Concurrent Training with Different Aerobic Exercises

Abstract

The aim of the present study was to compare the effects of using different intensities and types of aerobic exercise (i.e., cycle ergometer or running) during concurrent training on neuromuscular adaptations. A total of 44 young women were randomly assigned to 1 of 4 groups: concurrent strength and continuous running training (SCR, n = 10), concurrent strength and interval running training (SIR, n = 11), concurrent strength and continuous cycle ergometer training (SCE, n = 11), or strength training only (STO, n = 12). Each group trained twice a week during 11 weeks. The following strength measurements were made on all subjects before and after training period: maximal strength (1RM) in knee extension, bench press and leg press exercises; local muscular endurance (number of repetitions at 70% of 1RM) in knee extension and bench press exercises; and isometric and isokinetic peak torque of knee extension. There were significant increases in the upper and lower-body 1 RM, isometric and isokinetic peak torque in all training groups (p<0.001), with no differences between groups. The present results suggest that in young women, concurrent training performed twice a week promotes similar neuromuscular adaptations to strength training alone, regardless of the type and the intensity in which the aerobic training is performed.

Introduction

The compatibility of different modes of exercise, particularly strength and aerobic training has been investigated over the last 3 decades [10]. The simultaneous performance of these 2 forms of exercise is called concurrent training. The main question that arises regarding this issue is whether the changes produced by aerobic and strength training are antagonistic or compatible, since the performance of aerobic training simultaneously with strength training might impair the magnitude of strength increases [3,4,6,27]. When this effect occurs, it is denominated the “interference effect”. Studies evaluating the effects of concurrent training on cardiorespiratory adaptations have shown the compatibility of both types of training in the aerobic performance [2,5,17,26,30]. However, the findings regarding the strength adaptations that occur during concurrent training regimes are controversial since some studies have found interference [3,5,7,19,24], while others found no such interference [15,16,30,35,38]. Some authors suggest that the intensity of aerobic training is a possible cause of this interference, pointing out that it only occurs at intensities close to the maximal oxygen uptake (VO_{2max}) [9,10]. Chtara et al. [9] found interference in the strength and power gains in physically active men who performed concurrent training when aerobic exercise was performed at a velocity associated to VO_{2max} (V\text{V}O_{2max}). These authors explain their results as a consequence of the high intensity of the aerobic training[9]. In another study, De Souza et al. [11] investigated the acute effects of 2 aerobic exercises (one close to the second ventilatory threshold (VT2) and the other at the v\text{V}O_{2max}) on maximal dynamic strength (one-repetition maximal test-1RM) and local muscular endurance performance (number of repetitions at 80% of 1RM) and found that only the higher intensity aerobic exercise impaired local muscular endurance. If high intensity running results in acute impairment, the chronic interference effect may be more pronounced in higher rather than lower aerobic intensities. However, data about the effects of dif-

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- compatibility
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Bibliography

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different intensities of aerobic exercise during concurrent training in the strength adaptations are scarce.

Comparing studies that used different types of aerobic exercise, such as running [2,9,20] or cycle ergometer [6,13,24,34], it appears that the performance of aerobic exercise on the cycle ergometer results in an interference effect on the development of strength at lower intensities than those observed during walking or running exercise. This can be explained by the impact of cycle ergometer exercise on the neuromuscular function of the lower limbs [28]. However, in the only study we found comparing concurrent training regimes using different types of aerobic exercise, Gerley [14] observed lower strength increases after concurrent training, in which aerobic exercise was performed on the cycle ergometer or inclined treadmill walking, compared with strength training alone. Moreover, this author observed higher strength values in the concurrent group that included cycling than in the other concurrent group that included aerobic exercise on the treadmill. Interestingly, this result was found in men but not in women. Thus, the data regarding the effects of concurrent training using different types of aerobic exercise are controversial.

To the best of our knowledge, there are no studies in the literature that compare the effects of concurrent training using different intensities of aerobic exercise on strength adaptations. In addition, there is very little information on the possible consequences of using different types of aerobic exercise during concurrent training in women. Therefore, the purpose of the present study was to compare the effects of using different intensities and types of aerobic exercise (i.e., cycle ergometer or running) during concurrent training on strength adaptations in women. Our hypothesis was that the interference effect, if it occurred, would be more pronounced in the high intensity running and cycle ergometer groups.

