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Acute Effect of Drop-Set, Traditional, and Pyramidal Systems in Resistance Training on Neuromuscular Performance in Trained Adults

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Abstract

Costa, BDV, Ferreira, MEC, Gantois, P, Kassiano, W, Paes, ST, de Lima-Júnior, D, Cyrino, ES, and Fortes, LS. Acute effect of drop-set, traditional, and pyramidal systems in resistance training on neuromuscular performance in trained adults. *J Strength Cond Res* 35(4): 991–996, 2021—The aim of this study was to analyze the acute effects of resistance training (RT) systems on lower- and upper-limb performance in trained adults. Eighteen male young adults with experience in RT aged from 18 to 26 years underwent the 3 experimental conditions (drop-set [DS], decrescent pyramid [DP], and traditional [TR]). The subjects performed 2 exercises (bench press and leg press 45°). In the DS condition, they underwent 2 sets of 10 repetitions at 12RM, followed by 5 additional repetitions with an intensity of 15RM with 6-minute interval rest between sets. In the DP, it was performed 3 sets of 10 repetitions at 10RM, 12RM, and 15RM, respectively, and the rest interval was 3 minutes between sets. In the TR, the subjects performed 3 sets of 10 repetitions at 12RM with 3 minutes of rest between sets. Countermovement jump, peak power (W_{peak}), and force (F_{peak}) in the bench press were evaluated in the baseline, before, and 30 minutes after the experimental sessions. Countermovement jump performance decreased significantly only after the DS and DP conditions (-6.7 and -1.9%, respectively). The groups were significantly different in the post-intervention; the DS condition presented lower values when compared with the DP ($p = 0.01$) and TR ($p = 0.001$). According to F_{peak} and W_{peak}, only DS condition significantly decreased the performance (-3.8 and -4.1%, respectively). The results indicate the DS and DP conditions impair the neuromuscular performance of the lower limbs, whereas for upper limbs, only DS condition negatively affect upper-limb performance.

Key Words: strength training, peak force, peak power, countermovement jump

Introduction

Resistance training (RT) has been widely used to improve strength and increase muscle mass (5,9,14). In addition, several strategies are used within a training routine to maximize those adaptations, and the RT system is one of them (26,31). The RT system prevents the stagnation of gains in strength and muscle mass due to the manipulation of several acute variables (e.g., intensity, volume, order, choice of exercises, time under tension [TUT], and rest interval) used by coaches and athletes (1).

Among the RT systems, the most common are traditional (TR), decrescent pyramid (DP), and drop-set (DS) (8). The TR system, also known as multisets system, is composed of multiple sets with the same load; also, it is the most commonly used system among the RT practitioners (8). Decrescent pyramid consists of decreasing the load and increasing the number of repetitions in each set of the exercise, which allows for the increase of the total volume of training (26). In addition, DS is a training system widely used by individuals with RT experience (1). Drop-set consists of performing a set of an exercise, then the load is decreased and more repetitions are performed without or with rapid interval rest between the drops (6). This system increases metabolic stress due to the high number of repetitions performed in the set and is usually performed by bodybuilders (17).

Previous studies have shown that reduced neuromuscular performance during and after an RT session depends on the strategy that causes a minor impact on acute responses (e.g., countermovement jump [CMJ], peak power and force, and isometric strength) (7,17,21). The RT sessions that use momentary concentric failure, longer TUT, and shorter rest intervals between sets and sessions are examples of protocols that directly influence the decline of acute neuromuscular performance (7,24). In fact, previous research has reported that even when the volume load is equalized, higher TUT provides greater neuromuscular impairment (7,30). Thus, depending on the strategy, the neuromuscular performance might be increased, maintained, or impaired (15,23,28).

Concerning RT system, an investigation was conducted to compare the effects of TR and DS systems on maximal voluntary contraction (6). The results showed that a single training session

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of the DS system decreased up to 13% the performance of maximal voluntary contraction, with a significant difference when compared to the TR system. That is, different RT system generates varied acute responses on neuromuscular performance (15,23,28).

It is important to maintain performance during the RT session due to the volume load of training, which plays a main role on muscle hypertrophy (27), without increasing metabolic stress reducing acute performance (12). In addition, increased metabolic stress may lead to depletion of creatine stores and reduction of adenosine triphosphate, as well as augmented muscle damage markers (lactate, ammonia, and creatine kinase) (10,11,18). Those facts result in delayed resynthesis of recovery markers and, consequently, higher recovery periods (10,11,18). Thus, the weekly training frequency of a muscle group might be impaired, resulting in an inferior weekly volume load. Accordingly, RT systems with a greater ratio of stimulus/rest are uninteresting for RT practitioners who aim to accelerate neuromuscular recovery within and between training sessions (18).

