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EFFECTS OF CONCURRENT TRAINING AND STRENGTH TRAINING TO GAIN STRENGTH AND MUSCLE HYPERTROPHY

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Abstract: Concurrent training (CT) can be described as a type of training that involves aerobic training (AT) and strength training (ST) in the same session, with the order of execution being able to vary. The aim of this review was to analyze the findings of research that compared CT and ST in gaining strength and muscle hypertrophy. The search for works took place in the Google Scholar database and included the following descriptors: concurrent training; strength training; muscle strength and hypertrophy; Studies published in Portuguese (Brazil) in the period 2000-2021 were included and the sample was divided into at least the CT group and the ST group. A total of 500 titles and abstracts were analyzed and 10 studies were selected in full to compose the present review. From the results found, it can be concluded that both types of training promoted increases in muscular strength, both in adult women and men, and in elderly men and women, with no statistical differences between the modalities. For muscular hypertrophy, there was no difference between the modalities and the order of execution of aerobic training and ST within the TC does not seem to interfere with the gain of lean mass.
Keywords: Concurrent Training, Strength Training, Strength, Muscular Hypertrophy, Interference.

INTRODUCTION

Practicing physical activity is associated with improving aspects of quality of life, regardless of age, gender and professional occupation (SILVA et al., 2010). Specifically, weight training, also called bodybuilding, resistance training or strength training (ST) promotes strength gains and increases in lean mass (DOS SANTOS et al., 2002; DIAS et al., 2005).

People who are physically active, regardless of whether they practice weight or aerobic exercises, show better results in parameters related to quality of life (MACEDO et al., 2003). The study by Raso and Greve (2012) shows that both weight exercises and aerobic exercises produce results that improve performance in activities of daily living in elderly women. If administered correctly, physical exercise provides benefits to the psychobiological aspects of practitioners, improving their quality of life (MELLO et al., 2005).

Considering the gains in quality of life and physical capabilities, aerobic physical exercise also stands out as an important ally, especially from the point of view of preventing and treating cardiovascular diseases. (MARTINS-SANTOS et al., 2020).

In the literature, combined and concurrent training appear as very close concepts that can be described by a type of physical training that involves aerobic (AT) and strength training in the same session, with the order of execution being able to vary (PRADO, 2017; CADORE, 2009; GOMES, BREDA and CANCIGLIERI, 2017). In the present study, this type of training will be approached using the term concurrent training (CT). In this sense, CT has gained notoriety and new followers. A recent study showed that CT was able to generate a significant increase in muscle strength in both the upper and lower limbs, in addition to preventing a decrease in cardiorespiratory capacity in women aged between 40 and 60 years (DOS SANTOS et al., 2020).

Regarding health benefits, it is known that both modalities, CT and ST provide numerous benefits, however when we consider the gain in strength and muscular hypertrophy, it is still not very clear in the literature which modality has superior effects and there is still interference from the AT within the CT in this response. Therefore, the aim of the present study was to analyze the findings of research that tested CT strategies in comparison to ST

in gaining strength and muscle hypertrophy.

METHODS

This study was characterized by a descriptive literature review with the theme "Effects of concurrent training and strength training on strength gain and muscular hypertrophy".

PROCEDURES

A search was carried out in the Google Scholar database, with the following descriptors: concurrent training; strength training; strength; Muscular hypertrophy. The search for works in the Google Scholar database included the period 2000-2021, based on relevance, analyzing all titles in Portuguese of works found up to page 50, resulting in a total of 500 titles.

Initially, all titles that presented two or more keywords or their synonyms, that have a human sample and/or that the title was considered relevant to the objective of the present review were selected, resulting in 111 works. Subsequently, in the second moment, through titles and abstracts, the works were selected according to the inclusion and exclusion criteria listed in topic 2.2, resulting in 17 studies. In the third moment, a complete reading of the works found was carried out and 10 studies were selected to compose the review.

INCLUSION AND EXCLUSION CRITERIA

Original articles, dissertations and theses were selected. National studies published in Portuguese (Brazil) from the year 2000 onwards were included, which evaluated concurrent training and strength training, in a weight room, on strength gain and/or hypertrophy. Studies with adults and elderly people regardless of gender and who were divided into at least two groups in the study were included: concurrent training and strength training to analyze strength and/or muscular hypertrophy. On the other hand, abstracts, reviews, citations, reports, books, studies in other languages, studies with animals, with supplementation and studies with blood flow restriction were excluded.

