Rev Bras Cineantropom Desempenho Hum

original article

https://doi.org/10.1590/1980-0037.2023v25e85848

Effects of resistance training on consecutive and non-consecutive days on hormonal, neuromuscular and morphological responses in recreationally trained men

Efeitos do treinamento de força em dias consecutivos e não consecutivos nas respostas hormonal, neuromuscular e morfológica em homens treinados recreacionalmente

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Abstract – The purpose of the present study was to investigate the effect of two recovery periods between consecutive and non-consecutive days in strength training sessions on hormonal, neuromuscular and morphological variables in recreationally trained men. Nineteen young men completed the study and were randomly divided into two groups: 24R, 24-hour recovery group (n = nine) and 72R, 72-hour recovery group (n = ten). The strength training program (RT) lasted six weeks with two serial routines, with a weekly frequency of four times. The saliva sample was collected once a week in the morning to determine salivary testosterone. The 1RM, jump against movement and body composition tests were performed in the pre- and post-training periods. As for salivary testosterone, there was no significant effect with respect to time and between groups. Both groups improved maximal strength in terms of intervention time in the barbell bench press and in the leg press 45º, not differing between groups and body composition showed significant interaction in time to body fat percentage Δ% = -14.6 ± 10.0 (24R) and -17.2 ± 10.9 (72R); p = 0.00, fat mass Δ% = -13, 7 ± 9.2 (24R) and -18.2 ± 13.0 (72R); p = 0.00 and fat-free mass Δ% = 3.5 ± 2.7 (24R) and 2.5 ± 2 .8 (72R), p = 0.00. The recovery periods 24 and 72 hours between sessions induced similar responses in the parameters investigated in recreationally strength-trained men.

Key words: Testosterone; 1RM; Body composition; Total load lifted weekly.

Resumo – *O objetivo do presente estudo foi investigar o efeito de dois períodos de recuperação entre dias consecutivos e não consecutivos em sessões de treinamento de força sobre variáveis hormonais, neuromusculares e morfológicas em homens treinados recreacionalmente. Dezenove homens jovens completaram o estudo e foram divididos aleatoriamente em dois grupos: 24R, grupo de recuperação de 24 horas (n = nove) e 72R, grupo de recuperação de 72 horas (n = dez). O programa de treinamento de força (TF) durou seis semanas com duas rotinas seriadas, com frequência semanal de quatro vezes. A amostra de saliva foi coletada uma vez por semana no período da manhã para determinação da testosterona salivar. Os testes de 1RM, salto contra movimento e composição corporal foram realizados nos períodos pré e pós-treinamento. Quanto à testosterona salivar, não houve efeito significativo em relação ao tempo e entre os grupos. Ambos os grupos melhoraram a força máxima em termos de tempo de intervenção no supino reto com barra e no leg press 45º, não diferindo entre os grupos e composição corporal apresentaram interação significativa no tempo para percentual de gordura corporal Δ% = -14,6 ± 10,0 (24R) e -17,2 ± 10,9 (72R); p = 0,00, massa gorda Δ% = -13, 7 ± 9,2 (24R) e -18,2 ± 13,0 (72R); p = 0,00 e massa isenta de gordura Δ% = 3,5 ± 2,7 (24R) e 2,5 ± 2,8 (72R), p = 0,00. Os períodos de recuperação de 24 e 72 horas entre as sessões induziram respostas semelhantes nos parâmetros investigados em homens treinados de força recreacionalmente.*

Palavras-chave: *Testosterona; 1RM; Composição corporal; Carga total levantada semanalmente.*

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Received: February 23, 2022
Accepted: February 03, 2023

How to cite this article
Lopes CR, Brigatto FA, Camargo JBB, Germano MD, Marchetti PH, Aoki MS, Politano H. Effects of resistance training on consecutive and non-consecutive days on hormonal, neuromuscular and morphological responses in recreationally trained men. Rev Bras Cineantropom Desempenho Hum 2023, 25:e85848. DOI: https://doi.org/10.1590/1980-0037.2023v25e85848

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INTRODUCTION

Resistance training (RT) has been shown to promote several muscular adaptations such as muscle strength and hypertrophy, in a wide variety of populations and levels of physical performance[1]. However, in order to enhance RT-induced adaptations, the proper manipulation of training variables (e.g. exercise intensity, volume, rest intervals, type of exercises, muscle actions, movement velocity, exercise order, and frequency) is mandatory[2].