Therefore, the purpose of this study was to analyze the acute effects of RT systems on lower-limb (CMJ) and upper-limb (peak power [W_{peak}] and peak force [F_{peak}]) performance in trained adults. Because the strategy adopted in RT session affects neuromuscular responses (17,20), we hypothesized that lower- and upper-limb performance will be impaired after RT session; however, greater reductions will be seen after the DS system.

Methods

Experimental Approach of the Problem

This is a controlled, randomized, and cross-over investigation with 3 experimental conditions with a 1-week washout interval. The subjects were male young adults with previous experience in RT. They underwent the 3 experimental conditions after the 2 baseline visits that aimed the reproducibility of the dependent variables. The intervention order was randomized. That is, the subjects performed the systems (DS, DP, or TR) with the same exercises (bench press and leg press 45°) in a randomized order separated by a 1-week washout (Figure 1). Simple randomization was performed for the 3 experimental conditions (DS, DP, and TR). The random number table was generated on www.randomizer.org site.

The 12 repetition maximum (12RM) test was performed to define the training load as recommended by Haff and Triplett (13). Countermovement jump, W_{peak}, and F_{peak} in the bench press (70% of 12RM) were evaluated in the baseline, before (pre-experimental), and 30-minute after the experimental sessions. The subjects were instructed to abstain from any physical exercise, ingest alcohol 48 hours before experimental sessions, as well as abstain from caffeine at least 3 hours before experimental sessions.

Subjects

The subjects were recruited using the nonprobabilistic sampling method, yielding a total of 18 male volunteers aged 18 to 26 years (mean ± *SD*: 21.5 ± 2.4 years; 77.8 ± 7.1 kg; 1.8 ± 0.0 m; 23.8 ± 1.7 $kg \cdot m^{-2}$). A post hoc power analysis for differences in neuromuscular performance after the experimental conditions was greater than 95%. The subjects were engaged in RT for at least 2 uninterrupted years. Also, they had no history of muscular or joint injury and did not intake any ergogenic substance for strength or muscle mass in the past 6 months. The subjects were oriented to maintain their routines, eating habits, and abstain from any exercise program during the study. Importantly, all the procedures described below (e.g., tests and experiments) were performed at the same time of the day (i.e., 5–7 PM) because testing at different times of the experiment may affect the subjects' performance (2).

After receiving information about the procedures, the subjects signed in the written informed consent form. The study was approved by the Federal University of Pernambuco ethics and research committee (CAAE: 47571415.9.0000.5208) and followed the ethical principles contained in the Declaration of Helsinki (2008).

Procedures

Resistance Training Sessions. In the DS condition, the subjects underwent 2 sets of 10 repetitions at 12RM. Subsequently, without interval, the intensity was decreased to 15RM and the subjects performed 5 additional repetitions with 6-minute interval rest between sets. In the DP, it was performed 3 sets of 10 repetitions with a rest interval of 3 minutes. The first set was performed at 10RM, the second set at 12RM, and third set at 15RM. The number of repetitions in each set was maintained the same, that is, the subjects performed an equal number of repetitions in the 3 experimental conditions (i.e., 30 total repetitions). In the TR condition, the subjects performed 3 sets of 10 repetitions at 12RM with 3 minutes of rest between sets (Table 1). The subjects were instructed to exhale during the concentric phase and inhale in the eccentric phase during each repetition in both exercises. The aim was to maintain a ratio of 1:2

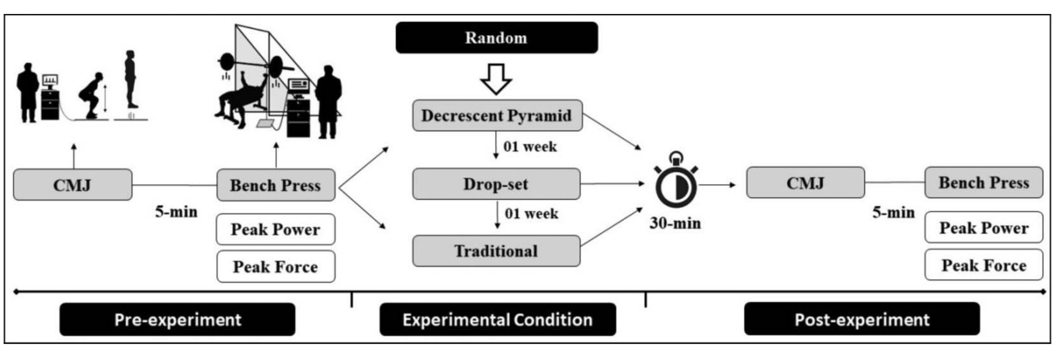

Figure 1. Experimental design. CMJ = countermovement jump.

