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Greater volumes are required to reduce muscle performance in well-trained individuals

Grandes volumes são necessários para reduzir o desempenho muscular em indivíduos bem treinados

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Abstract – A specific drop jumps (DJs) protocol (using 100 jumps) has been largely used to induce muscle damage. However, it failed to show relevant drop in performance in well-trained individuals. Trained subjects may require a protocol with greater volume to induce decrease of muscle performance. The aim of this study was to assess muscle performance after two DJs damaging protocols with different volumes in well-trained individuals. Eighteen strength and/or power-trained males (4.92 ± 2.78 years of training experience) were randomly assigned into one of two groups: DJ100 (five sets of 20 DJs) or DJ140 (seven sets of 20 DJs), with 2-min of rest interval. DJs were performed from a 60-cm box. After landing, the volunteers performed a maximal vertical rebound jump. Muscle swelling increased significantly on both DJ100 and DJ140 ($p < 0.001$). Maximal isometric torque (MIT) decreased significantly on both DJ100 ($p = 0.005$) and DJ140 ($p < 0.001$). MIT showed no between-group difference on pre-assessment ($p = 0.815$). However, on post-assessment, MIT was significantly lower on DJ140 than DJ100 ($p = 0.043$). Countermovement jump (CMJ) decreased significantly on DJ140 ($p = 0.001$), but not on DJ100 ($p = 0.802$). There was no between-group difference on pre-assessment ($p = 0.978$). However, on post-assessment, CMJ was significantly lower on DJ140 than DJ100 ($p = 0.038$). DJ140 induced greater drop in isometric strength than DJ100 and only DJ140 significantly reduced jump performance. These results demonstrated that well-trained individuals require a great volume of DJs to reduce substantially muscle performance.

Key words: Muscle performance; muscle strength; exercise volume; athletes

Resumo – *Um protocolo específico de Drop Jumps (DJs), com 100 saltos, tem sido amplamente utilizado para induzir o dano muscular. Entretanto, este protocolo tem falhado em mostrar uma queda relevante em indivíduos treinados. Objetivou-se avaliar o desempenho muscular após dois protocolos de DJs com diferentes volumes em indivíduos treinados. Dezoito homens treinados em força e/ou potência (4,92 ± 2,78 anos de treinamento) foram aleatoriamente designados em um dos dois grupos: DJ100 (cinco séries de 20 DJs) ou DJ140 (sete séries de 20 DJs), com 2 minutos entre as séries. Os DJs foram executados de uma caixa de 60 cm de altura. Após a aterrisagem, os voluntários executaram um salto vertical máximo. O inchaço muscular aumentou significativamente em ambos os grupos ($p < 0,001$). O torque isométrico máximo (TIM) reduziu significativamente tanto no DJ100 ($p = 0,005$) quanto no DJ140 ($p < 0,001$). O TIM não apresentou diferenças entre grupos no momento pré ($p = 0,815$). Entretanto, no momento pós, o TIM foi significativamente inferior no DJ140 em relação ao DJ100 ($p = 0,043$). O salto com contra movimento (SCM) reduziu significativamente no DJ140 ($p = 0,001$), mas não no DJ100 ($p = 0,802$). No momento pós, o SCM foi significativamente inferior no DJ140 em relação ao DJ100. O DJ140 induziu uma queda maior na força isométrica em relação do DJ100, e somente o DJ140 reduziu significativamente o desempenho no salto. Esses resultados demonstraram que indivíduos bem treinados requerem um grande volume DJs para reduzir substancialmente o desempenho muscular.*

Palavras-chave: *Desempenho muscular; força muscular; volume de exercício; atletas*

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INTRODUCTION

A strenuous exercise session may reduce muscle performance due to a complex sequence of events, such as a long-lasting fatigue, myofibril's rupture, inflammatory response, muscle soreness, and energetic impairments[1,2]. Consequently, athletes suffer a decline in muscle performance that may last minutes, hours, or several days[1,3]. The decline in muscle performance could be due to muscle fatigue and depends on contractile function, muscle activation, neurotransmitters, metabolites, oxygenation, pain, wakefulness, and energetic demand[4]. Otherwise, the long-lasting decline in muscle performance usually followed by soreness is referred as exercise induced muscle damage[5]. Such impairments might be characterized according the post-exercise decline in force production capacity as: mild reduction (20% or less of muscle strength decline), moderate reduction (20 to 50% of muscle strength decline) and large reduction (more than 50% of muscle strength decline)[1].