Methods

Experimental design

In order to investigate the influence of intensity and type of aerobic exercise in the strength adaptations to concurrent training, the participants were assigned to one of 4 groups: concurrent strength and continuous running training (SCR), concurrent strength and interval running training (SIR), concurrent strength and continuous cycle ergometer training (SCE), or strength training only (STO). The concurrent training groups performed both the aerobic and strength training programs in a single session, always beginning with aerobic training. A 2-min recovery period separated the training sessions. The total duration of training in the present study was 11 weeks, in which the subjects trained 2 times a week. Before the start of the training, subjects completed 2 familiarization sessions to practice the exercises they would perform during the training period. Before and after training, all subjects were tested for each of the following dependent variables: lower-body isometric and isokinetic peak torque, lower and upper-body 1 RM and local muscular endurance. All pre- and post-training testing procedures were completed within 1-week periods. Each subject performed the tests at the same time of day throughout the period of the study and the different tests were conducted on different days to avoid fatigue. In addition, an incremental treadmill test was performed at beginning of the training for all subjects to determine the VO2max, vVO2max and heart rate associated to the second ventilatory threshold (HRVT2). Moreover, the same cardiorespiratory data were determined during an incremental cycling test in the subjects assigned to the SCE group. These measures were repeated in the SIR, SCR and SCE groups halfway through the training to adjust the intensity of running or cycle ergometer training.

Subjects

48 women agreed to participate in this study. Subjects were all physically active but had not engaged in any structured training program for at least 3 months before the study and they were free from acute or chronic musculoskeletal disorders. 4 participants dropped out during the training period due to professional problems. At the end of the study, the number of subjects in each group was: SCR = 10; SIR = 11; SCE = 11; and, STO = 12. The study was conducted according to the ethical standard of the International Journal of Sports Medicine described by Harriss and Atkinson [19], and was approved by the Ethics Committee of the Federal University of Rio Grande do Sul, Brazil. Exclusion criteria included any history of neuromuscular, metabolic, hormonal and cardiovascular diseases. Subjects were advised to maintain their normal dietary intake throughout the study. Besides, all subjects were informed about the procedures and potential risks and gave their written informed consent to participate in the study. The baseline characteristics of the subjects who completed the training period in each group are presented in Table 1.

Body composition

Body mass and height were measured using an Asimed analog scale (resolution of 0.1 kg) and an Asimed stadiometer (resolution of 1 mm), respectively. Body composition was assessed using the skinfold technique. The same technician obtained all anthropometric measurements, on the right side of the subject’s body. Skinfold thickness was obtained with a Cescorf skinfold

<table>
<thead>
<tr>
<th></th>
<th>Strength training (STO n = 12)</th>
<th>Strength and continuous running training (SCR n = 10)</th>
<th>Strength and interval running training (SIR n = 11)</th>
<th>Strength and cycle ergometer training (SCE n = 11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>age (years)</td>
<td>23.5 ± 2.5</td>
<td>22.3 ± 2.1</td>
<td>24.3 ± 5.0</td>
<td>21.6 ± 1.8</td>
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<tr>
<td>body mass (kg)</td>
<td>59.2 ± 8.3</td>
<td>59.8 ± 6.7</td>
<td>59.0 ± 5.9</td>
<td>60.8 ± 6.5</td>
</tr>
<tr>
<td>height (cm)</td>
<td>165.8 ± 6.5</td>
<td>162.2 ± 4.5</td>
<td>166.7 ± 4.0</td>
<td>164.8 ± 2.1</td>
</tr>
<tr>
<td>% fat mass</td>
<td>27.7 ± 4.0</td>
<td>27.9 ± 4.0</td>
<td>27.1 ± 4.2</td>
<td>28.3 ± 3.6</td>
</tr>
<tr>
<td>VO2max (ml.kg⁻¹.min⁻¹)</td>
<td>33.7 ± 3.6</td>
<td>34.0 ± 5.0</td>
<td>34.6 ± 4.0</td>
<td>31.2 ± 4.1</td>
</tr>
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</table>

Values are means ± SD. No significant differences between training groups (p > 0.05). VO2max values were measured during a treadmill maximal test.
caliper. A 7-site skinfold equation was used to estimate body density [25] and body fat was subsequently calculated using the Siri equation [21].