Table 1
Resistance training sessions.*

Week	DS	DP	TR
Intensity zone	12RM and 15RM	10RM, 12RM, and 15RM	12RM
Sets × repetitions	2 × (10 + 5)	3 × 10	3 × 10
Rest between sets	6 min	3 min	3 min
Total rest	6 min	6 min	6 min

*DS = drop-set; DP = decrescent pyramid; TR = traditional; RM = repetition maximum.

for the concentric and eccentric actions, respectively, as recommended in a prior study (22).

Neuromuscular Measurements: Bench Press W_{peak} and F_{peak}. W_{peak} *and* F_{peak} were analyzed using a Smith machine and free weights (Righetto, São Paulo, Brazil). The bench throw was performed at an intensity of 70% of 12RM. The subjects lay down in the supine position, lowered the bar to touch their chest, and in the concentric phase explosively threw the load. Three attempts were performed with a 30-second interval, and the highest value was adopted. W_{peak} was analyzed by the bar velocity, whereas the F_{peak} was calculated using a T-Force linear encoder (T-Force, Murcia, Spain) (3). The linear encoder was attached to the bar using a retractable cord that provides W_{peak} and F_{peak} measurements. The intraclass correlation coefficient (ICC) was used to determine the test-retest reproducibility as well as the coefficient of variation (CV): F_{peak} (ICC = 0.99, CV = 0.59%) and W_{peak} (ICC = 0.99, CV = 0.73%).

Countermovement Jump. The CMJ was evaluated using a contact platform (Cefise, São Paulo, Brazil). The subjects were instructed to perform a squat with ~90° knee flexion and hands on the hips. Then, the subject was asked to perform a jump with the highest possible height. Three attempts were performed with 30-second rest between them (19). The ICC for CMJ was acceptable (ICC = 0.98, CV = 1.75).

Maximum Repetitions. Initially, the intensity zone of 12RM was determined after the 12RM test. The exercises performed were bench press and leg press 45°. The subjects performed the 12RM test in 2 distinct sessions with a recovery time of 48 hours, one familiarization session and the test itself. Two attempts were made with intervals of 10 minutes between sets. Accordingly, a warm-up (2 sets of 15–20 repetitions with 70% of predicted 12 RM, adopting rest intervals of 120-second between sets) was performed before the 12RM test. Verbal encouragement was given throughout the 12RM test. The ICC and CV determined the test-retest reproducibility for the 12 RM (bench press [ICC = 0.93, CV = 3.8 kg] and leg press 45° [ICC = 0.91, CV = 8.0 kg]). The intensity of 10RM was obtained by addition of ~5% to the equivalent weight of 12RM, whereas the 15RM was calculated by subtracting ~5% of the weight corresponding to 12RM.

Anthropometry. Body mass was measured to the nearest 0.1 kg using a calibrated electronic scale (Welmy, W300, Caxias do Sul, Brazil). Height was measured with a stadiometer to the nearest 0.1 cm, with the subjects wearing no shoes. Body mass index was calculated as body mass in kilograms divided by height in meters squared.

Statistical Analyses

The Shapiro-Wilk test was used to analyze the data distribution. Levene's test assessed the homoscedasticity of the groups. All the data are described as mean and SD. Repeated-measures two-way analysis of variance analyzed the interaction between time (pre vs. post [30 minutes after]) and interventions (DS vs. DP vs. TR) for the CMJ and bench press W_{peak} and F_{peak}. Bonferroni's post hoc test found the significant differences, if any. The percent delta (Δ%) from pre- to post-experiment was calculated as follows: Δ% = ([post − pre]/pre) × 100. Moreover, effect size (ES) revealed differences in a practical point of view. According to Rhea (25), the following criteria were adopted: $d < 0.35$ = trivial ES, $0.35 \leq d < 0.8$ = small ES, $0.8 \leq d < 1.5$ = moderate ES, and $d \geq 1.5$ = large ES. Confidence intervals (CIs = 95%) were used to specify the estimation of changes. The data were analyzed using the software SPSS 21.0, and alpha level adopted was 5%.