In order maintain a great performance in athletes, several strategies to improve muscle recovery have been studied, such as cryotherapy[6], compression garments[7], active recovery[8], and nutritional interventions[9]. Each modality has a specific mechanism, increasing protein synthesis and decreasing protein degradation, decreasing inflammatory response, protecting muscle fibers, and/or repairing energetic function[5].

Therefore, to study recovery modalities, firstly muscle damage must be induced by an exercise protocol. Several protocols to induce muscle damage have been used in accordance with the objective and specificity of population[10]. Such inducing muscle damage protocols include strenuous eccentric exercise to enhance disruption in sarcomere, cell membrane and sarcoplasmic reticulum, and muscle damage[11]. In this way, a specific drop jumps protocol has been largely used to assess muscle damage and recovery in lower limbs. This damaging protocol is composed by five sets of 20 drop jumps from a 0.6 m box with 2-min rest intervals between sets, and induce a decrease of muscle performance and an increase in muscle soreness through eccentric and fast concentric contractions[12].

Previous studies that applied this drop jump protocol to induce muscle damage had included recreational or untrained subjects, or had shown small muscle damage[13,14]. In a classic study, Miyama et al [12] assessed muscle damage induced by this drop jump protocol in untrained male individuals. They reported a decrease of 40% in strength capacity and 20% in power capacity immediately after exercise. In the same way, other studies that included non-athletes and individuals who had little or no experience in strength and/or power training showed a decrease of 20% to 40% in force production capacity and a decrease of 13% to 20% in power production capacity immediately after protocol[14-17]. On the other hand, Bridgeman et al [18] and Shenoy et al [19] had applied different DJs protocol in strength trained or power trained athletes and showed a small decrease in maximal strength and muscle power immediately and 24 hours after protocol.

Apparently, well-trained subjects develop a protective and learn capacity from training, named repeated bout effect. Such phenomenon occurs after a single training session and may last for up to six months[20]. Although Izquierdo et al [21] have showed that force production capacity falls after a resistance exercise session regardless training status, some studies have proposed that strength trained men are less susceptible to eccentric exercise-induced strength loss[22]. Whereas exercise induced muscle damage seems dependent, at least partially, on training experience[23], it could be hypothesized that strength trained athletes may require greater volume of a drop jumps protocol to induce substantial decrements in muscle performance. Thus, the purpose of this study was to assess muscle strength, performance, and swelling following the traditional drop jump protocol (DJ100) and a modified drop jump protocol (DJ140) performed with a greater volume in well-trained individuals.

METHODOLOGICAL PROCEDURES

Subjects

Well-trained individuals were volunteers recruited from a university community and from high-performance centers. Twenty strength-trained and/or power-trained males were recruited to participate in this study. All volunteers were regularly engaged in strength and/or power training, besides competing in sports such as rugby, swimming, cycling, or basketball. Individuals were excluded if they had cardiovascular, respiratory, metabolic and/or neuroendocrine diseases. They were also excluded if they had been consuming alcohol, creatine, beta-alanine, caffeine, ephedrine, ornithine, branched chain amino acids, carnitine, leucine or its metabolites, arginine, tryptophan, and/or antioxidants in the previous 30 days before the study protocol. Additionally, participants were excluded if they had used anabolic steroids and/or hormonal precursors in the previous year before the study protocol. All participants were fully informed of the purpose, procedures, risks and discomforts associated with the study, and provided a written informed consent. The study was approved by the University Institutional Ethics Committee (Ethics Committee: College of Health Sciences, University of Brasília, CAAE: 61443416.5.0000.0030) and was conducted in accordance with ethical standards. Two subjects were excluded after DJs protocol due to non-attendance on subsequent days.

