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HYPERTROPHIC ADAPTATIONS OF LOWER LIMB MUSCLES IN RESPONSE TO THREE DIFFERENT RESISTANCE TRAINING REGIMENS

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ABSTRACT

Introduction*: The research tested the effects of training in three different load zones. The hypothesis is that this type of training can provide more complete hypertrophic gains compared to workouts performed in a specific, single load area.*

Materials and methods*: 37 participants were divided into 4 groups (SE; S; E; C). The first group trained simultaneously with high loads and low repetitions and with low loads and high repetitions; the second group trained in the high load condition, the third with low loads and high repetitions brought to the point of fatigue and the last control group had not practiced any type of training. The participants performed the training program 3 times a week for an eight-week period.*

Results*: The internal group comparison of the 1RM squat values, shows an important mean improvement emerged in the participants of the SE sample, a similar increase was recorded in group S, while in group E there was no increase, but a slight average decrease in the 1RM of squats. In group C the decrease in the 1RM of squats was significant.*

Conclusions*: Resistance training performed simultaneously in different load areas (SE) optimizes muscle hypertrophy. These data underline both the reactivity of skeletal muscle to mechanical load alterations and the importance of metabolic stress as a necessary factor for increasing muscle volume.*

Keywords: *Strength training, resistance training, hypertrophy, metabolic adaptations, neuronal adaptations.*

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Introduction

Resistance training (RT) is the most powerful non-pharmacological interventional strategy to achieve increases in skeletal muscle size(1). As each muscle district is composed of different types of fibers depending on the isoform of the heavy myosin chain which is mainly expressed (Type I, Type IIa and Type IIx)(2), there seems to be a specific response of the fiber type in relation to the intensity of the load(3) and that, the latter, is often divided into load zones, i.e., range of repetitions classified as heavy (1 - 5RM), medium (6 - 12RM) and light (15+RM(4), hypertrophy can be achieved in all load zones.

Vinogradova et al.(5) compared high load training (80-85% 1 RM) to low load training (50% 1 RM) in a group of untrained young people, finding that the high load group achieved the greatest increases in type II muscle fibre size, while the low load group achieved the greatest increases in type I muscle fibre size. Similar results to those presented by Vinogradova et al.(5) were reported by the same laboratory by Netreba(6).

In this regard, Grgic et al.(7), pointed out that the different types of muscle fibres have different characteristics, in particular, type II muscle fibres have a rapid calcium kinetics, a higher shortening speed and the ability to generate more energy than type I muscle fibres, which have a higher oxidative capacity and a higher fatigue threshold. Campos et al.(8) examined 32 untrained young men who participated in an 8-week RT training program. The subjects were divided into four groups: a low repetition group, an intermediate repetition group, a high repetition group and a non-exercise control group. At the end of the study, it was found that the maximum strength improved significantly more for the Low Rep group than for the other training groups and that the maximum number of repetitions at 60% 1RM improved more for the High Rep group. In addition, all three major fiber types (Types I, IIA and IIB) were hypertrophied for the Low Rep and Int Rep groups, while no significant increases were demonstrated for the High Rep and control groups.

Results similar to those of Campos et al.(8) emerged from the Schuenke et al.(9) trial. Although lower than those found by Schuenke et al.(9), similar growth rates with high RT of the lower body load were observed in the literature(10, 11). Hakkinen et al.(12) proposed to eleven male subjects (20-32 years) accustomed to RT, a protocol of progressive strength training at high load for 24 weeks with intensities varying between 70 and 120% each month. The protocol was followed by 12 weeks of stop. During the most intensive training months there was an increase in maximum isometric strength, correlated with significant increases in neural activation (IEMG) of the extensor muscles of the legs(60).

During lower intensity training, the maximum IEMG value decreased. In addition, during the first 12 weeks, an increase in the volume of fast contracting muscle fibres was noted. Therefore, studies that have analysed muscle hypertrophy suggest that light loads have a preferential effect on type I fibre hypertrophy, emphasise metabolic stress and promote greater increases in local muscle resistance, while, training with heavy loads produces greater increases in the cross-section of type II fibres, requires great mechanical tension and improves the ability to lift heavier loads due to greater neural adaptations(61). The aforementioned relationship between the intensity of the load and the specific response of muscle fibre types is attributed to the recruitment of the latter, which follows the principle of size, explained first by Henneman et al.(13), who proposed that motor units are recruited according to fibre size, since their size is directly proportional to the capacity to produce force. Thus, with low workloads only the smaller motor units, consisting of type I fibres, are recruited and, as the demands for force generation increase, also motor units with a higher activation threshold, consisting of type II fibres, are activated. However, research indicates that when fatigue increases during prolonged sub-maximal exercise, recruitment thresholds decrease proportionally(14, 15), increasing the activation of fast contracting fibres, provided the set is led to muscle failure.