Maximal dynamic strength
Maximal dynamic strength was assessed using the 1 RM on the exercises bench press, leg press and bilateral knee extension. 1 week prior to the test day, subjects were familiarized with all procedures. On the test day, the subjects warmed up for 5 min on a cycle ergometer, stretched all major muscle groups, and performed specific movements with 1 set of 15 repetitions with light load (30% of the first test load) in the exercise tests. Each subject’s maximal load was determined with no more than 5 attempts with a 4-min recovery between sets. Performance time for each contraction (concentric and eccentric) was 2 s, controlled by an electronic metronome (Quartz, CA, USA). The test-retest reliability coefficients (ICC) were over 0.96 for all exercises.

Local muscular endurance
The local muscular endurance (LME) consisted of the maximal number of repetitions achieved with 70% of the 1 RM load on the bench press and bilateral knee extension. For this test, the participants performed the same familiarization, warm-up and execution time procedures as in the 1 RM test. This test was finished when the participants were unable to perform more repetitions within the established execution time (2 s in each contraction phase) and/or with full movement amplitude. The post-training LME measurements were performed at the same relative load and compared to the pre-training measurements. The test-retest reliability coefficient (ICC) was over 0.87 for both exercises.

Isometric and isokinetic peak torque
Isometric and isokinetic testing was measured using a Cybex Norm II Isokinetic machine (Lumex Co., Ronkonkoma, NY, USA), calibrated according to manufacturing standards prior to each day of testing. 1 week prior to the test day, subjects were familiarized with both isometric and isokinetic tests. Each subject performed a similar warm-up consisting of 5 min of cycling and stretching. The subjects were maintained in position after adjustment of the height of the dynamometer and the length of the support lever, allowing the axis of rotation of the dynamometer to be aligned with the subject’s knee joint. Each subject was stabilized at the chest, waist, and thigh with a strap. A shin strap was secured to the lower leg proximal to the malleoli; the test was performed on the dominant limb.

Isometric peak torque was determined by measuring peak torque produced during a 5-s isometric knee extension at a knee angle of 45° from full extension (0°). 3 maximal 5-s isometric contractions were performed with 3-min rest intervals between each contraction. The contraction with the highest torque value was used in data analysis. The test-retest reliability coefficient (ICC) was 0.94. To determine the isokinetic concentric peak torque produced at speeds of 60 and 180°.s⁻¹, participants performed a maximal set of 5 repetitions at the 2 speeds. The set at 60°.s⁻¹ always preceded the faster set. Between the sets, 5 min intervals were utilized. The test-retest reliability coefficients (ICC) were over 0.95 for both velocities.

Maximal oxygen consumption and second ventilatory threshold
In order to measure the VO₂max and VT₂, all subjects performed a treadmill maximal test. The treadmill protocol consisted of an initial velocity of 5 km.h⁻¹ with 1% inclination for a period of 2 min. After this warm-up, the velocity was increased each minute by increments of 1 km.h⁻¹, and the inclination was maintained until the subjects reached their maximal effort. The assessment was considered valid when some of the following criteria were met at the end of the test [23]: estimated maximal heart rate (HRmax) was reached (220-age), plateau in VO₂ with increase in the treadmill velocity and a respiratory exchange ratio greater than 1.15 was reached. Indeed, the subjects of SCE group performed a second incremental test on a cycle ergometer (Cybex, USA) that was used to prescribe the intensity of aerobic exercise. They initially cycled with a 25 W load in the first 2 min, which was progressively increased by 25 W every 1 min, whilst maintaining a cadence of 70–75 rpm, until exhaustion. The test was halted when subjects were no longer able to maintain a cadence of over 70 rpm.

