0.2 ± 0.1	0.000‡
3-kg ball throw (m)	2.2 ± 0.4	2.4 ± 0.4	−0.2 ± 0.1	0.000‡
SL jump (m)	1.3 ± 0.2	1.4 ± 0.2	−0.1 ± 0.1	0.000‡
CM jump (m)	0.2 ± 0.0	0.2 ± 0.0	0.0 ± 0.2	0.000‡
20-m sprint (s)	4.4 ± 0.3	4.3 ± 0.3	−0.1 ± 0.1	0.000‡
GC				
$\dot{V}O_2max$ (ml·kg^{-1}·min^{-1})	44.8 ± 3.6	45.0 ± 4.0	−0.2 ± 1.6	0.386
1-kg ball throw (m)	3.6 ± 0.6	3.7 ± 0.6	−0.1 ± 0.1	0.053
3-kg ball throw (m)	2.2 ± 0.4	2.2 ± 0.5	−0.1 ± 0.2	0.057
SL jump (m)	1.3 ± 0.2	1.3 ± 0.2	−0.1 ± 0.1	0.066
CM jump (m)	0.2 ± 0.1	0.2 ± 0.1	0.0 ± 0.2	0.103
20-m sprint (s)	4.4 ± 0.3	4.4 ± 0.3	0.0 ± 0.1	0.076

*$\dot{V}O_2max$ = multistage shuttle run (ml·kg^{-1}·min^{-1}); 1-kg Ball Throw = chest 1-kg medicine ball throwing (m); 3-kg Ball Throw = chest 3-kg medicine ball throwing (m); SL Jump = standing long jump (m); CM Jump = counter movement jump onto a box (m); 20-m Sprint = 20-m sprint running (s).

†Mean ± *SD* and paired t-test to maximal oxygen uptake ($\dot{V}O_2max$) and muscle strength variables pretraining and post-training in intrasession strength before aerobic training (GSA), intrasession aerobic before strength training (GAS) and control group (GC).

‡$p < 0.001$.

§$p \leq 0.05$.

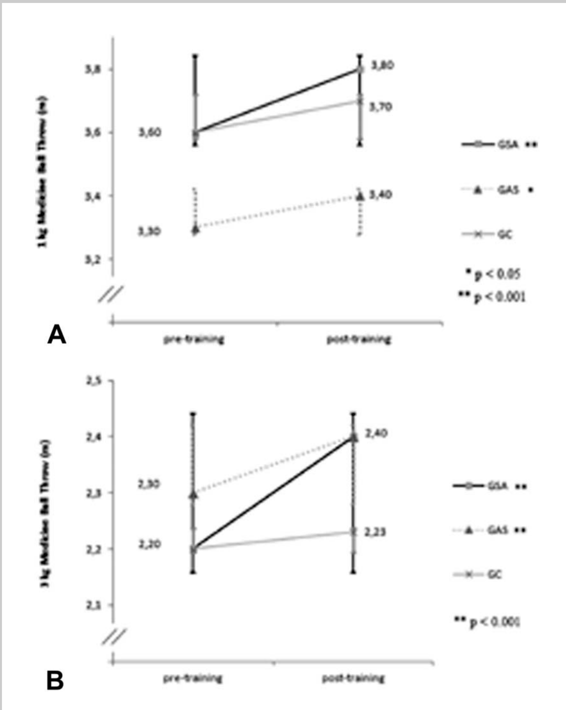

Figure 1. A) Obtained values in pretest and post-test of training in intrasession strength before aerobic training (GSA), intrasession aerobic before strength training (GAS), and control group (GC) on 1-kg medicine ball throw, (B) obtained values in pretest and post-test of training in intrasession strength before aerobic training (GSA), intrasession aerobic before strength training (GAS), and control group (GC) on 3-kg medicine ball throw.

Results

In pretraining, the results showed no differences in BMI, body fat, or any explosive strength variables between groups, with the exception of age ($F_{(2,125)} = 3.36$, $p \leq 0.05$) and aerobic capacity ($\dot{V}O_2max$) ($F_{(2,125)} = 5.44$, $p \leq 0.05$). We also showed differences between the GSA and GAS groups, and between the GAS, GSA, and GC groups (Table 2).

The explosive strength variables and the aerobic capacity variable increased significantly in the GSA and GAS groups from before to after the 8-week training session. The GC group presented no significant increases in the explosive strength variables nor in the aerobic capacity variable (Table 3). These results did not support the hypothesis that $\dot{V}O_2max$ increases independently from the implemented exercise training programs.