Vollestad et al.(16) examined muscle glycogen depletion in 5 subjects during an exhaustive pedalling exercise, at 75% of VO2 max. At rest, prior to training, the glycogen content was 16% higher in Type II fibers than Type I fibers. Since the start of the exercise, the same rate of glycogen depletion was observed in Type I and Type IIA fibers. The type IIAB and IIB glycogen content remained unaltered during the first part of the exercise(59).

Subsequently, a decrease was observed, first in IIAB fibers and finally in IIB fibers, suggesting a lowering of the threshold force of these fiber types. Sahlin et al.(17) also studied the effect of prolonged submaximal pedalling exercise, performed at 75% VO2 max to the point of fatigue, on muscle energy, finding that mean phosphocreatine at rest was about 20% higher in type II fibers than in type I fibers and that, when subjects reached muscle failure, PCr concentrations were similar in the two fiber types. The reduction of PCr in all fibres in the fatigue condition indicated that they were all recruited at the end of the exercise. Although these data show that training against high resistance is not the only strategy to achieve full recruitment of the motor unit pool, as seen above, with high loads and low repetitions, preferential hypertrophic effects are achieved on fast contracting fibres; conversely, light loads and longer time under tension favour the growth of slow fibres, suggesting that although the ability to recruit as much as possible of all available fibres in a given motor unit pool is essential to maximise hypertrophic response, the recruitment of a fibre does not necessarily promote hypertrophic response.

In this regard, it emerges the concept that increased muscle volume is the result of three mechanisms: mechanical tension, metabolic stress and muscle damage. In accordance with what has just been described, in the present study it is hypothesised that training simultaneously in different load zones can provide more complete hypertrophic gains than training performed in a given load zone(18). Therefore, to evaluate this hypothesis, 37 subjects aged between 21 and 28 years were divided into 4 groups. The first group (SE = 10) trained at the same time with high loads and low repetitions and with low loads and high repetitions until momentary muscle failure, the second group (S = 10) trained in the high load condition, the third (E = 10) with low loads and high repetitions brought to the point of fatigue and the last group (C = 7) did not perform any kind of training. The subjects performed squat and leg extension exercises 3 times a week for a period of eight weeks. The hypertrophic effects on the lower limbs were assessed by detecting body circumferences before and after the experimental protocol; moreover, the maximum strength (1RM) for squat exercise was tested pre and post the protocol.

Methods and materials

37 young men (age 23.9 ± 2.3 years at the beginning of the study) with RT experience volunteered for this study. All subjects were considered well trained, as they had been practicing strength training for at least a year and each of them was able to perform a maximum repetition (1RM) of squat with a load greater than their body weight. Individuals were randomly assigned to a low repetition group (S n=10), a high repetition group (E n=10), a high and low repetition group (SE n=10) and a group that did not perform any training (C n=7). Mean and DS of weight, thigh circumference, estimated percentage of fat mass (BF) (19), and 1RM squat values of subjects are shown in Table 1.

Group	Weight (Kg)	Thigh Circumference (cm)	%Bf	1Rm squat (kg)
S	80,2 (12,3)	58,7 (3,3)	14 (4,3)	124,6 (18,1)
E	76,1 (12,4)	56,1 (4,5)	13 (4,5)	104,8 (18,5)
SE	87,1 (9,7)	60,2 (3,4)	13,3 (3,4)	116,1 (17,1)
C	81,8 (11,3)	58,2 (3,6)	13,6 (4)	111,8 (16,2)

Table 1: Mean and standard deviation.
Table note: mean and standard deviation for body weight, thigh circumference, percentage of fat 1 RM squat values for subjects of group: S (n=10); E (n=10); SE (n=10); C (n=7).

Training

The subjects in each group, with the exception of those in the control sample, exercised their lower limbs 3 times a week for 8 weeks, performing squats and leg extensions at each session. Both exercises were practiced in different (SE) or equal (S, E) load zones and with reference to the 1RM tested upstream in the respective exercises. Specifically, subjects in the SE group followed a progression of strength on the squat exercise from a load intensity of 82% of 1 RM, which was increased by 2% each week up to 94%, while reducing the volume, linearly on the repetitions and in a undulating manner on the series; also they carried out the leg extension in the light load area, starting from an intensity of 28% of 1RM which has been progressively increased up to 34% in week 7, performing each set until muscle failure and reducing the series with the same criteria adopted for squat exercise. Group S performed the exercises following the progression of force applied to squat in the SE group, while individuals in group E performed both exercises until muscle failure using the same method used by the SE group for leg extension exercise.