In this sense, recovery is necessary between training sessions or between stimuli for the same muscle group in divided routines. Furthermore, it is crucial for some adaptation mechanisms, especially during high-intensity training, such as appropriate time to restore muscle glycogen stores or repair damaged tissue[3,4]. It is consensual in the literature that the recovery between training sessions for the same muscle or muscle group is at least 48 hours, because normally after a workout, a new workout only occurs after a full recovery, which probably happens after 48 hours[5,6].

The American College of Sports Medicine (ACSM)[2] recommends weekly training sessions for beginners (two to three times), intermediate (three to four times) and advanced (four to six times), and based on this recommendation, It is suggested that depending on the volume and intensity applied, beginners would require longer recovery intervals between sessions and advanced individuals would require shorter intervals between training sessions, which is a common practice but adopting serial training routines.

The recovery interval between training sessions so far has been little investigated. It is known that the increase in the training load, without proper recovery between training sessions, can generate increased responses in the loss of neuromuscular performance[6-8].

However, when sharply investigating the variables of strength, speed and power of the upper limbs, Lopes et al.[9] pointed out that both the 24-hour and 48-hour recovery intervals were similar and the recovery allowed, under the same conditions, to perform the second training session. training in relation to the first in the variable intensity and volume. Carvalho and Santos[10], in their seven-week chronic study, found an increase in maximal strength and similarity in body composition between groups that trained three consecutive days vs three non-consecutive days a week, adopting the full body methodology.

In this sense, the present study aimed to evaluate and compare the effect of two recovery periods between strength training on consecutive vs non-consecutive days on hormonal, neuromuscular and morphological responses in trained men.

METHODS

Experimental design

A randomized longitudinal study design was used to assess hormonal, neuromuscular, and morphological effects on two equal RT regimens in resistance-trained men. Both protocols differed only in relation to the recovery time provided between training sessions: 24h (24R) or 72h (72R) rest period. In the week prior to the RT intervention, the baseline (maximum voluntary muscle strength) for each subject was determined over 2 days (i.e., test and retest) for the bench press exercises with barbell and leg press 45º. The countermovement jump test was performed the following day, avoiding any possibility of interference from the 1RM test. The assessment of body composition was performed 3 days after the final baseline strength test session, and thereafter the subjects started the training intervention. The RT program lasted 6 weeks and the total weekly load lifted (TLL) of the session was monitored in all training sessions and was computed weekly. Salivary testosterone was assessed weekly. At the end of the experimental period, muscle strength tests and body composition measurements were repeated.

Subjects

Participated in the study 20 young people with a mean age of 23.1 ± 4.9 years, total body mass of 85.6 ± 10.4 kg, with experience in TR of 3.9 ± 3.7 years and a relative strength of 1.1 ± 0.2 for the barbell bench press and 4.4 ± 0.6 for the 45º leg press, classifying them as trained, according to Santos et al.[11]. Then, the subjects were paired according to the maximum strength baseline identified in the barbell bench press and 45º leg press, and then randomly divided according to strength levels into two groups: group 24R and group 72R. The 24R group trained with a 24-hour recovery interval for the same strength exercises, consecutive day, and the 72R group trained with a 72-hour recovery interval for the same non-consecutive strength exercises. All participants signed an informed consent form after being informed about the research and the experimental protocol. This study was approved by the local Research Ethics Committee (protocol 1.749.141). The following criteria were used for study participation: (a) men with at least one year of continuous RT experience at least three times a week; (b) perform the 1RM test with at least 100% of body mass in the barbell bench press; (c) no previous injury that could interfere with the study. The following did not participate in the study: (a) women, adolescents and the elderly; (b) men with no experience in strength training; (c) men who used food supplements. One subject from the 24R group dropped out of the study for personal reasons and 19 subjects completed the study, being the 24R group n = nine; and group 72R n = ten. No injuries were reported and program adherence was 100% for both groups.

Measurements

Salivary Testosterone: Saliva samples were collected once a week in the morning during the study period. The subjects were instructed to not eat, drink or brush teeth at least 30 minutes before the collection of the samples, to avoid possible changes in salivary composition and blood contamination. In addition, the subjects were instructed to rinse out their mouth with distilled water 10 minutes prior to saliva collection. After this initial procedure, the saliva was collected into a sterile tube. The mucins were separated by centrifugation at 3000 rpm for 15 minutes at 4˚C. Samples were stored at -80˚C for subsequent analysis. Salivary testosterone was determined in duplicate using the commercial kit (DiaMetra, Italy – code DKO021) by the enzyme immunoassay method (ELISA Technologies, USA), with assay range values of 10 – 1000 pg/mL and sensitivity of 3.28 pg/mL, according to the manufacturer's instructions.