DATA EXTRACTION

After identifying the keywords in the title and abstract, the studies were selected and read in full. The search and analysis of studies occurred independently by one evaluator, with the final analysis debated by a second evaluator, reaching a final consensus. The following characteristics of the studies were recorded: name of the first author, year of publication, sample size, average age, aerobic physical exercise protocol - frequency, duration and intensity, volume of concurrent and strength exercises and the main results found for strength gain and hypertrophy.

Figure 1 describes the flowchart of the work selection process.

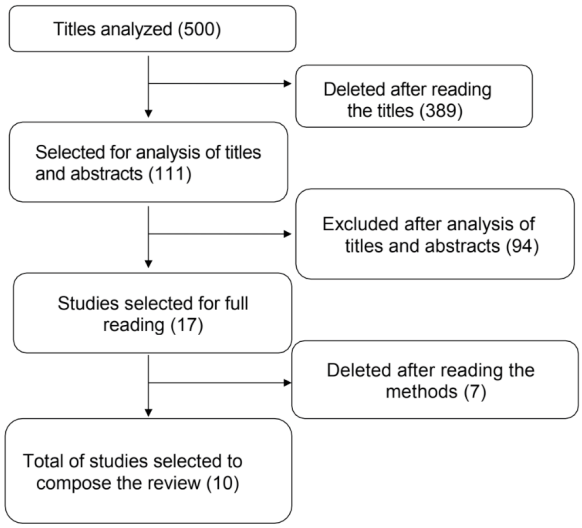

Figure 1 - Study search and analysis stages.

LITERATURE REVIEW

This review sought to substantiate and discuss the effects of CT, mainly on the development of strength and muscular hypertrophy. Given this, the beginning of the review addresses some of the studies that included CT protocols in their research, as well as the presentation of findings relating to this method, and finally, the review ends by addressing the effects of CT in comparison with ST, in development of strength and hypertrophy, in accordance with the studies found in the previously described method.

EFFECTS OF CONCURRENT TRAINING

Several studies have used different concurrent training (CT) strategies to investigate the responses of this training in the human body, among them, there are studies comparing the effects of CT on the functional autonomy of elderly practitioners and non-practitioners (NUNES-JUNIOR, 2010), on strength and body composition in postmenopausal women (BONGANHA et al., 2008), on waist circumference (WC) and resting metabolic rate in menopausal women (ROSSI et al., 2013), on biochemical parameters, cardiovascular fitness, neuromuscular and WC in elderly women (CAMPOS et al., 2013), in maximum strength, anaerobic threshold and oxygen consumption (VO2peak) in middle-aged men (LIBARDI, 2011), in strength and balance gains in elderly women (DEL PONTE, 2013), in exercise variation and aerobic intensity in the cardiorespiratory and neuromuscular responses of young women (SILVA, 2010) and in muscle activation and strength, hormonal concentrations and endurance capacity in elderly men (CADORE, 2009).

Regarding the effects of CT on functional autonomy, the work of Nunes Júnior (2010) compared the aspects of functional autonomy in elderly people who practiced CT or not. For this study, the sample consisted of 31 elderly people over 60 years of age who were divided into a practicing group (n=15) who underwent CT for at least three months prior to the testing period and a non-practicing group (n=16), the battery of tests (GDLAM) used movements characteristic of everyday life and evaluated the time spent by the elderly to carry out activities. It was seen that in all the variables observed, the group of practitioners showed better results compared to the group of non-practitioners, showing that in elderly people, in accordance with time savings, CT can result in greater autonomy in activities of daily living.

In addition, the study by Bonganha et al. (2008), used 10 weeks of CT to compare the results in muscle strength, flexibility and body composition of postmenopausal women who were or were not undergoing hormone replacement therapy, dividing 18 volunteers into a group with therapy (n =8) and group without therapy (n=10), participants performed 3 CT sessions per week, the sessions were composed of weight training and aerobic training, at the end of the study increases were observed in indicators of maximum muscular strength (1 -RM) without significant difference between the groups, but with a significant difference between the pre- and post-intervention moments. In the assessment of flexibility, the groups showed a significant increase only in the Wells bench test. Both groups did not show significant differences in body composition variables.