For all groups, the last week of training included an active unloading to provide systemic refreshment to subjects and prepare them for the maximum squat strength test performed the following week. The unloading provided a decrease of the main stressor of the protocols, represented by the intensity of the load, which was increased in a ascending manner over the weeks, therefore, for all exercises, the load of week 8 was equal to that used in week 1. Moreover, although to a lesser extent, the volume (series and repetitions) was also reduced. The sets of exercises with light loads were not carried out until muscle failure, but a number of 20 repetitions was set for each series. Below are shown the training protocols for each group.

Measurements

Weight and height of the subjects were measured Pre- and post-experimental training (week 9) and the waist and neck circumferences were detected. The height, waist circumference and neck circumference of the subjects were used to derive an estimate of individuals body fat the using the Wilmore & Behnke formula for male subjects:

495/{1.0324 - 0.19077 [log(waist - neck)] + 0.15456 [log(height)] - 450

In addition, the thigh circumference of pre and post-training period was measured to verify changes in lower limb size in response to different resistance training regimens. A maximum strength test for squat and leg extension exercises was performed before the start of the study and the squat 1RM was tested at the end of the training period. The maximal strength test on both occasions and for both exercises was carried out by having subjects perform different sets of 1 repetition, with recovery times between 3 and 5 minutes, slightly increasing the load lifted at each attempt, to the point where they were unable to complete the lift with a full ROM (range of motion).

A within-group comparison was made and pre and post-test data related to body weight (BW), estimated percentage of fat mass (FM), thigh circumference (CC) and 1RM of squat were analyzed using a paired t-test with the α level set at $p \leq 0.05$.

Results

No significant differences were found within groups (p> 0.05) between the subjects' mean body weight from pre to post protocol: S (pre = 80.2±12.3 kg and post = 80 kg.±12 Kg) (p = 0.78); E (pre = 76.1±12.4 Kg. E post = 75.2±10.9 Kg.) (P = 0.28); SE (pre = 87.1 ± 9.7 kg and post = 86.2±9.4 kg) (p = 0.15); C (first 81.8 Kg.±11.3 Kg and after 81.6±11.7 Kg) (p = 0.84). Regarding FM, no significant decreases (p>0.05 and = 0.18) were found in group S from start to finish of the training protocol. Likewise, in group E, no significant reductions in BF were recorded (p> 0.05 e = 0.11) following the proposed training. On the other hand, the significant reduction in FM found in the SE group (p <0.05 e = 0.01) at the end of the 8 weeks of training is interesting. Regarding groups S and E, sample C did not experience any significant change (p> 0.05 e = 0.4) in FM during the 8 weeks of non-training. The data collected on the changes in the circumference of the thigh of each subject showed an average increase (p<0.05) of the latter, for all groups of exercises (S, E, SE) with the most significant increases (p = 2.94359E-08) detected in SE (pre = 60.2±3.4 cm and post = 62.18 [+ 2 cm and 3.3%]±3.4 cm). Slightly smaller but statistically significant (p = 0.0002) increases were found in group S (pre = 58.7±3.3 cm and post = 59.6 cm [+ 0.9 cm and 1.5%] ± 3.1 cm). Group E also showed increases, albeit smaller (p = 0.0005) (pre = 56.1±4.5 cm and pole = 56.5 cm [+ 0.46 cm and 0.8%]±4.5 cm). As expected, subjects who did not do any type of training (C) reported a significant mean decrease (p> 0.05 e = 1) in thigh circumference, i.e. (pre = 58.2±3.6 cm and post = 56.4 cm [- 1.65 cm and 2.8%]±3.4). The average circumference of the thighs of the subjects of the 4 groups was superimposed, with the relative variations from pre to post experimentation.

Discussion

From the internal comparison of the 1RM squat values groups, a significant mean improvement in the subjects of the SE sample (p<0.05 e = 1.26275E-05) (pre = 116.1 Kg. and post = 131.2 Kg. {+15.1 Kg. and 13%}), a similar increase was recorded in the S group (p<0.05 e = 8.81E-07) (pre = 111.3 Kg. e post = 124.6 Kg. {+ 13.3 Kg. and 11.9%}), while in group E there was not an increase, but a slight mean decrease of 1RM of squat (p>0.05 e = 0.08) (pre = 104.8 Kg. e post = 100.7 Kg. {- 4.1 Kg. and 3.9%}). In group C the decrease of squat 1RM was significant (p<0.05 e = 0.0001) (pre = 111.8 Kg. and post = 97.7 Kg {-14.1 Kg. and -12.6%}).

From the experimentation conducted, it can be seen that resistance training performed simultaneously in different load zones (SE) optimizes muscle hypertrophy, compared to training performed with a single range of repetitions (S, E).