Experimental Design

Due to the influence of the repeated bout effect on muscle damage levels and time course of recovery, a cross-over design was not applied in the present study[14]. Volunteers were randomly assigned into one of two groups: 1) five sets of 20 drop jumps (DJ100), or 2) seven sets of 20 drop jumps (DJ140). The volunteers visited research laboratory just once and the experimental procedure were done in approximately 120 minutes. The markers of muscle performance were assessed through three outcome variables: muscle swelling, countermovement jump (CMJ), maximal isometric torque (MIT). The markers of muscle performance were measured at baseline (Pre) and immediately after exercise protocol (Post). All measurements and protocols were conducted on morning to avoid circadian variations.

Damaging protocol

The exercise protocol to induce muscle damage was adapted from other studies[12,13,24] and consisted of five sets (DJ100) or seven sets (DJ140) from a 60-cm box, with two minutes of rest interval between sets. After dropping down from the box and landing on the floor, the volunteers were instructed to perform a maximally explosive vertical jump upward and then land on the floor. They were instructed to flex their knees at 90º (0º = full extension) during all landings and to keep their hands on their hips during the jumps. They were verbally encouraged to exert maximal effort during all repetitions. Each repetition took, on average, five seconds. This exercise protocol requires the activation of a large lower-limb muscle mass with the stretch-shortening cycle and a high-intensity eccentric characteristic.

Muscle Swelling

Muscle swelling was measured on right knee extensors using a B-mode ultrasound (Philips, VMI, Lagoa Santa, Brazil). A 7.5-MHz scanning probe was placed on the skin perpendicular to the tissue interface. The scanning probe was coated with a water-soluble transmission gel to provide acoustic contact without depressing the dermal surface. No additional pressure was applied to standardize the compression on the dermal surface. The measurement of muscle swelling was taken at 60% of the distance from the greater trochanter to the lateral epicondyle and 3 cm lateral to the midline of the anterior thigh[25]. The ultrasound intra-rater reliability was 0.94 and the coefficient of variation was 2.4%. Once the examiner found a satisfactory image, it was frozen on the monitor, stored and analyzed in software Image-J (National Institute of Health, USA, version 1.49). The distance between subcutaneous adipose tissue-rectus femoris interface and vastus intermedius-bone interface was designated as knee extensors muscle swelling. All measurements and analyses were performed three times by the same researcher and the mean value was considered for analysis. The measurement point had been marked at baseline to assure that the same point has been measured in post-assessment.

Maximal Isometric Torque

Maximal isometric torque (MIT) was measured using a Biodex System 3 dynamometer (Biodex Medical, Inc., Shirley NY, USA). Subjects were positioned on the dynamometer seat with safety belts fastened to the trunk, pelvis and thigh to avoid extraneous body movements that could affect MIT. The lateral epicondyle of the femur was used to align the knee rotation axis and the dynamometer rotation axis, allowing free knee extension and flexion from 85º flexion up to full extension. Gravity correction was obtained by measuring the torque exerted by the lever arm and the subject's leg at 30º flexion as well as in a relaxed position. The values of the isokinetic variables were automatically adjusted for gravity with the software Biodex Advantage (Biodex Medical Systems, Inc., New York, USA). The calibration of the dynamometer was carried out according to the specifications provided by the manufacture. For the test, participants were asked to cross their arms across the chest. MIT was measured at 60° of knee flexion (0º = full extension). The volunteers had two attempts of four seconds to achieve their maximal isometric torque with 1-min rest interval between attempts. The same researcher carried out the test procedures for all participants and provided verbal encouragement. Test-retest reliability coefficient (ICC) value for knee extensor peak torque was 0.91 in our laboratory.

Countermovement jump performance

The CMJ performance is usually measured as a functional marker of muscle performance[24]. CMJ was calculated by the flight time, measured on an AMTI force plate (model BP400600-HF-2000; Advanced Mechanical Technology Inc., Watertown, MA, USA), with a sampling rate of 1000Hz. The data were obtained from acquisition software (AMTI Acquisition Software, v.42; Advanced Mechanical Technology, Inc., Watertown, MA, USA) during vertical jumps and were processed with the software MATLAB (version R2008a7, The MAthWorks Inc., Natick, MA, USA). To perform CMJ, the volunteers were asked to keep their hands on their hips, star the movement on the standing position, flex knees and hip, and jump as high as possible. A self-determined range of motion was permitted and they received verbal encouragement by the same researcher. The subjects performed five CMJ (two as warm-up/familiarization and three attempts to achieve their best jump performance). Between all jumps the volunteers rested for 60 seconds. The greatest jump height was considered as CMJ performance and was used for further analyses. Jump height was calculated by the flight duration (fd) according the following equation: jump height = $(fd^2 \times 9.81)/8$. All measurements and analyses were conducted by the same researcher. The countermovement jump intra-rater reliability was 0.93 and the coefficient of variation was 4.1%.