With the aim of verifying WC and resting metabolic rate (RMR) in menopausal women after eight weeks of CT, Rossi et al. (2013), selected a sample that consisted of 33 women, divided into a control group (CG) (n=13) and a training group (TR) (n=20), the TR group performed CT sessions three times a week on non-consecutive days, each session It lasted

90 minutes, the session time was divided into 50 minutes for resistance training, 30 minutes for AT and 10 minutes of stretching to end the session. At the end of the intervention, the authors reported a reduction in body fat and an increase in lean mass in the TR group, resulting in significant differences when compared to the CG, whereas in the RMR, the intervention did not result in an increase.

Observing the studies that investigated the effects of CT on body composition, it is possible to find divergences, as some studies such as those by Rossi et al. (2013) and Libardi (2011) present positive results of increasing lean mass, while studies by Bonganha et al. (2008) and Campos et al. (2013), did not find a significant improvement in this variable after CT intervention, even with the training duration varying between 8 and 16 weeks (BONGANHA et al., 2008; CAMPOS et al., 2013; ROSSI et al., 2013; LIBARDI, 2011).

On the other hand, in CT, the increase in muscular strength can be observed more frequently in several studies, which varied the protocols between 10 and 16 weeks in duration (BONGANHA et al., 2008; CAMPOS et al., 2013; LIBARDI, 2011; DEL PONTE, 2013; SILVA, 2010; CADORE, 2009).

De Sá et al., (2013) used a longer recovery time between strength training and endurance training sessions in order to evaluate the results of strength, oxygen consumption and hypertrophy. The study lasted 12 weeks and had a weekly frequency of 3 sessions, with strength training carried out in the morning and endurance training in the afternoon, with an interval of approximately 7 hours between them. The authors concluded that there were no significant effects on anthropometric aspects and that there were gains in aerobic power and muscular strength, very similar to training protocols carried out in isolation. However, the strength variable was negatively influenced in concomitant training.

Regarding the order of execution of strength and aerobic exercises, some authors observed the influence on the order of CT on several variables, among them, the physical fitness aspects of women over 50 years old (SILVA; ROMBALDI; CAMPOS, 2010), the response on post-exercise oxygen consumption (EPOC) according to the order and type of training (LIRA et al., 2007) and body composition of young women (GUIMARÃES; COELHO; MARESANA, 2017).

Trindade (2011), for example, observed the development of the training load of elderly men who performed 3 weekly sessions for 12 weeks, divided into two groups that performed CT in reverse order. At the end of the study, the author concluded that over the weeks of training, as exercise intensities increased, the order of exercise execution appeared to influence development results, showing greater gains in the group that performed strength training prior to aerobic training. On the other hand, Wilhelm Neto (2013), also studied elderly people and concluded that performing 2 weekly CT sessions, for 12 weeks, with aerobic exercise performed at moderate intensity, the results in gaining muscle strength seem to show no interference, even in different orders of aerobic exercise.

Different results could also be observed in other studies, such as that by Silva (2020), who found no difference in the order of exercises, and by Cadore (2012), who found greater results in muscle strength in the group that performed ST before AT.

It is important to highlight that such differences in results between studies can be explained by variations in sample selection, such as mean age, number of male and female individuals differing and also the use of different ergometers to perform aerobic training as well as the variation of exercises in the weight room.

EFFECTS OF CONCURRENT TRAINING AND RESISTANCE TRAINING ON STRENGTH GAIN AND MUSCLE HYPERTROPHY

In recent times, CT has been studied by several researchers and the results regarding the effects on the development of strength and muscular hypertrophy are not yet well defined (CADORE, 2009; SILVA, 2010; SOUZA, 2010; LIXANDRÃO et al., 2012; MENDES JUNIOR et al., 2012; CAMPOS et al., 2013; DEL PONTE, 2013; CONCEAÇÃO, 2015; PARMEZZANI, 2017; PRADO, 2017).

While some studies sought to observe the effects of CT on muscle strength (CADORE, 2009; SILVA, 2010; DEL PONTE, 2013; CONCEAÇÃO, 2015), others also evaluated body changes, such as increased lean mass (SOUZA, 2010; LIXANDRÃO et al, 2012; MENDES JUNIOR et al., 2012; CAMPOS et al., 2013).