The VO₂max and VT₂ were measured using a mixing-box-type portable gas analyzer (VO2000, Inbramed, Porto Alegre, Brazil). The gas analyzer was calibrated prior to each collection session, according to the manufacturer’s instructions. The sampling rate of the collected values was 10 s. In addition, for the determination of HR at ventilatory threshold (HRVT₂), a Polar monitor (FS1, Shangai, China) was used. The VT₂ was determined using the ventilation curve corresponding to the second point of exponential increase in the ventilation in relation to the load [18]. In addition, to confirm the data, VT₂ was determined using the CO₂ ventilatory equivalent (VE/VO₂CO₂). 3 experienced, independent physiologists determined the corresponding points.

Training programs
Subjects of each group took part in a training program that lasted 11 weeks. These subjects trained on Mondays and Thursdays or on Tuesdays and Fridays. All the training sessions were carefully supervised by at least 2 experienced personal trainers.

Strength training
The same strength-training program was performed for all groups and was designed to improve muscular endurance in the first 5 weeks and subsequently to stimulate muscular hypertrophy and maximal strength gains [1, 7]. These individuals performed 7 exercises (inclined leg press, knee extension, leg curl, bench press, inverted fly, upright row and sit-ups) 2 times a week on non-consecutive days. In each session, subjects performed muscle specific stretching and a standardized warm-up with 1 set of 25 repetitions with light load to upper and lower body. During the training program, all the sets were performed until failure. In each set the workload was adjusted when the repetitions performed were either under or above the repetitions established. The recovery time between sets was 120 s. The absolute total load of the 4 groups was recorded at the start of each mesocycle (weeks 1, 3, 6 and 9), and is presented in the Table 2. There were no differences between groups in the absolute total load in the mesocycles evaluated.

Concurrent training
Subjects performed both strength and aerobic programs on the same day, in which the aerobic sessions were performed first and were immediately followed by the strength session. The
concurrent groups had their training programs differentiated by the intensity or type of aerobic training, in which SCR and SCE (using running and cycle ergometer, respectively) realized continuous training at a heart rate equivalent to 95% of the VT2 (±± bpm) and SIR realized interval running training which consisted of 1 min bouts at vVO2max, with 1 min of active recovery bouts at 50% of maxVO2. The participants in all groups performed the same duration of aerobic exercise. In each session, subjects performed a standardized warm-up lasting 5 min at comfortable intensity on treadmill or cycle ergometer. The whole strength and aerobic training periodization is shown in Table 3.

Statistical analysis

The data are presented as mean ± standard deviation of the mean (SD). The normality of the data distribution was tested using the Shapiro-Wilk’s test. The training-related effects were assessed using a 2-way Analysis of Variance (ANOVA) with repeated measures (group × time). When a significant P-value was achieved, Bonferroni post-hoc procedures were used to locate the pairwise differences. Selected relative changes between groups were compared via one-way ANOVA. An alpha level of 0.05 was used for all statistical tests, which were performed using the SPSS software (version 15.0).

Results

All subjects performed at least 90% of training with no difference between groups in the number of sessions performed (STO, SCE and SIR: 21 of 22 and SCR: 20 of 22 sessions). There were no differences among groups in any dependent variables studied before the start of the training (P > 0.05).

The 1 RM values are shown in Table 4, Fig. 1a, b, c. There were significant increases in the upper (bench press) and lower-body (leg press and knee extension) 1 RM strength in all training groups (P < 0.001). The results showed no time × group interactions in the bench press (P = 0.955), leg press (P = 0.311) and knee extension exercise (P = 0.212), indicating that the training effect was independent of the group. Moreover, no differences between groups in percent increases were present (leg press: P = 0.218; knee extension: P = 0.113; and bench press: P = 0.650).

The isokinetic muscular torque values are shown in the Table 4, Fig. 2a, b. There were significant increases in knee extension isokinetic torque at 60° (P < 0.01) and 180° s⁻¹ (P < 0.001) in all training groups. The results demonstrated no time × group interactions at velocities of 60° (P = 0.516) and 180° s⁻¹ (P = 0.951) and no differences in percent increases between groups (60°: s⁻¹: P = 0.804; 180° s⁻¹: P = 0.772).

The isometric muscular torque values are shown in the Table 4 and Fig. 2c. There was a trend towards time effect in the knee extension isometric torque (P = 0.055) in all training groups. There was no time × group interactions in the isometric muscular torque (P = 0.928) and no differences in percent increases between groups (P = 0.906).