Regarding the effects of different types of training on explosive strength, changes from pretraining to post-training were observed (Table 3). The GSA group showed better improvement in the 1-kg medicine ball throw, 3-kg ball medicine ball throw, SL jump, CM jump, and 20-m sprint running tests compared with the other experimental group. The GAS group showed better improvement in $\dot{V}O_2max$ than GSA group.

There was a small effect of the group factor on changes in explosive strength measures from pretraining to post-training ($\eta_p^2 = 0.37$, $p < 0.001$). Moreover, medium effect sizes of the group factor were found for $\dot{V}O_2max$ ($\eta_p^2 = 0.27$, $F_{(2,125)} = 22.10$, $p < 0.001$) and 20-m sprint running ($\eta_p^2 = 0.30$, $F_{(2,125)} = 25.18$, $p < 0.001$). Small effect sizes of the group factor were found for the 1-kg medicine ball throw

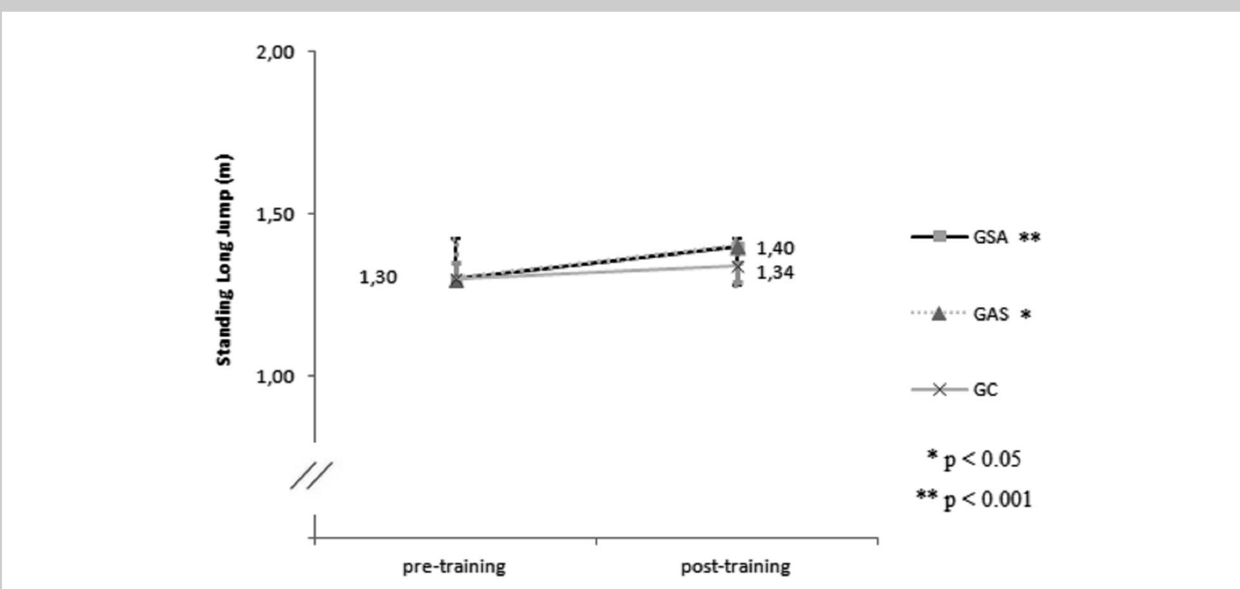

Figure 2. Obtained values in pretest and post-test of training in intrasession strength before aerobic training (GSA), intrasession aerobic before strength training (GAS), and control group (GC) on standing long jump.