1-Repetition Maximum (1RM) Testing: The determination of the maximum dynamic muscular strength was evaluated by the 1RM test for the straight bench press exercises and 45º leg press. Initially, the subjects performed a specific warm-up consisting of 2 sets of 10 repetitions at approximately 40-60% of their load that they were used to performing. After a 5-minute rest period, subjects were instructed to perform a single repetition of the test exercise until muscular failure. If a repetition maximum was successfully completed, the external load was adjusted by 5-10% until the subject was unable to complete the exercise throughout the full range of motion. Therefore, the first 1RM test performed was the barbell bench press, where subjects were instructed to maintain a 5-point body contact (ie, head, back and hips in contact with the bench and feet in contact with the floor) when raising and lowering the bar. It is advisable to hold 200% of the biacromial distance[12]. To characterize a complete repetition, the volunteer must start from the starting position with the elbows extended, lower the bar in a controlled manner until touching the pectoral and return to the starting position with the elbows extended. Ten minutes after the end of the first test, the 1RM test of the 45º leg press started. The subjects were instructed to perform the descending movement (eccentric) until 90º of knee flexion and the ascending movement (concentric) until full knee extension. A researcher verified the whole range of motion to validate each repetition. Two researchers were present to provide verbal encouragement and ensure the safety of the participants. Each test was performed with a maximum of 5 attempts, with rest intervals of 3 to 5 minutes. The 1RM was considered the largest external load successfully lifted. The 1RM maximum score, for the barbell bench press and leg press 45º exercises, showed high test-retest reliability (intraclass correlation coefficients = 0.98 and 0.97, respectively). And stops were not allowed in the execution of the movement between the eccentric and concentric phases and only the attempts in which the correct execution of the exercises will be performed were considered valid. To minimize errors in the tests, the following strategies were adopted: a) the individuals received adequate technical information about each exercise before the tests; b) the execution of each exercise was monitored and corrected when necessary; c) the subjects were verbally encouraged during the tests.

Countermovement jump (CMJ): The height of the vertical jump was determined by the counter-movement jump. Initially, the subjects were familiarized with the test following the protocol and started standing with the trunk straight and both hands on the hips. After verbal instruction, a vertical jump against rapid countermovement was performed. The height of the vertical jump was measured using a contact mat (CEFISE, São Paulo, Brazil). Three trials were performed with a 1-minute rest interval between each test. The highest vertical jump achieved was considered for further analysis and values were expressed in centimeters (cm).

Total Load Lifted (TLL): sets x repetitions x external load [kgf] was calculated from training logs filled out by research assistants for every TR session. The weekly TLL (TLL_{WEEK}) was calculated as the values corresponding to the sum of the loads calculated for the four RT sessions in each week. The accumulated TLL (ATLL) was the sum of all TR weeks. Only repetitions performed through a full range of motion were included for analysis. The data were expressed in kilogram-force units (kg).

Body Composition: Initially, body mass was measured using a mechanical scale (Welmy, São Paulo, Brazil, precision = 0.1 kg). Body composition (percentage of body fat) was estimated by skinfold thickness measurements by a Lange skinfold caliper (Beta Tecknology, Santa Cruz, California), then fat mass and lean mass were estimated. Measurements were taken from the subjects' right side using a 7-site skinfold at the triceps, subscapularis, pectoralis, midaxillary, suprailiac, abdominal, and anterior thigh. The skinfold was detached using the thumb and index finger and slightly pulled away from the underlying skeletal muscle before applying the calipers. Each skinfold site was measured 3 times by the same experienced investigator and the mean of these 3 values was used for analysis. Body density was estimated using the formula proposed by Jackson and Pollock[13], and body composition was estimated using the Siri equation[14].

Resistance Training Intervention: The subjects performed 6 weeks of a split RT routine (A-B) at a weekly frequency of 4 sessions for approximately 1 hour per day. Subjects in both 24R and 72R groups performed 4 sets of 10RM, reaching concentric failure, with 1-minute rest between sets and 2-3 minutes between RT exercises. The 24R group performed routine A on Monday and Tuesday and routine B on Thursday and Friday, and 72R group performed routine A on Monday and Thursday and routine B on Tuesday and Friday. The exercise order for each routine is described in Table 1.

Table 1. Description of Routine A and B.