Statistical Analysis

Data are presented as mean ± standard deviation. Normal distribution parameters were checked with Shapiro-Wilk test. Physical characteristics and training status were compared between groups by an independent t test. Muscle swelling, CMJ, and MVT were analyzed by a two-way mixed-model analyses of variance (group x time). The Bonferroni adjustment was applied as post hoc analysis if any interaction was found. The effect size was calculated and reported (h_p^2). The Statistical Package for Social Sciences (SPSS), version 21.0 (IBM, USA) was used for statistical analysis. The alpha level was set at 5% ($p \le 0.05$). Retrospective statistical power (1-b) was calculated by the G*Power software (version 3.1.9.2).

RESULTS

There were no between-group differences ($p > 0.05$) for physical characteristics and training status (Table 01). Nine well-trained individuals concluded the experimental procedures in each group. Ten individuals were high-performance rugby players, six individuals were high-performance swimmers, and two individuals were high-performance basketball players.

Table 1. Physical characteristics and training status reported in mean ± standard deviation.

Variables	DJ100 (n = 9)	DJ140 (n = 9)
Age (years)	23.00 ± 2.74	22.89 ± 3.37
Weight (kg)	82.46 ± 8.11	79.89 ± 10.06
Height (m)	1.78 ± 0.26	1.74 ± 0.08
BMI ($kg.m^{-2}$)	26.02 ± 2.23	26.44 ± 3.81
Training Experience (years)	5.22 ± 3.15	5.61 ± 2.74
Training Frequency (days/week)	4.00 ± 0.87	4.11 ± 0.78
Training Duration (min/day)	92.22 ± 26.35	101.67 ± 33.35

BMI: body mass index

On muscle swelling (Figure 1), there was no significant group by time interaction ($F = 1.217$; $p = 0.286$; $\eta_p^2 = 0.071$; power (1-b) = 0.597). Muscle swelling increased similarly on both groups after the exercise protocol ($p < 0.001$).

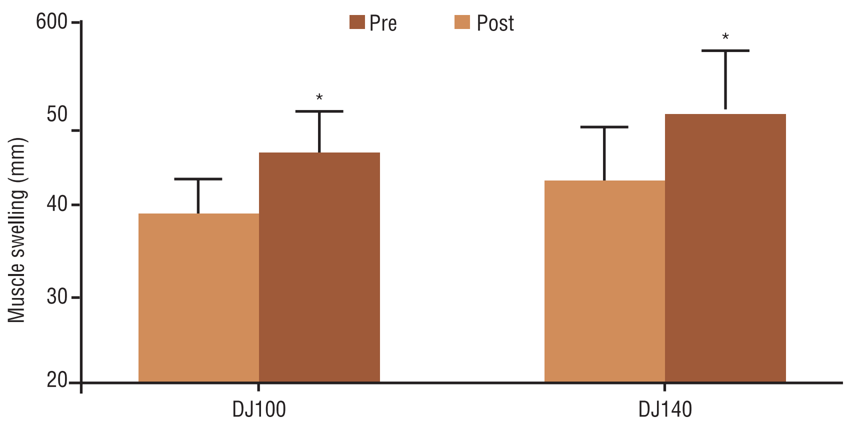

Figure 1. Muscle swelling on both DJ100 and DJ140 before and after damaging protocol (mean ± SD). * p ≤ 0.05, significantly different from pre-assessment.

On MIT (Figure 2), there was also a significant group by time interaction ($F = 4.841$; $p = 0.043$; $\eta_p^2 = 0.232$; power (1-b) = 0.843). MIT decreased on both DJ100 (pre: 299.17 ± 48.09 N.m vs. post: 264.92 ± 43.49 N.m; $p = 0.005$) and DJ140 (pre: 294.81 ± 26.62 N.m vs. post: 227.76 ± 35.09 N.m; $p < 0.001$). There was no between-group difference on pre-assessment ($p = 0.815$). However, on post-assessment, MIT was significantly lower on DJ140 than DJ100 ($p = 0.043$).