Results

All the subjects completed the experimental sessions and were included in the study.

Neuromuscular Performance

The CMJ, F_{peak}, and W_{peak} performance before and after the 3 experimental conditions are presented in Table 2. In the CMJ performance, significant interaction was observed for the intervention vs. time ($F_{(2,34)} = 8.111$, $p = 0.001$), time ($F_{(1,17)} = 24.4$, $p < 0.001$), as well as for group ($F_{(2,34)} = 7.878$, $p = 0.002$). The post hoc pairwise comparisons revealed that CMJ performance decreased significantly from pre- to post-intervention after the DS and DP conditions ($p < 0.001$, CI 95% = 1.1 to 3.0, Δ% = −6.7%, ES = 0.70 [small], and $p = 0.04$, CI 95% = 0.0 to 1.3, Δ% = −1.9% and ES = 0.20 [trivial], respectively), whereas the TR condition showed no difference in time ($p = 0.26$, CI 95% = 20.2 to 0.7, Δ% = −0.7%, ES = 0.08 [trivial]) (Figure 2). The changes between groups were significantly different in the post-intervention; DS condition presented lower scores when compared with the DP ($p = 0.01$, CI 95% = −2.6 to −0.2) and TR conditions ($p = 0.001$, CI 95% = −3.1 to −0.7) (Figure 2). No difference was observed between DP and TR conditions ($p = 0.65$, CI 95% = −1.5 to 0.5) (Figure 2).

According to F_{peak}, significant effect for intervention vs. time ($F_{(1,3,23,5)} = 16.860$, $p < 0.001$), time ($F_{(1,17)} = 8.356$, $p = 0.01$), and group ($F_{(2,34)} = 3.326$, $p = 0.04$) was found. The DS condition significantly decreased from pre- to post-intervention ($p < 0.001$, CI 95% = 9.3 to 25.2, Δ% = −3.8%, ES = 0.27 [trivial]) (Figure 3). No difference was observed for DP and TR conditions ($p > 0.05$, CI 95% = 23.5 to 3.5, Δ% = 0.02, ES = 0.00 [trivial], and $p = 0.86$, CI 95% = 25.7 to 4.8, Δ% = 0.00, ES = −0.01 [trivial], respectively) (Figure 3). The changes between the groups were different in post-intervention; DS condition was significantly lower when compared with the DP ($p = 0.006$, CI 95% = −25.8 to −4.1) and TR ($p = 0.01$, CI 95% = −27.8 to −3.1) conditions. No difference was found between DP and TR conditions ($p > 0.05$, CI 95% = −9.4 to 8.4) (Figure 3).

For W_{peak}, significant effect for intervention vs. time was observed ($F_{(1,4,23,9)} = 21.121$, $p < 0.001$) as well as for time ($F_{(1,17)} = 10.424$, $p = 0.005$). No significant difference for group ($F_{(2,34)} = 3.133$, $p = 0.056$) was found. The DS system condition showed a significant decrease in time ($p < 0.001$, CI 95% = 11.0 to 26.0, Δ% = −4.1%, ES = 0.13 [trivial]) (Figure 4). No difference was found for DP and TR conditions ($p = 0.75$, CI 95% = 24.7 to 3.5, Δ% = −3.2%, ES = −0.01 [trivial], CI 95% = −4.7 to 3.5; and $p = 0.83$, Δ% = −4.1, ES = 0.01 [trivial], respectively).

Table 2
Neuromuscular responses (CMJ, W_{peak}, and F_{peak}) to the experimental conditions.*†

	Condition					
	DS		DP		TR	
	Pre	Post	Pre	Post	Pre	Post
CMJ (cm)	31.1 ± 3.0	29.0 ± 3.2‡	31.1 ± 3.4	30.4 ± 3.0‡§	31.2 ± 3.5	30.9 ± 3.4§
F_{peak} (N)	461.2 ± 64.2	444.0 ± 67.7‡	459.0 ± 61.7	459.0 ± 61.5§	459.0 ± 63.4	459.5 ± 67.7§
W_{peak} (W)	455.1 ± 63.7	436.6 ± 66.5‡	451.9 ± 61.6	452.5 ± 61.7§	453.0 ± 63.5	452.5 ± 67.1§

*DS = drop-set; DP = decrescent pyramid; TR = traditional; CMJ = countermovement jump; F_{peak} = peak force; W_{peak} = peak power.
†Data are presented as mean ± *SD*.
‡$p < 0.05$ different to pre values.
§$p < 0.05$ different to DS.