Silva (2010), for example, compared the results of different training programs, varying the type and intensity of aerobic exercise in the CT protocol; divided 44 young, physically active women into 4 groups: strength group (ST), competitor 1 (GCC: continuous competitor), competitor 2 (GCI: interval competitor) and competitor 3 (GCB: continuous competitor on cycle ergometer); After 11 weeks of intervention, the author concluded that although an increase in strength may have been observed, there were no significant differences between the groups, concluding that the type and intensity of aerobic exercise did not interfere with the development of muscular strength, even when comparing the CT groups with the group that performed ST alone.

Corroborating these findings, the study by Souza (2010), in order to evaluate the muscular strength and hypertrophy of the lower limbs in active individuals, chose to analyze the muscular cross-sectional area of the quadriceps femoris muscle, and the muscular strength in the leg exercise press, using the 1 repetition maximum (1-RM) test.

The results observed regarding muscle development demonstrated positive effects in both training, with no difference between the ST and CT groups, a result similar to the data presented in the 1-RM test, which after the training period, the ST and CT groups showed increases in the pre- and post-intervention moments, but no significant difference was found between the two groups, suggesting that after 8 weeks of study, the CT group presented similar results to strength training carried out in isolation, indicating that the high intensity of the training, combined with a period of 8 weeks, did not generate an interference effect.

The research of Cadore (2009), demonstrated that when separating twenty-three elderly men into different training groups, it was possible to observe that after 12 weeks, there was an increase in muscular strength both in the group that performed only ST, and in the group that performed CT. In the lower limbs, more precisely in a test that assessed maximum strength in knee extension, the ST group showed greater results in this variable than the CT group, showing a significant difference, however in the upper limbs, through evaluation in the bench press, this difference in results was not significant between the two groups. Suggesting a local interference effect when, in the CT protocol, the aerobic activity uses the same muscle group and was performed prior to the AT.

On the other hand, other studies suggest that performing AT before ST promotes similar increases between ST and CT groups (SILVA, 2010; PARMEZZANI, 2017; CAMPOS et al., 2013), while other authors found an interference effect on strength using AT before ST (CADORE, 2009; DEL PONTE, 2013).

Campos et al. (2013), verifying the effects

of CT on strength and body composition in elderly women, selected a sample of 22 active elderly women, who were divided into 5 groups, namely, strength training (ST: n=4), aerobic training (AT : n=5), strength and aerobic (SA: n=5), aerobic and strength (AS: n=5) and control group (CG: n=3). After 12 weeks of training, the authors observed that for muscle strength, there was no significant difference in the groups that performed the strength training. The authors concluded that the results of concurrent training protocols were considered similar to strength training performed separately.

When comparing the study by Campos et al. (2013) with that of Del Ponte (2013), it is possible to identify similarities in the studied population, consisting of active elderly women who performed AT on a treadmill, but obtained different results; with Del Ponte (2013), showing an interference effect on the production of maximum strength in a 10-week intervention, a shorter time than the study by Campos et al. (2013), which lasted 12 weeks, but did not observe differences between the groups, in both, those evaluated performed 3 sessions per week. Possibly, the divergence between these works was due to the sample number being larger in the study by Del Ponte (2013) compared to that by Campos et al. (2013).

Despite the reverse order of execution of the exercises, studies by Silva (2010) and Prado (2017) observed that there was no significant effect of interference on the development of muscular strength in CT when compared to ST in different modalities and intensities of aerobic exercise.

There are results showing that the performance of the CT without interference in strength occurs when in the CT protocol, the ST is performed prior to the AT (LIXANDRÃO et al., 2012; MENDES JUNIOR et al. 2012; CONCEAÇÃO, 2015; PRADO, 2017). On the other hand, Parmezzani (2017), Campos et al. (2013) and Silva (2010), did not find a significant difference when performing the AT before the ST. Additionally, Souza (2010) did not obtain an interference effect on muscle strength, performing the CT in alternating order.

When observing the aspects related to the increase in muscle mass, the studies found showed no difference between the groups, either in cases where there was an increase (MENDES JUNIOR, 2012; SOUZA, 2010), or in cases where there was no difference after the weeks of training (LIXANDRÃO et al., 2012; CAMPOS et al., 2013).

Table 1 describes the studies discussed in this review that used concurrent training and strength training to gain strength and/or muscular hypertrophy.