The LME values (number of repetitions at 70% of 1 RM) are shown in Table 4. There were significant decreases in the upper (bench press) and lower-body (knee extension) LME in all training groups (P < 0.001). The results also showed no time × group interactions in the bench press (P = 0.793) and knee extension exercise (P = 0.473).

Discussion

The primary finding of the present study was the similar results in all training groups in the maximal strength, isometric and isokinetic torque and LME, regardless of the type of aerobic exercise and the intensity at which it was performed. Thus, our hypothesis was rejected since the results showed no interference effect in the concurrent training groups.

In the last 3 decades, several studies have evaluated the effects of concurrent training on a number of neuromuscular parameters [2–6,9,12,13,15–17,20,22,27,30,31,34,35,37]. Some studies found conflicting results, since some found interference in the group that performed the concurrent training [4,6,9,22,27], while others found no such interference [15,16,30,35,38]. Our findings corroborate those of studies that reported similar strength gains in strength and concurrent training groups [15,16,30,35,38], since there was no interference in any of the analyzed variables.

It has been suggested that different aerobic modalities (running and cycle ergometer) present different motor unit recruitment patterns when individuals exercise at the same physiological intensity. The cycle ergometer exercise presents a higher excitation threshold for motor unit recruitment (responsible for greatest strength production) when compared to running exercise, especially at intensities close to the second ventilatory threshold [11,28]. This fact would lead to a competitive recruitment of motor units used in both types of training, creating localized fatigue in these motor units, resulting in impaired development of muscular strength [6], especially in individuals performing aerobic exercise on a cycle ergometer. To answer this question, this study used the same relative physiological intensity of aerobic exercise, but in different modalities: running and cycle ergometer, in 2 groups (SCR and SCE groups). The different motor unit recruitment patterns produced in running and on the cycle ergometer were not enough to interfere with strength adaptations from the concurrent training. Our results are in accordance with those reported by Gerley [14], who, when comparing women in a concurrent group performing cycling with another performing aerobic exercise on a treadmill, found no
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... interference in the strength adaptations. The discrepancies between the studies that observed an interference effect using a cycle ergometer as an aerobic modality during concurrent training and our findings might be explained by the volume of training per week, since the interference effect in these studies was observed when the number of training sessions in both modalities (i.e., strength and aerobic) was equal to, or higher than 3. For example, Bell et al. [5], when investigating young women, showed the interference effect in the concurrent group performing 3 sessions per week in each modality (i.e., strength and cycling aerobic exercise). In the present study, each type of training was performed twice a week, which was an insufficient volume to induce differences in the increase of the analyzed strength variables. Another possible explanation could be the greater time window between training sessions applied in the present study (~72 h), when compared to other studies of concurrent training (~48 h) [5,6], which might have been sufficient to allow adequate muscle recovery.

Recent studies have found interference in different strength parameters [9,11] and suggested that the intensity of aerobic training is crucial to the appearance of such interference. Chitara et al. [9] found interference in strength gains and muscle power in men who performed a concurrent training twice a week dur-
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ing 12 weeks, in which aerobic exercise was performed at high intensity interval training (close to VO2max). These authors suggested that this high intensity may be responsible for the results, and that fatigue in the muscles involved in both training modes was crucial to the impairment of these adaptations. To answer this question, the present study used different intensities (one corresponding to 95% of HRVT2 and the other to the vVO2max) in various training modes, including a group (SIR) which performed high-intensity interval training (vVO2max) and no interference was found.

Some studies [11, 29] have demonstrated that strength might be acutely compromised when the concurrent training session starts with an aerobic exercise. This interference is explained by the existence of residual fatigue resulting from the first activity (aerobic exercise), resulting in reduced performance during the second activity (strength training). These authors suggested that this sharp drop in force production after aerobic exercise could chronically compromise strength development. In the present study, the sessions always began with aerobic exercise in order to maximize any potential acute interference based on the hypothesis suggested by the above-mentioned authors. However, no interference was found in the groups that underwent concurrent training, a fact that nullifies this hypothesis related to the order of training as an explanation for the lower gains in neuromuscular variables found in these studies.