Discussion

The aim of this study was to analyze the acute effects of an RT session, adopting a different training system, on neuromuscular performance. The main findings demonstrated that: (a) the DS system decreased CMJ, W_{peak}, and F_{peak} (bench press) performance; (b) the DP system condition only decreased the CMJ performance, and (c) the neuromuscular performance was similar after the TR system. Therefore, those results partially agree with the hypothesis of this study.

Regarding the neuromuscular performance, only DS and DP conditions affected negatively CMJ performance. W peak, and F peak in the bench throw, however, were affected only by the DS condition, reducing performance. Considering that the DS system commonly adopts momentary concentric failure, the response is not a surprise, because concentric failure is the result of an acute decrease in the muscle capacity of force generation, mostly attributed to the accumulation of neuromuscular fatigue. However, the protocol adopted in this investigation did not use momentary concentric failure. The subjects performed 2 sets of 15 total repetitions, 10 performed with 12RM intensity and 5 additional repetitions with the intensity of 15RM performed after the drop. Although some acute variables were not evaluated, we can speculate possible explanations. The execution velocity of the repetitions in the DP and TR conditions were performed in average of 3 seconds (1:2 concentric and eccentric phases, respectively), that is, the subjects experienced 30 seconds of TUT by sets, whereas in the DS condition, the TUT was 45 seconds. Therefore, we suggest that these results may also have been influenced by TUT by sets that consequently led to fatigue rapidly.

In fact, Fisher et al. (7) submitted 8 volunteers to 4 RT experimental sessions until momentary concentric failure, with the aim of evaluating acute fatigue. The sessions were divided into: (a) high-load, (b) low-load, (c) forced repetitions, and (d) breakdown sets. The researchers concluded that the conditions that showed the longest TUT, low-load, and breakdown sets were responsible for a greater decrease in the maximum isometric force. Moreover, previous studies have shown that the combination of a higher number of repetitions and increased TUT might lead to fatigue (7,29). The combination of those 2 strategies induces to high central motor output, reducing the force and declining neuromuscular performance (16). This phenomenon is a result of peripheral metabolic changes within the muscle (i.e., accumulation of H^+ ions, lactate dehydrogenase, and calcium levels above optimum levels for overlapping contractile units), which leads to decreased transmission of the muscle action potential and higher levels of fatigue (4). Because mechanistic processes were not assessed in our investigation, we can only speculate the mechanism that could explain the greater decrease in neuromuscular performance after the DS system is the combined near-to-momentary concentric failure with longer TUT by sets in comparison with DP and TR systems. Thus, in addition to the training setup until near or momentary concentric failure, the time of the stimulus seems to play an important role in the acute neuromuscular responses.

Regarding the decrease on CMJ performance found in the DP condition, we affirm that in the DS condition, momentary concentric failure causes greater influence on the neuromuscular responses, even with less TUT between the 2 conditions. Noteworthy, DS condition causes more decrement in CMJ performance

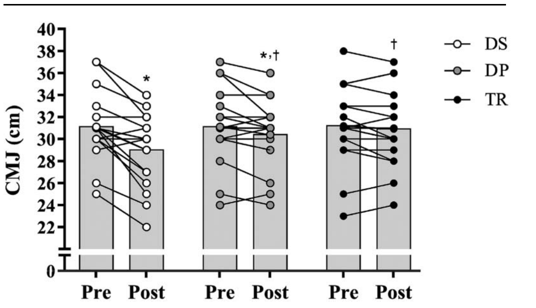

Figure 2. Countermovement jump performance for each experimental condition at pre and post. Bars are means, and circles are individual values. CMJ = countermovement jump; DS = drop-set; DP = decrescent pyramid; TR = traditional. *Post-experimental values lower than pre-experimental ($p < 0.05$); †CMJ performance greater ($p < 0.05$) when compared with DS.