Routine A	Routine B
Bench Press	Seated Cable Row
Pec Deck	Unilateral Row
Flat Bench Dumbbell Fly	Row Sitting with Closed Grip
Dumbbell Biceps Curl	Cable Triceps Press Down
Preacher Curl	Overhead Dumbbell Triceps Extension
Standing Calf Raise	Back Squat
Reverse Crunch	Leg Press
	Abdominal Crunch

All RT sessions were supervised by a researcher to ensure that the objective was achieved. In sets where he could not reach the minimum of 10 RM, there was a 10% reduction in load, and in sets that exceeded the limit of 10 RM, there was a 10% increase. This care occurred for all individuals, in all sessions and in all series that required load adjustment as a measure to guarantee the established concentric muscle failure[15-17].

Estimate of Food Intake: To avoid potential dietary confounding of the results, subjects were advised to maintain their usual nutritional regimen and not take any supplements during the study period. Dietary nutrient intake was assessed by 24-hour dietary recalls on 2 non-consecutive weekdays and 1 weekend day. The subjects were instructed to record in detail: time of consumption, types and quantity of food preparations consumed during 24 hours. The quantity of food was recorded in cooking units (spoons. cups and glass) and transformed into grams. The estimation of energy intake (macronutrients) was analyzed by NutWin software (UNIFESP, Sao Paulo, Brazil). The estimated food intake was assessed during weeks 1, 3, and 6 of the training intervention period.

Statistical analysis

Initially, the Shapiro-Wilk normality test was used to test the normal distribution of the data, where for the strength variable there was no difference in the bench press exercise with bar p=0.872 and for the 45º leg press, p=0.096, an analysis a priori power analysis revealed that 19 subjects would provide 80% power to detect differences at a level of 0.05. Then, a two-way repeated measures analysis of variance (two-way ANOVA) was performed to compare the change in outcome measures over time between groups for variables that have two measures over time (pre and post): strength max, jump and body composition. For variables that were measured 6 times (testosterone and TLL), a factorial ANOVA (2x6) to examine weekly differences between groups was applied. When a significant interaction effect or time effect was found, a post hoc Bonferroni test was performed for multiple comparisons. The Mann-Whitney test (1RM bench press and leg press strength) was used to compare baseline and pre- and post-training values (Δ%). The significance level was set at 0.05 and the statistical procedures were performed using the GraphPad Prism software, version 9.0. Test-retest reliability (ICC) was calculated for 1RM tests. Cohen's formula was used to calculate the effect size (ES). According to Rhea et al.[18], the ES for RT is considered trivial for ES values <0.35, small for ES values between 0.35 and 0.80, moderate for ES values between 0.80 and 1.50 and large for ES values > 1.50. An alpha of 0.05 was used to determine statistical significance. All data are presented as mean ± standard deviation.

RESULTS

Baseline values

Among individuals in each group, no significant differences were observed for age (24R = 24.3 ± 5.1 vs. 72R = 21.9 ± 4.7 years, p = 0.33); body height (24R = 183.9 ± 8.4 vs. 72R = 177.1 ± 5.3 cm, p = 0.06), total body mass (24R = 89.6 ± 10.3 vs. 72R = 82 ± 9.5 kg, p = 0.77). RT experience was similar between groups and no significant difference was observed in pre-intervention values for any of the dependent variables between groups (p>0.05).

Salivary testosterone

During the six weeks of intervention, no significant effect was observed regarding time (F = 1.06, p = 0.39) and group interaction effect (F = 1.00, p = 0.34) for the responses of salivary testosterone, as shown in Figure 1.

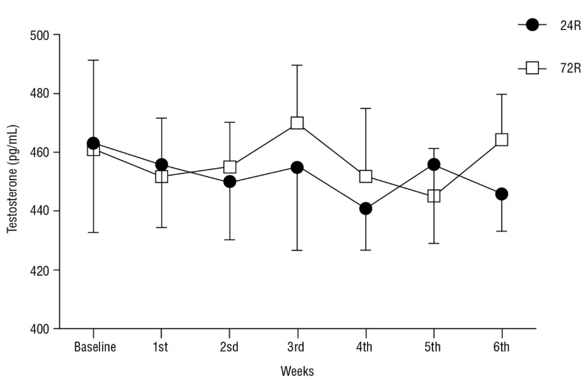

Figure 1. Salivary testosterone values during six weeks of strength training for the 24R and 72R groups. Data are expressed as mean ± SD. DiaMetra kit – code DKO021) by the ELISA method, with assay range values of 10 – 1000 pg/mL.