Some authors suggest that the interference effect in concurrent training mainly occurs in muscle power gains [13, 15], and this may be associated with the neural mechanisms of strength production [17]. Dudley and Djamil [13] and Glowacki et al. [15] found increases in isokinetic torque at high (180°.s−1) and low (60°.s−1) speeds in all training groups, but the magnitude of the response was smaller at the higher speed in the concurrent training group when compared to the strength group. In the present study, the isokinetic torque was assessed at different speeds in order to verify if the pattern reported in the above study was repeated. However, no interference was observed in this variable, regardless of speed. This discrepancy between the results of the present study and those reported by Dudley & Djamil [13] and Glowacki et al. [15] may be due to methodological differences between the studies. These findings suggest that even in rapid manifestations of strength (torque at 180°.s−1), the methodology adopted in our study for the groups that underwent concurrent training was adequate to obtain results similar to those found when strength training is performed alone.

It is important to note that the subjects of the present study were physically active women and it is unclear if the same strength development pattern would be observed in athletes, since the initial level of physical fitness seems to be one of the factors that might influence the strength adaptations to concurrent training.

Table 4 One repetition maximum test (1RM), LME (number of repetitions at 70% of 1 RM), peak torque of knee extension (isometric and isokinetic at 60 and 180°.s−1) pre and post-training in strength group (STO), concurrent strength and continuous running group (SCR), concurrent strength and interval running group (SIR) and concurrent strength and continuous cycle ergometer group (SCE).

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<td>Pre</td>
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<td>Pre</td>
<td>180°s−1</td>
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<tr>
<td>1RM knee extension (kg)</td>
<td>74.7±10.8</td>
<td>104.7±10.9</td>
<td>86.3±12.9</td>
<td>109.8±13.4*</td>
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<tr>
<td>1RM leg press (kg)</td>
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<td>1RM bench press (kg)</td>
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<tr>
<td>LME knee extension (N)</td>
<td>10.1±1.2</td>
<td>9.1±1.3*</td>
<td>9.0±1.5</td>
<td>8.3±1.1*</td>
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<tr>
<td>LME bench press (N)</td>
<td>12.1±1.7</td>
<td>11.6±1.8*</td>
<td>12.7±2.3</td>
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<tr>
<td>Isokinetic peak torque (Nm)</td>
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<td>Isokinetic peak torque (Nm)</td>
<td>146.8±19.3</td>
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<td>141.9±30.7</td>
<td>151.6±41.6*</td>
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<tr>
<td>Pre</td>
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<tr>
<td>1RM knee extension (kg)</td>
<td>74.7±10.8</td>
<td>104.7±10.9</td>
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<td>1RM leg press (kg)</td>
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<td>1RM bench press (kg)</td>
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<td>Isokinetic peak torque (Nm)</td>
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Values are means ± SD. *Significant difference from pre training values (P<0.01)
rent training and could partially explain the variability found in the results regarding the interference phenomenon [15,30]. Therefore, the present concurrent training protocol, using high-intensity aerobic training and a longer time window between training sessions should be investigated in well-conditioned subjects or athletes as a way of avoiding the interference effect. The reduction seen in all the groups in the number of repetitions performed at 70% of 1 RM in the knee extension and bench press exercises was unexpected, since Shimano et al. [33] suggest that the number of repetitions performed at different percentages of 1 RM does not vary with the level of training. Even though these results show a different response from that found in the literature, it is important to note that this pattern was similar in all the training groups, so that any possible interference in the responses of muscle resistance related to concurrent training can be discarded.

In conclusion, our findings do not support the existence of an “interference effect” between concurrent strength and aerobic training with respect to strength gains. The results of this study suggest that in young women, concurrent training performed twice a week does not seem to affect the changes that occur in terms of strength development in response to 11 weeks of training, regardless of the type of aerobic exercise and the intensity at which it is performed. It should be highlighted that the volume performed per week and the time window between training sessions applied in the present study (72 h) appear to be appropriate to avoid the interference effect. These findings have important implications for professionals designing exercise programs to improve health and fitness in the general population.

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