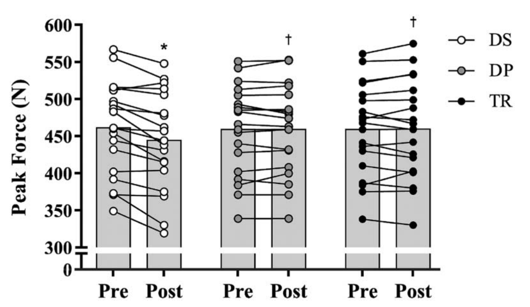

Figure 3. Peak force for each experimental condition at pre and post moment. Bars are means, and circles are the values of the subjects. N = Newtons; DS = drop-set; DP = decrescent pyramid; TR = traditional; CMJ = countermovement jump. *Different from pre values ($p < 0.05$); †CMJ performance greater when compared with DS ($p < 0.05$).

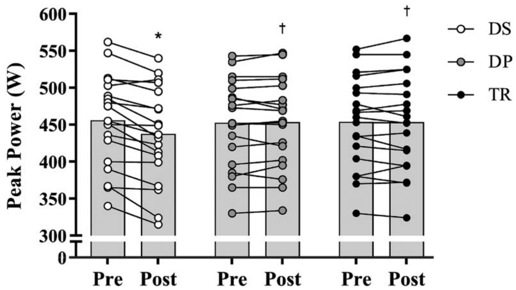

Figure 4. Peak power for each experimental condition at pre and post. Bars are means, and circles are the values of the subjects. W = watts; DS = drop-set; DP = decrescent pyramid; TR = traditional; CMJ = countermovement jump. *Different from pre values ($p < 0.05$); †greater CMJ performance when compared with DS ($p < 0.05$).

when compared with DP ($\Delta\% = -6.7$ vs. -1.9; ES = 0.70 vs. 0.20), showing that the combination of near or momentary concentric failure with greater TUT observed in the DS condition affects the magnitude of neuromuscular performance decrement. Nonetheless, these results were only seen in the lower limb. The possible explanation for this finding may be the difference between the exercise performed and the test used to assess the lower-limb performance. The subjects in our study performed the leg press exercise, whereas the test to evaluate the performance was the CMJ. That is, in the leg press, the equipment moves and the body remains static, whereas in the CMJ, the body moves instead, characterizing distinct motor tasks (32).

To the best of our knowledge, this is the first study that analyzed the acute effect of the RT training systems on CMJ (lower limbs), W_{peak}, and F_{peak} (upper limbs). Our data support the results of previous research that showed a decrease in neuromuscular parameters (7,29). However, due to the specificity of the responses, we may only extrapolate those results to the bench press and leg press. A previous research using isolated lumbar extension compared 2 conditions: high-load and low-load in the RT until momentary failure; the results were similar to those presented in the current investigation. In other words, when the volunteers were performing the "low-load" condition, until momentary failure, they presented longer TUT, leading to higher levels of fatigue and lower values in the maximum isometric force of the trunk extensors (29). Thus, it seems that different muscle groups respond in a similar way, acutely, when submitted to the same training strategy. However, investigations conducted with other muscles or muscle groups are necessary to confirm whether this behavior is, in fact, similar.

Although our study presents a strong design, our data should be analyzed with caution because it has limitations. We are only considering the immediate responses. Thus, future studies are required to analyze those responses over a longer period, such as 24 and 48 hours after exercise. Another important factor was the lack of mechanism assessments that could better sustain our results (i.e., electromyography). Nevertheless, those responses explain the decline in performance. In addition, the data may only be extrapolated to trained young men and cannot be generalized to other populations. Future researches are required to investigate the acute response of the RT system in other age and training level groups.

Finally, our data suggest that the adoption of an RT system leads the subject close to the momentary failure for a long period, acutely, and may lead to a greater decrease in neuromuscular performance for both lower and upper limbs. From a practical point of view, this study may clarify that RT systems can be adopted to avoid or induce greater acute fatigue, especially if the influence of the fatigue on performance parameters is aimed.

Practical Applications

Those findings have shown that, acutely, the RT systems result in different responses, reducing performance in CMJ, W_{peak}, and F_{peak}. Thus, maintaining performance during the training sessions is important for preserving the volume load throughout the periodization. Thus, adopting systems that attenuate those responses may not be a good choice, mainly because those strategies require longer recovery periods, which may result in a decrease in training frequency for the same muscle group. However, those responses seem to be limb dependent because the DP system only influenced the lower limbs, whereas the DS system decreased the performance of both. Based on the aforementioned information, only the TR system maintained the neuromuscular performance of both limbs; in addition, this system seems to be a good strategy to reduce the recovery period between sessions. Nonetheless, this statement should be viewed with caution because no investigations have analyzed responses to RT systems over time (24–48 hours).

Acknowledgments

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