Neuromuscular performance

In Table 2, a significant group by time interaction was observed for 1RM in the barbell bench press ($F = 66.03$, $p = 0.00$) and for the leg press 45º ($F = 210 .10$, $p = 0.00$). However, there was no significant interaction effect between groups for 1RM barbell bench press ($F = 0.00$, $p = 0.96$) and 1RM leg press 45º ($F = 2.26$, $p = 0.15$). Non-significant time ($F = 0.87$, $p = 0.36$) and group effect ($F = 0.44$, $p = 0.51$) for countermovement jump height were observed. The analysis of pre- and post-training changes (Δ%) also did not indicate any significant differences between the groups for 1RM barbell bench press ($p = 0.93$) leg press 45º 1RM ($p = 0.20$) and countermovement jump ($p = 0.33$). ES analysis showed, according to the classification of Rhea et al.[18], as can be seen below in Table 2, a trivial effect size for 1RM in the barbell bench press, a small effect size for 1RM in the 45º Leg press. In the countermovement jump, however, a trivial and small effect size was observed between moments.

Table 2. Maximal 1RM strength and countermovement jump height pre- and post-6 weeks resistance training.

Variable		24R group	72R group	Effect Size
1RM bench press (kg)	Pre	97.3 ± 15.4	97.0 ± 21.1	0.02 (trivial)
	Post	107.1 ± 17.9*	106.6 ± 21.5*	0.02 (trivial)
	Δ%	10.1 ± 6.5	10.4 ± 4.3	0.05 (trivial)
1RM leg press (kg)	Pre	399.7 ± 83.1	350.3 ± 42.9	0.75 (small)
	Post	521.1 ± 72.4*	491.5 ± 33.8*	0.52 (small)
	Δ%	32.3 ± 13.3	41.9 ± 18.2	0.60 (small)
Countermovement Jump (cm)	Pre	46.8 ± 6.3	46.34 ± 4.7	0.08 (trivial)
	Post	48.7 ± 5.8	46.31 ± 3.9	0.48 (small)
	Δ%	4.9 ± 11.2	0.4 ± 8.4	0.45 (small)

Note. * Significant difference ($p < 0.05$) compared to pre-values. Caption: 1RM- one repetition maximum; 24R = experimental group with a 24-hour recovery interval; 72R = experimental group with a recovery interval of 72 hours.

Total Load Lifted (TLL)

In Figure 2, there was a significant effect of time for weekly TLL ($F = 93.30$, $p < 0.001$). However, there was no significant group interaction effect for TLL ($F = 1.21$, $p = 0.29$).

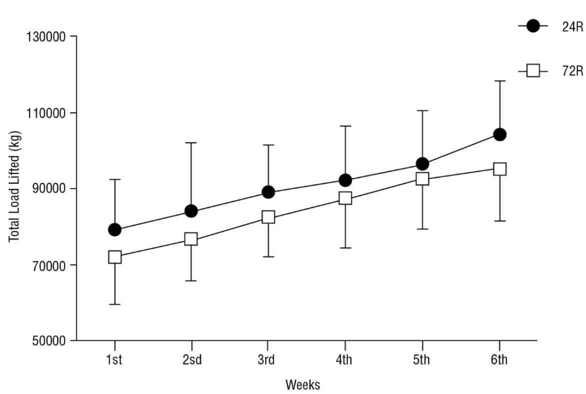

Figure 2. Mean and SD of the values of the total load lifted during 6-weeks resistance training for 24R and 72R groups.

Body composition

There was no significant group by time interaction for body mass (F = 0.12; p = 0.73). A significant group by time interaction was observed for body fat percentage (F = 31.32; p < 0.001), fat mass (F = 33.18; p < 0.001), and fat free mass (F = 25.68 p < 0.001). However, there was no significant interaction effect between groups for body mass (F= 2.93; p = 0.10), body fat percentage (F = 0.01; p = 0.92), fat mass (F = 0.21; p = 0.65), and fat free mass (F = 3.57; p = 0.08). Analysis of pre- to post-training changes (Δ%) did not indicate significant differences between-groups for body mass (p = 0.14), body fat percentage (p = 0.60), fat mass (p = 0.40), and fat free mass (p = 0.29). ES analysis showed, according to the classification of Rhea et al.[18], as seen below in Table 3, a small effect size for body mass, trivial for body fat percentage (%F), trivial for fat mass and for fat-free mass the size was moderate.

Table 3. Body composition parameters pre and post 6 weeks resistance training.