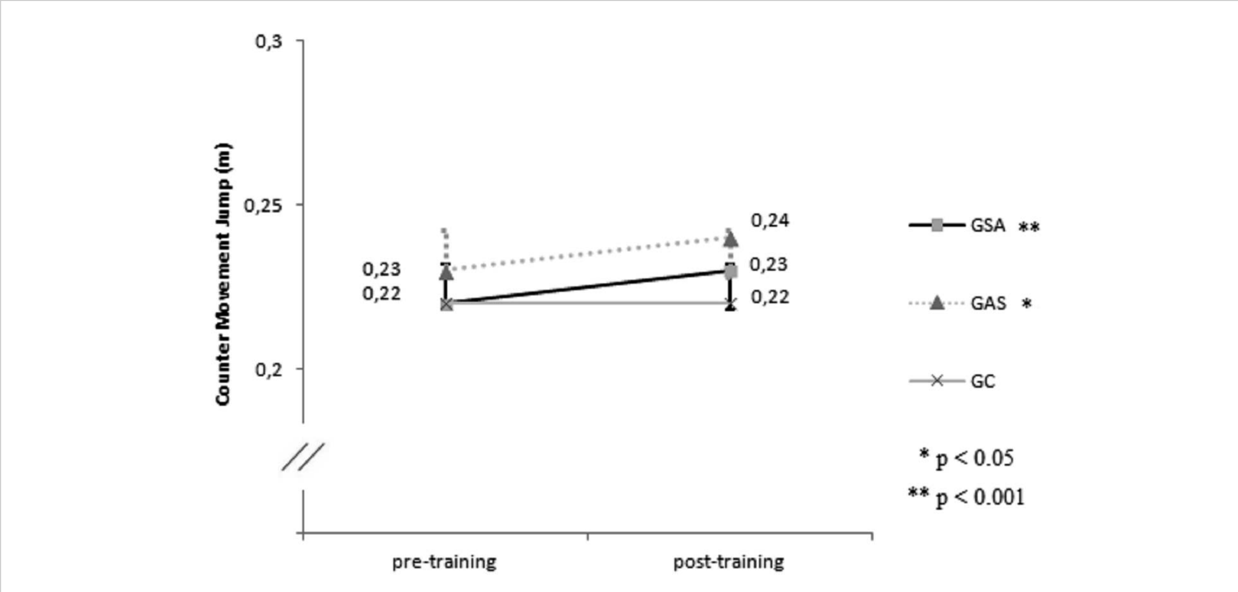

Figure 3. Obtained values in pretest and post-test of training in intrasession strength before aerobic training (GSA), intrasession aerobic before strength training (GAS), and control group (GC) on counter movement jump.

($\eta_p^2 = 0.17$, $F_{(2,125)} = 12.40$, $p < 0.001$), 3-kg medicine ball throw ($\eta_p^2 = 0.16$, $F_{(2,125)} = 11.60$, $p < 0.001$), and SL jump ($\eta_p^2 = 0.05$, $F_{(2,125)} = 3.37$, $p \leq 0.05$). A small effect size was also found for the CM jump ($\eta_p^2 = 0.04$, $F_{(2,125)} = 2.22$, $p = 0.11$), but the differences in the CM jump results between groups were not statistically significant.

We presented changes in the 3-kg medicine ball throw (Figure 1B), SL jump (Figure 2), and CM jump (Figure 3). Results from before to after training were significantly higher in the GSA and GAS groups than in the GC group. The increases in the 1-kg medicine ball throw (Figure 1A) and 20-m sprint running (Figure 4) results were significantly