CONCLUSION

Taking into account the aspects related to the studies that addressed ST and CT in some way, comparing their results on muscular strength and/or hypertrophy, it is possible to observe that the majority of the studies analyzed concluded that there was no interference effect on the development of muscular strength in CT practitioners, in the same way, they showed that performing AT on different ergometers and intensities does not seem to negatively influence strength gains. On the other hand, there was a negative influence on the CT in some results that found an interference effect, performing the AT before the ST.

Given this, it is possible to conclude that both modalities offer increases in maximum strength markers, both in adult women and men, and in elderly men and women. Although muscle hypertrophy was rarely observed in the present study, there was no difference between the CT and ST groups.

Therefore, to address the effects of CT

Author(s), year and type of study	Sample	Aerobic type	CT Order	Frequency and duration	Main results
Cadore (2009), dissertation	23 healthy men (65 ± 4 years), without systematic training for at least 1 year.	Cycle ergometer	ET+ST	3 times a week, for 12 weeks.	**FM (1RM):** MMII: Knee extension (GF: ↑↑), (GC: ↑). MMSS: Bench press (GF: ↑), (GC:↑)
Silva (2010), dissertation	44 apparently healthy, physically active women, 18-28 years old.	Treadmill and cycle ergometer	AT+ST	2 times a week for 11 weeks	**FM (1RM):** there was no significant difference between the groups. (GF: ↑), (GCC: ↑), (GCI: ↑), (GCB: ↑).
Souza (2010), dissertation	37 active individuals (23.7±5.5 years old), without exercising their lower limbs for at least 6 months.	Treadmill	Alternated	Twice a week, for 8 weeks.	**FM (1RM):** Leg press**.** MMII (GF: ↑), (GC: ↑) **HM:** ASTM. MMII**:** (GF: ↑), (GC: ↑)
Lixandrão etal. (2012), dissertation	24 postmenopausal women.Not physically active.	Athletics track	ST+AT	3 times a week for 16 weeks	**FM (1RM):** (GF: ↑), (GC: ↑) **HM:** AMC no significant difference after training.
Mendes Junior et al. (2012), original article	49 clinically healthy middle-aged men who did not practice systematic exercise.	Athletics track	ST+AT	3 times a week for 16 weeks	**FM (1RM):** Leg press. (GF: ↑), (GC: ↑) **HM:** ASTC: (GF: ↑),(GC: ↑)
Campos etal. (2013), Original article	22 physically active elderly women.	Treadmill	ST+ATe AT+ST	3 times a week for 12 weeks	**FM (1RM):** (GF: ↑), (both from GC:↑) **HM:** no significant difference after training.
Del Ponte(2013), dissertation	32 elderly women, active in the intervention group and sedentary in the control group	Treadmill	AT+ST	3 times a week for 10 weeks.	**FM (1RM):** (GF: ↑↑), (GC: ↑)
Conceição(2015), dissertation	33 elderly men (66±5 years) apparently healthy, who had not exercised for at least 6 months.	Cycle ergometer	ST+AT.	2 to 4 times a week for 12 weeks.	**FM (1RM):** Knee extension. (GF: ↑), (ambos do GC: ↑).
Parmezzani(2017), dissertation	16 eutrophic men aged 18-35 years, practicing PT for at least 6 months.	Treadmill	AT+ST	Twice a week, for 12 weeks.	**FM (1RM)**: (GF: ↑), (GC: ↑). **HM:** There was no difference after training.
Prado (2017), thesis	Adults of both sexes, 20-60 years old. Physically active or not.	Pool	ST+TN	3 times a week for 12 weeks.	**FM (1RM):** Knee extension, elbow extension and shoulder extension. (GF: ↑), (GC: ↑)

Table 1 - Data from studies with concurrent training and strength training to gain strength and/or muscular hypertrophy (continues)

Subtitle: CT= concurrent training; ST= strength training; AT= aerobic training; ET= endurance training; TN= swimming training; Sem= week; FM= muscle strength; 1RM= dynamic strength in the 1 repetition maximum test; HM= muscular hypertrophy; LL = lower limbs; ASTM= muscular cross-sectional area; ASTC= thigh cross-sectional area; GC= concurrent training group; GF= strength training group; ↑= increase in pre- and post-training momentum; ↑↑= significantly greater increase between groups.

Source: author (based on the studies mentioned)

with greater clarity, it is interesting that new studies will be carried out using CT strategies and that these aim to compare ST, so that it is possible to observe strength performance and the development of muscular hypertrophy in both modalities, in order to establish a model that can be a reference for practice without the occurrence of interference.

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