Variables		24R group	72R group	Effect Size
Body Mass (kg)	Pre	89.6 ± 10.3	82.0 ± 9.5	0.77 (small)
	Post	90.5 ± 11.2	81.4 ± 11.6	0.79 (small)
	Δ%	0.9 ± 1.4	-0.9 ± 3.4	0.69 (small)
Body Fat (%)	Pre	16.7 ± 6.6	17.3 ± 4.5	0.11 (trivial)
	Post	14.3 ± 5.6*	14.3 ± 4.5*	0.00 (trivial)
	Δ%	-14.6 ± 10.0	-17.2 ± 10.9	0.25 (trivial)
Fat Mass (kg)	Pre	15.2 ± 6.4	14.4 ± 4.3	0.15 (trivial)
	Post	13.2 ± 5.6*	11.8 ± 4.5*	0.28 (trivial)
	Δ%	-13.7 ± 9.2	-18.2 ± 13.0	0.40 (small)
Fat-Free Mass (kg)	Pre	74.4 ± 8.6	67.6 ± 8.2	0.81 (moderate)
	Post	76.9 ± 7.9*	69.3 ± 8.6*	0.92 (moderate)
	Δ%	3.5 ± 2.7	2.5 ± 2.8	0.36 (small)

Note. * Significant difference (p < 0.05) compared to pre values. Caption: 24R = experimental group with a 24-hour recovery interval; 72R = experimental group with a recovery interval of 72 hours.

DISCUSSION

This study is pioneering, as far as we know, in order to compare the effect of training on consecutive vs non-consecutive days in training routines divided into A and B on hormonal, neuromuscular and morphological responses.

It was observed after the six weeks of intervention that there were no significant differences between the groups that performed strength training sessions on consecutive and non-consecutive days (24R and 72R respectively), however, both groups showed interaction effects by time, showing that for recreationally trained men with experience in RT, both the 24-hour and/or 72-hour recovery interval proved to be efficient in promoting adaptations in neuromuscular variables and body composition in serial training routines in A and B.

It is known that there is little scientific evidence about the recovery interval between training sessions, but it is consensual that the higher the training intensity, the longer the time to generate recovery from the training stimuli implemented[19]. Because the persistent increase in the training load, without proper recovery between sessions, can compromise physical performance[6-8].

Charro et al.[20] when sharply investigating two forms of training organization, through the traditional vs. pyramidal methods, through the bench press, pectoral flight and decline bench press exercises, did not verify significant changes in testosterone in young adults with six months of age RT experience.

Leite et al.[21] acutely evaluated ten recreationally trained men with a mean age of 24.5±7.6 years, in two protocols with different volumes, the first protocol consisting of three sets at 80% of 6RM and the second of three sets at 80% of 12RM with two minutes of rest between sets and exercises, separated by seven days between them. The sequence and order of the exercises were: bench press with barbell, leg press, front handle of the machine, leg flexion, shoulder abduction and leg extension. When analyzing testosterone, they also did not find a statistically significant difference between 80% of 6RM and 80% of 12RM.

In another study, Uchida et al.[22] evaluated the behavior of testosterone in male soldiers undergoing a training session in different forms of organization. Subjects were separated into four different groups with prior experience, at least one year, in the bench press (50%-1RM – 4 x 20 repetitions, 75%-1RM – 5 x 11 repetitions, 90%-1RM – 10 x 4 repetitions). repetitions and 110%-1RM -8 x 4 eccentric repetitions) according to baseline values found at the first laboratory visit. In the second visit to the laboratory, the groups were submitted and evaluated according to the forms of organization to improve hypertrophy, strength and resistance with equalized total lifted load. After the experiment, there were no significant differences between groups in free testosterone at any time post-exercise.

It is verified by the present study that salivary testosterone also did not present significant effects in terms of time and between the groups at different recovery intervals, in both forms of RT organization, remaining practically stable during the six weeks of intervention, even with progress of the total load lifted weekly, without differences between the groups. This absence of differences in hormonal levels can be explained by equalized training volume.

Both groups showed a positive result in the maximum strength (1RM: bench press with barbell and leg press 45º), as well as in the increase in lean mass and decrease in the percentage of body fat and fat mass, however, in the performance of the CMJ was not affected.

Lopes et al.[9] in their cross-sectional study with eight hard-trained men, investigated the total load lifted in two randomized and crossed exercise routines, with recovery intervals of 24 hours and 48 hours. The exercise routines consisted of two exercises: challenge, incline and decline supine and were performed in five sets of 10 repetitions with an intensity of 70% of a maximum repetition (1RM) for each exercise. However, no significant difference was observed for the total volume of load lifted between the two exercise routines, suggesting that the shorter recovery interval (24 hours) was sufficient to recover the upper limbs in men trained for strength, power and speed.