As shown by the results, in fact, considering that no significant changes in body weight were found in subjects in all groups, the SE protocol induced reductions in BF, increases in thigh circumference (+ 3.3%) and increases in maximum strength in squat (+ 13%) more marked than the S and E protocols. However, the high load condition (S) deserves attention because, although it did not change the BF of individuals, it increased their thigh circumferences by 1.5% on average and allowed them to improve 1RM in squat exercise by about 12%. Although not as large as those that emerged from the SE and S progressions, increases in thigh circumferences (+ 0.8%) in the absence of significant changes in BF, were found in subjects who trained with the high repetition protocol performed until temporary muscle failure with reduced loads (E). The 1RM of squat in these subjects had slight decreases, probably due to neural depotentiation.

These data underline both the high reactivity of skeletal muscle to mechanical load alterations, reinforcing the hypothesis of several researchers that mechanical tension is the main driving force in the hypertrophic response of regular resistance training, and the importance of metabolic stress as a necessary factor for muscle volume increase(58-62). Therefore, the research conducted and presented in this paper, promotes an approach to muscle training based on the integration of different load intensities, with the main objective of developing maximum strength and mixing training routines with exercises with high metabolic impact; in addition, the significance of the results detected in the SE group after 8 weeks of training represents a solid basis for future research that could investigate the effects of training carried out simultaneously in different load zones for a longer period of time (Table 2-3-4).

SQUAT			
Week 1	82%	5x4 sets	rest. 5’.00”
Week 2	84%	5x3 sets	rest. 5.30”
Week 3	86%	4x4 sets	rest. 5’.00”
Week 4	88%	4x3 sets	rest. 5’.30”
Week 5	90%	3x4 sets	rest. 5’.00”
Week 6	92%	3x3 sets	rest. 5’.30”
Week 7	94%	3x3 sets	rest. 6’.00”
Week 8	82%	4x4 sets	rest. 5’.00”
Week 9	Squat Test		

Leg extension			
Week 1	28%	2 sets X failure. rest. 1’.00”	rest. 1’00”
Week 2	28%	3 sets X failure	rest.1’.30”
Week 3	30%	2 sets X failure rest. 1’.00”	rest. 1’00”
Week 4	30%	3 sets X failure. rest. 1’.30”	rest. 1’30”
Week 5	32%	2 sets X failure	rest.1’.00”
Week 6	32%	3 sets X failure rest. 1’.30”	rest.1’.30”
Week 7	34%	2 sets X failure	rest.1’.00”
Week 8	28%	3 sets X 20 reps	rest.1’.00”
Week 9	Squat Test		

Table 2: SE group training protocol.

SQUAT			
Week 1	82%	5x4 sets	rest. 5’.00”
Week 2	84%	5x3 sets	rest. 5’.30”
Week 3	86%	4x4 sets	rest. 5’.00”
Week 4	88%	4x3 sets	rest. 5’.30”
Week 5	90%	3x4 sets	rest. 5’.00”
Week 6	92%	3x3 sets	rest. 5’.30”
Week 7	94%	3x3 sets	rest. 6’.00”
Week 8	82%	4x4 sets	rest. 5’.00”
Week 9	Squat Test		

Leg extension			
Week 1	82%	5x4 sets	rest. 1’.45”
Week 2	84%	5x3 sets	rest.2’.00”
Week 3	86%	4x4 sets	rest.1’.45”
Week 4	88%	4x3 sets	rest.2’.00”
Week 5	90%	3x4 sets	rest.1’.45”
Week 6	92%	3x3 sets	rest.2’.00”
Week 7	94%	3x3 sets	rest.2’.00”
Week 8	82%	4x4 sets	rest.1’.45”
Week 9	Squat Test		

Table 3: S group training protocol.

SQUAT			
Week 1	28%	2 sets X failure	rest. 1’.00”
Week 2	28%	3 sets X failure	rest. 1’.30”
Week 3	30%	2 sets X failure	rest. 1’.00”
Week 4	30%	3 sets X failure	rest. 1’.30”
Week 5	32%	2 sets X failure	rest. 1’.00”
Week 6	32%	3 sets X failure	rest. 1’.30”
Week 7	34%	2 sets X failure	rest. 1’.00”
Week 8	28%	3 sets X 20reps	rest. 1’.00”
Week 9	Squat Test		

Leg extension			
Week 1	28%	2 sets X failure	rest. 1’.00”
Week 2	28%	3 sets X failure	rest. 1’.30”
Week 3	30%	2 sets X failure	rest. 1’.00”
Week 4	30%	3 sets X failure	rest. 1’.30”
Week 5	32%	2 sets X failure	rest. 1’.00”
Week 6	32%	3 sets X failure	rest. 1’.30”
Week 7	34%	2 sets X failure	rest. 1’.00”
Week 8	28%	3 sets X20 reps	rest. 1’.00”
Week 9	Squat Test		

Table 4: E group training protocol.

Conclusions

Resistance training performed simultaneously in different load areas (SE) optimizes muscle hypertrophy. These data underline both the reactivity of skeletal muscle to mechanical load alterations and the importance of metabolic stress as a necessary factor for increasing muscle volume.

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