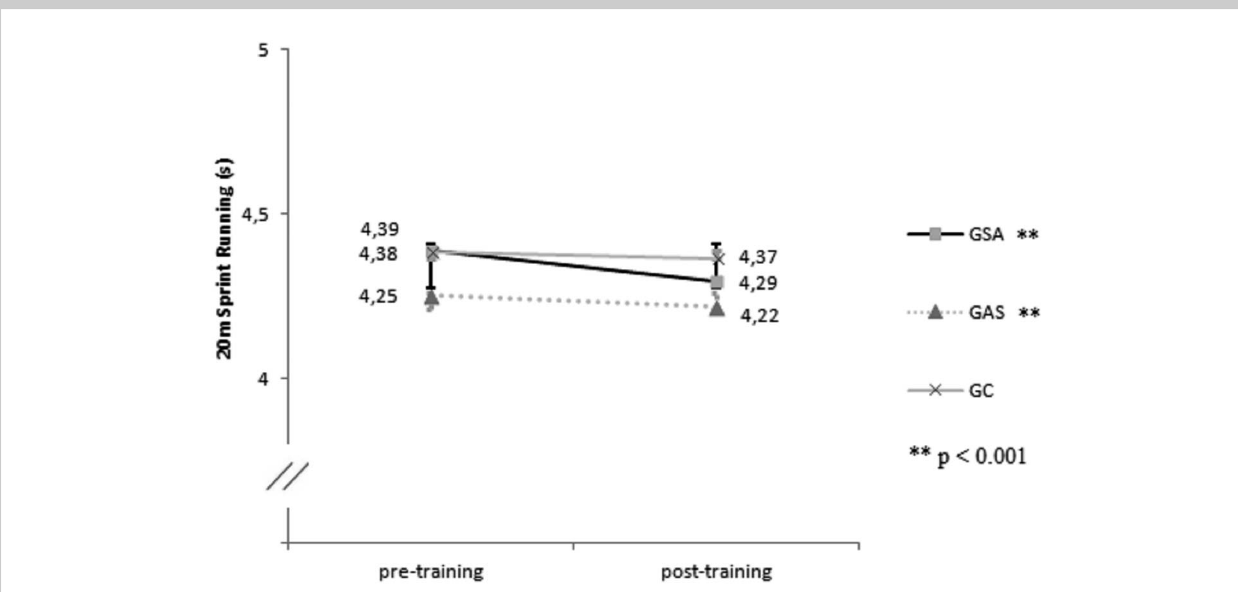

Figure 4. Obtained values in pretest and post-test of training in intrasession strength before aerobic training (GSA), intrasession aerobic before strength training (GAS), and control group (GC) on 20-m sprint running.

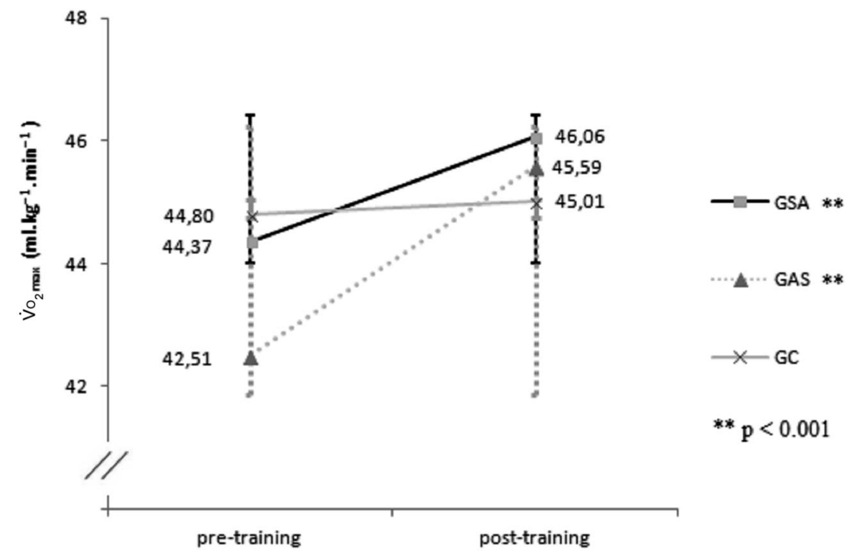

Figure 5. Obtained values in pretest and post-test of training in intrasession strength before aerobic training (GSA), intrasession aerobic before strength training (GAS), and control group (GC) on maximal oxygen uptake ($\dot{V}O_2$max).

higher in the GSA group than in the GAS group. In addition, $\dot{V}O_2$max (Figure 5) increased more in the GAS group than in the GSA group.

Discussion

The present study is the first to investigate the order effect of concurrent strength and aerobic training among prepubescent children. Specifically, the purpose of the current study was to compare the effects of an 8-week period of concurrent strength and aerobic training order on explosive skills and $\dot{V}O_2$max training parameters in prepubescent children. The main findings indicated that the intrasession concurrent training order (strength before aerobic training/aerobic before strength training) programs investigated here were effective, well-rounded exercise programs that can be performed to improve explosive strength in prepubescent children. Nevertheless, the GSA group produced better results than the GAS group. Additionally, the GAS group showed greater improvement in cardiorespiratory fitness than the other experimental group. These results are of great interest and are useful for optimizing and innovating school-based programs at sports clubs for children.

Concurrent strength and aerobic training have the potential to improve cardiorespiratory and muscular fitness simultaneously (6,8,40). However, for concurrent training, the best order for aerobic and strength intrasession training is unclear. For example, there are studies (4,11) that have reported that intrasession strength and aerobic training, regardless of training order, can similarly improve aerobic capacity and muscular strength and conclude that both training orders are equally effective. Yet, in the recent study, Kang and Ratamess (25) found that each intrasession training order had its own advantages that should be considered to make concurrent training more effective. Although the order effect of intrasession concurrent strength and aerobic training on training-induced explosive strength in prepubescent children has not yet been explored, the present study may provide reliable and useful information in this area.