According to Carvalho and Santos[10], in their seven-week chronic waves study, we found an increase in maximal strength and similarity in body composition between groups that trained three consecutive days vs three non-consecutive days per week, using the full body method, alternating from one to two exercises per muscle group, totaling an average of eight to 14 weekly series. We will identify that the protocol of three consecutive days, with a recovery period of 24 hours, promotes the same adaptations as the group of three non-consecutive days, with the same volume of training.

There is no study on the purpose of series A and B training with weekly volume of 16 to 24 series per muscle group, which promoted a significant effect on muscle strength in terms of percentage decrease of body fat in both groups, shows that the volume equalized by denser provides such changes in both groups. In addition, a progressive increase in the total weight lifted weekly was observed in the evaluated groups, consecutive and non-consecutive (24R and 72R respectively).

In this sense, is possible to speculate, in part, that trained individuals have better adaptations, possibly due to the effect of the repeated session being present in a significant way[7]. Likewise, the prescription of strength training can be elaborated on consecutive days for the same muscle group for recreationally trained men, and that the weekly distribution of training does not interfere negatively with the adaptive responses, once the elaboration of the training proposal was equalized. The results found in the present study, or training protocol on consecutive and non-consecutive days, with a recovery interval of 24 hours and/or 72 hours, composed of two serial training routines in A and B, they show to be functional organizational strategies of RT can be applied with the objective of improving muscular strength capacity and body composition in recreationally trained men.

CONCLUSION

I concluded that the recovery interval of 24 or 72 hours, either, training performed two consecutive days vs two non-consecutive days, will promote after six weeks similar responses in terms of time of intervention in hormonal, neuromuscular and body composition variations in trained men recreationally in RT, organized in two serial training routines in routines A and B. In this sense, it also becomes viable within the training plan to apply this strategy in order to optimize or increase muscle strength and decrease body composition. However, new studies are suggested in other populations and/or in greater periods of intervention.

ACKNOWLEDGEMENTS

This study was carried out with the support of the National Council for Scientific Development and Technology - Brazil (CNPq) and the Coordination for the Improvement of Higher Education Personnel - Brazil (CAPES).

COMPLIANCE WITH ETHICAL STANDARDS

Funding

This research did not receive any specific grants from funding agencies in the public, commercial, or not-for-profit sectors. This study was funded by the authors.

Ethical approval

Was obtained from the Human Research Ethics Committee of the Methodist University of Piracicaba - Piracicaba - São Paulo, under protocol (nº 1.749.141) and was written according to the standards established by the Declaration of Helsinki.

Conflict of interest statement

The authors of the article entitled "Effects of different recovery periods between consecutive and non-consecutive days of strength training on hormonal, neuromuscular and morphological responses in recreationally trained men" declare that there is no potential conflict of interest in relation to this article submitted to Revista Brasileira of Kinanthropometry and Human Performance.

Author Contributions

Authors who made substantial contributions to the conception and/or design of the manuscript, in addition to data acquisition, analysis and interpretation: CRL, FAB, JBBC, MDG, PHM, MSA, HP; authors who participated in writing the manuscript and carried out the critical review, in addition to approving the final version: CRL, FAB, JBBC, MDG, PHM, MSA, HP.