Regarding CMJ (Figure 3), there was a significant group by time interaction ($F = 7.421$; $p = 0.015$; $\eta_p^2 = 0.317$; power (1-b) = 0.825). CMJ decreased on DJ140 (pre: 43.52 ± 8.21 cm vs. post: 35.80 ± 9.26 cm; $p = 0.001$), but not on DJ100 (pre: 43.62 ± 7.90 cm vs. 43.15 ± 7.85 cm; p =

0.802). There was no between-group difference on pre-assessment (p = 0.978). However, on post-assessment, CMJ was significantly lower on DJ140 than DJ100 (p = 0.038).

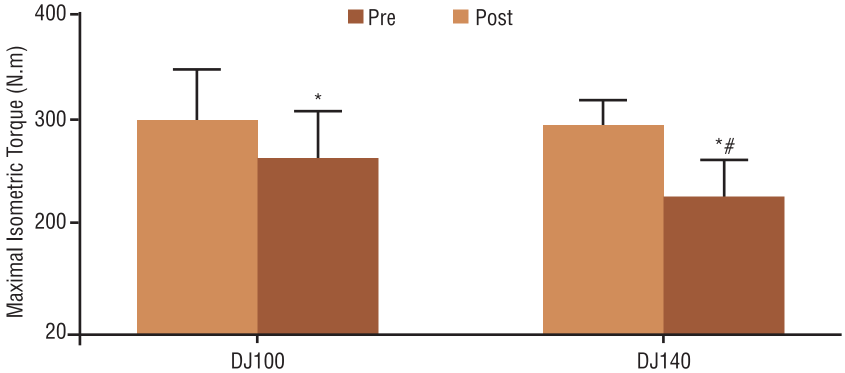

Figure 2. Maximal Isometric Torque on both DJ100 and DJ140 before and after damaging protocol (mean ± SD). * $p \leq 0.05$, significantly different from pre-assessment. # $p \leq 0.05$, significantly different from DJ100.

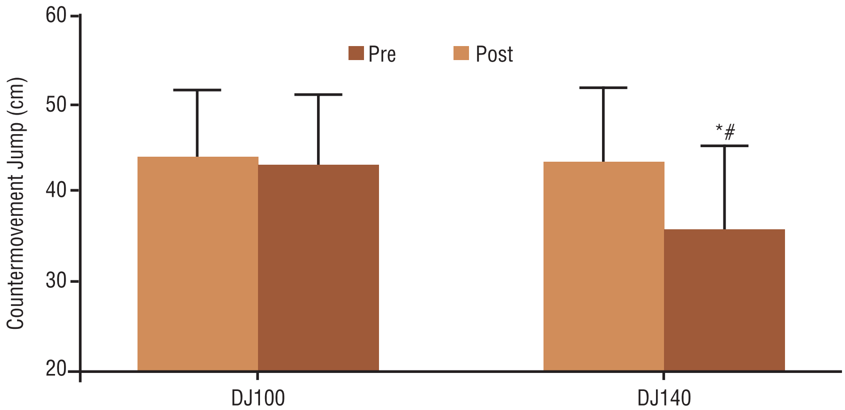

Figure 3. Countermovement jump on both DJ100 and DJ140 before and after damaging protocol (mean ± SD). * $p \leq 0.05$, significantly different from pre-assessment. # $p \leq 0.05$, significantly different from DJ100.

DISCUSSION

This study aimed to compare the decrements of muscle performance induced by two DJs protocols in well-trained athletes. The results showed that seven sets of 20 drop jumps induced similar responses of muscle swelling, but greater decrements of muscle strength and power than five sets of 20 drop jumps. Additionally, five sets of 20 drops jumps did not affect muscle power in well-trained athletes.