In the current study, no significant differences were found between experimental groups (GSA and GAS) after training on the variables related to explosive strength and aerobic capacity, with the exception of the 1-kg medicine ball throw ($p \leq 0.05$). Moreover, there were overall increases in explosive strength of the upper and lower limbs for both experimental training groups, suggesting that intrasession strength training before aerobic training and intrasession aerobic training before strength training are both beneficial training stimuli for enhancing explosive strength and aerobic capacity in prepubescent children. The GSA group showed higher improvements than the GAS group in muscle strength variables: the medicine ball throws were higher (2.7 and 2.2% for the 1-kg and 3-kg medicine balls, respectively; $p \leq 0.05$), the jumps were higher (1.1 and 0.5% for the CM and SL jumps, respectively; $p \leq 0.05$), the 20-m times were lower (2.3%, $p < 0.001$). These results indicated that intrasession strength before aerobic training may be more effective than intrasession aerobic training before strength training to improve explosive strength in young children. This is consistent with studies by Cadore et al. (6,7) that observed greater maximal dynamic strength gains (upper and lower body) and greater force per unit of muscle mass in elderly men from a concurrent training group that performed strength training before aerobic training (maximal dynamic strength of upper body: +15%, maximal dynamic strength of lower body: +35.1%, and force per unit of muscle mass: +27.5%, $p < 0.001$, $p < 0.01$, and $p < 0.001$, respectively) compared with the reverse order (maximal dynamic strength of upper body: +11.5%, maximal dynamic of lower body: +21.9%, and force per unit of muscle mass: +15.2%, $p < 0.001$, $p < 0.01$, and $p < 0.02$, respectively).

Interestingly, the $\dot{V}O_2max$ was significantly greater after training in the GAS group compared with the GSA group (GAS: +7.3%; GSA: +3.8%, $p < 0.001$), suggesting that intrasession aerobic training before strength training may be more effective than intrasession strength training before aerobic training at improving aerobic capacity in prepubescent children. Nevertheless, this difference could have been because of the order of training used in the different groups or to acute neuromuscular fatigue induced by strength training (used in the GSA and GAS groups). Such residual fatigue may reduce the quality of aerobic training, leading to a reduction in aerobic development over time (38). In fact, the results of the present study are in line with the results of Chtara et al. (9), who investigated training order of concurrent aerobic and strength training on aerobic capacity and performance in male sports students (during 12 weeks, twice a week) and found that performing aerobic training before strength training could improve running performance and $\dot{V}O_2max$ to a greater extent than the reverse order (+8.57 and +13.71%, $p < 0.01$ and $p < 0.01$ vs. +4.66 and +11.01%, $p \leq 0.05$ and $p < 0.01$, respectively).

There is no consensus on the interference of intrasession concurrent training order in performance adaptations. There are studies (2,36,41) that have reported that intrasession strength and aerobic training, regardless of training order, does not impair physiological and performance adaptations. In contrast, other studies have provided evidence that the order of intrasession strength and aerobic training may affect performance adaptations (4,9,21). However, our findings may clarify previous evidence. Thus, in the current study, improvements in the explosive strength and in the aerobic capacity for both experimental training groups were found, indicating that concurrent training, regardless of training order, does not affect performance in school-age children. This is consistent with recent work showing that concurrent training is equally effective on training-induced explosive strength as only strength training in prepubescent children (33).

In brief, our data suggested that training order influences muscle strength and aerobic capacity improvement in prepubescent children. Therefore, these results are meaningful for the development of explosive strength and cardiorespiratory fitness training in school-based programs and sports clubs' programs, improving the specificity of training related to children characteristics, and contributing for the achievement of the results proposed. Furthermore, intrasession concurrent training order (strength training before aerobic training or aerobic training before strength training) seems to be effective at improving both explosive strength and aerobic capacity. Although all programs were effective, the GSA group produced better improvement in muscle strength variables than the GAS group, and the GAS group produced better improvement in aerobic capacity variables than the GSA group. Thus, it is also suggested that the effectiveness of the intrasession strength and aerobic training order may be dependent on the programs' priorities. Nevertheless, there are some limitations of this study that should be addressed: (a) field tests were only applied in the experimental training groups, and laboratory tests with higher control standards may have generated more accurate data; (b) different methods of organizing training workouts can lead to different training-induced outcomes.

Practical Applications

To increase the efficiency of physical education classes and to optimize exercise programs, intrasession strength before aerobic training and intrasession aerobic before strength training programs should be considered in school-based and sports clubs' programs. Furthermore, the youth strength and conditioning programs should include explosive strength and aerobic training as these are related with improvements in health, fitness, academic performance, and quality of life (5,37). However, if the main purpose is to improve aerobic capacity, intrasession aerobic before strength training should be used. To improve muscular strength, intrasession strength before aerobic training would be the most suitable alternative. Therefore, the current study is innovative, and these findings can be helpful for teachers, coaches, and researchers in their efforts with prepubescent children.

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