REFERENCES

1. Bird SP, Tarpenning KM, Marino FE. Designing resistance training programmes to enhance muscular fitness: a review of the acute programme variables. Sports Med. 2005;35(10):841-51. http://dx.doi.org/10.2165/00007256-200535100-00002. PMid:16180944.
2. American College of Sports Medicine. Progression models in resistance training for healthy adults. Med Sci Sports Exerc. 2009;41(3):687-708. http://dx.doi.org/10.1249/MSS.0b013e3181915670. PMid:19204579.
3. Jentjens R, Jeukendrup A. Determinants of post-exercise glycogen synthesis during short-term recovery. Sports Med. 2003;33(2):117-44. http://dx.doi.org/10.2165/00007256-200333020-00004. PMid:12617691.
4. Chargé SB, Rudnicki MA. Cellular and molecular regulation of muscle regeneration. Physiol Rev. 2004;84(1):209-38. http://dx.doi.org/10.1152/physrev.00019.2003. PMid:14715915.
5. Platanov VN, Bulatova MM. A preparação física. Rio de Janeiro: Sprint; 2003.
6. Radaelli R, Bottaro M, Wilhelm EM, Wagner DR, Pinto RS. Time course of strength and echo intensity recovery after resistance exercise in women. J Strength Cond Res. 2012;26(9):2577-84. http://dx.doi.org/10.1519/JSC.0b013e31823dae96. PMid:22037095.
7. Falvo MJ, Schilling BK, Bloomer RJ, Smith WA. Repeated bout effect is absent in resistance trained men: an electromyographic analysis. J Electromyogr Kinesiol. 2009;19(6):e529-35. http://dx.doi.org/10.1016/j.jelekin.2008.10.010. PMid:19059793.
8. Häkkinen K. Neuromuscular fatigue and recovery in male and female athletes during heavy resistance exercise. Int J Sports Med. 1993;14(2):53-9. http://dx.doi.org/10.1055/s-2007-1021146. PMid:8463025.
9. Lopes CR, Crisp AH, Sindorf MAG, Germano MD, Lutgens LG, Nardin CA, et al. Efeito do intervalo entre sessões de exercício de força sobre o desempenho neuromuscular. Rev Bras Med Esporte. 2014;20(5):402-5. http://dx.doi.org/10.1590/1517-86922014200501808.
10. Carvalho A, Santos J. Nonconsecutive versus consecutive-day resistance training in recreationally trained subjects. J Sports Med Phys Fitness. 2018;58(3):233-40. http://dx.doi.org/10.23736/S0022-4707.16.06660-3. PMid:27682004.
11. Santos ERT Jr, Salles BF, Dias I, Ribeiro AS, Simão R, Willardson JM. Classification and determination model of resistance training status. Strength Condit J. 2021;43(5):77-86. http://dx.doi.org/10.1519/SSC.0000000000000627.
12. Marchetti PH, Arruda CC, Segamarchi LF, Soares EG, Ito DT, Da Luz DA Jr, et al. Bench press exercise: a brief review in the biomechanical aspects. Brazilian Journal of Sports and Exercise Research. 2010;1(2):135-42.

13.Jackson AS, Pollock ML. Generalized equations for predicting body density of men. Br J Nutr. 1978;40(3):497-504. http://dx.doi.org/10.1079/BJN19780152. PMid:718832.

14.Siri WE. Body composition from fluid spaces and density: analysis of methods. 1961. Nutrition. 1993;9(5):480-91, discussion 480, 492. PMid:8286893.

15.Drinkwater EJ, Lawton TW, Lindsell RP, Pyne DB, Hunt PH, McKenna MJ. Training leading to repetition failure enhances bench press strength gains in elite junior athletes. J Strength Cond Res. 2005;19(2):382-8. PMid:15903379.

16.Rooney KJ, Herbert DR, Balnave JR. Fatigue contributes to the strength training stimulus. Med Sci Sports Exerc. 1994;26(9):1160-4. PMid:7808251.

17.Schoenfeld BJ, Peterson MD, Ogborn D, Contreras B, Sonmez GT. Effects of low- vs. high-load resistance training on muscle strentgh and hipertrophy in well-trainade men. J Strength Cond Res. 2015;29(10):2954-63. http://dx.doi.org/10.1519/JSC.0000000000000958. PMid:25853914.

18.Rhea MR, Alvar BA, Burkett LN, Ball SD. A meta-analysis to determine the dose response for strength development. Med Sci Sports Exerc. 2003;35(3):456-64. http://dx.doi.org/10.1249/01.MSS.0000053727.63505.D4. PMid:12618576.

19.Souza RW, Aguiar AF, Carani FR, Campos GE, Padovani CR, Silva MD. High-intensity resistance training with insufficient recovery time between bouts induce atrophy and alterations in myosin heavy chain content in rat skeletal muscle. Anat Rec (Hoboken). 2011;294(8):1393-400. http://dx.doi.org/10.1002/ar.21428. PMid:21714108.

20.Charro MA, Aoki MS, Coutts AJ, Araújo RC, Bacurau RF. Hormonal, metabolic and perceptual responses to different resistance training systems. J Sports Med Phys Fitness. 2010;50(2):229-34. PMid:20585303.

21.Leite RD, Prestes J, Rosa C, Salles BF, Maior A, Miranda H, et al. Acute effect of resistance training volume on hormonal responses in trained men. J Sports Med Phys Fitness. 2011;51(2):322-8. PMid:21681169.

22.Uchida MC, Crewther BT, Ugrinowitsch C, Bacurau RF, Moriscot AS, Aoki MS. Hormonal responses to different resistance exercise schemes of similar total volume. J Strength Cond Res. 2009;23(7):2003-8. http://dx.doi.org/10.1519/JSC.0b013e3181b73bf7. PMid:19855324.