Increasing volume seems to be an effective strategy to drop performance in well-trained individuals. Apparently, well-trained athletes are adapted to exert a great physical effort and perform a greater amount of work even with physiological changes induced by exercise, showing a great resilience during the activity[26]. In this way, Newton et al [22] proposed that trained men experienced smaller changes in muscle function, swelling, and physiological parameters than untrained subjects after damaging exercise. Furthermore, individuals adapted to strength or power training may be exposed to the repeated bout effect, which promotes a better muscle recovery, less muscle pain and muscle soreness, and an attenuated inflammatory response[27].

Otherwise, Izquierdo et al [21] suggested that the magnitude of neuromuscular changes is not dependent on training status because the muscle is able to work more and accumulate more metabolites before task failure, with a greater loss of functional capacity. Such phenomenon may be supported by Faigenbaum et al [28], who affirmed that greater force production capacity is directly related to the magnitude of the decrease of muscle performance in strength exercises. However, in the present study, the individuals that performed 100 drop jumps suffered a small reduction on muscle strength and no reduction on muscle power. It might be explained by differences in damaging protocol used in the present study compared with aforementioned studies. The contraction mode seems to affect muscle function distinctly because they are related to different recruitments pathways. It is well established that eccentric contractions result in a greater mechanical overload on muscle fibers as well as non-contractile structures[20]. It potentially may compromise in a greater extent the muscle function.

To study the effect of protein ingestion in muscle performance recovery after a strenuous exercise, Shenoy et al [19] applied 100 drop jumps in well trained athletes in order to induce muscle damage. Their results showed a slight reduction in knee extensors strength (~15%). Similarly, Fonda et al [29] applied 50 DJs followed by 50 eccentric leg curls in moderated active men who were familiar with plyometric exercises. They also demonstrated a mild reduction in maximal torque and jump height one hour post-exercise. Additionally, it seems that, even when intensity is upraised, no additional drop in performance could be achieved. Bridgeman et al [18] increased drop jumps intensity adding an extra load. However, they did not find any further decrement in muscle strength immediately after exercise. Likewise, our results on DJ100 group showed a similar mild reduction in muscle strength and no reduction in muscle power in well-trained athletes.

In the present study, the greater volume protocol induced a moderate reduction in isometric strength capacity (22%)[1], whereas DJ100 only induced to a mild reduction (11%). Moreover, only DJ140 was able to reduce significantly muscle power (17%) in well-trained athletes. The magnitude of reduction in CMJ and MIT is consistent with previous studies that applied only 100 DJs and assessed subjects without familiarization with strength or plyometric exercises and were recreationally exercisers[14,15].

In time, the individuals that composed DJ140 performed a volume 40% greater than those from DJ100. Several studies have applied a large range of variation between high volume and low volume protocols (20 to 50%) to study the effect of exercise volume on acute physical outcomes[30]. Considering that some studies have reported differences in myofibrilar protein accumulation and in hormonal responses between protocols with 50% of variation in volume, we chose the greatest increase in volume that did not exceed the usual variation and respected the sets arrangement (20 drop jumps per set).

Another controversy point of this study, the responsiveness of CMJ seems to be different from MIT because, even with a not enough volume protocol, the force production capacity reduced 11%, while muscle power showed no reduction. Apparently, the responsiveness of isometric muscle strength differs from the responsiveness of muscle power after a DJs protocol, since the jump performance involves multiple mechanisms to generate power from the myotendinous complex[14]. Probably, the assessment of muscle performance may be more accurate if it be done through jump performance.

The results of this study suggest that well-trained athletes may require greater volume of drop jumps to induce muscle damage. This may be supported by Paschalis et al [23] who suggest that exercise volume are more prone to reduce muscle performance than exercise intensity. An important limitation of this study was the sample size. However, the grate statistical power supports the results. A study's limitation may be the absence of muscle performance measurements in the following days post-exercise. However, the magnitude of drop in force-generating capacity immediately after exercise is related to the time-course of muscle recovery[1]. Therefore, this study may contribute to the selection of the most appropriate protocol to induce muscle damage in trained individuals.

CONCLUSION

Five sets of 20 drop jumps were not able to reduce muscle power in well-trained subjects, whereas seven sets were. Additionally, seven sets reduced isometric strength to a greater extent than five. Therefore, the muscle performance decrement following DJs exercise seems to be dependent on exercise volume. These results suggest that well-trained individuals require great volume of DJs to reduce muscle power and strength.

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