The Effects of Accentuated Eccentric Loading on the Drop Jump Exercise and the Subsequent Postactivation Potentiation Response

Lee A. Bridgeman,[1] Michael R. McGuigan,[1] Nicholas D. Gill,[1,2] and Deborah K. Dulson[1]

[1]Sports Performance Research Institute New Zealand, AUT University, Auckland, New Zealand; and [2]New Zealand Rugby Union, Wellington, New Zealand

Abstract

Bridgeman, LA, McGuigan, MR, Gill, ND, and Dulson, DK. The effects of accentuated eccentric loading on the drop jump exercise and the subsequent postactivation potentiation response. *J Strength Cond Res* 31(6): 1620–1626, 2017—The aims of this study were (a) to investigate the acute effects of different drop jump (DJ) accentuated eccentric loading (AEL) protocols and (b) to investigate the effect of these AEL DJ protocols on subsequent countermovement jump (CMJ) performance. The subjects were 12 strength-trained athletes; initially, baseline CMJ performance was assessed and individual optimal DJ drop height identified. In subsequent weeks, subjects completed 1 set of 5 DJs with no additional load or an AEL of 10, 20, or 30% of their individual body mass (BM) using dumbbells to provide the extra load. After the AEL DJ protocols, 3 CMJs were completed after 2, 6, and 12 minutes rest. A generalized linear mixed model was used to investigate the effects of AEL load and time post-DJs on CMJ height, peak power, and ground reaction force. The 20% AEL condition resulted in greater CMJ height in comparison with all other conditions ($p < 0.001$). CMJ height was significantly greater after 2 and 6 minutes rest compared with 12 minutes ($p < 0.001$ and $p \leq 0.05$ respectively). Greater peak power was also found during the CMJs after the 20% AEL condition compared with baseline, BM, and 10% AEL ($p \leq 0.05$). In conclusion, 5 DJs with 20% AEL followed by a 2 minutes recovery period resulted in significant enhancement in CMJ height and peak power.

Key Words countermovement jump, jump height, peak power

Address correspondence to Lee A. Bridgeman, lee.bridgeman@aut.ac.nz.

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Introduction

The drop jump (DJ) is a plyometric exercise which is widely used by strength and conditioning (S&C) (18). It involves an athlete stepping off a box and then on making contact with the ground immediately performing an explosive vertical jump (3). The DJ exercise has been suggested to result in improved utilization of the SSC (3,10,34) and results in high eccentric force production (16). Previously, training using the DJ exercise has been reported to lead to: improvements in sprint performance (6,10), improvements in jumping performance (9,14,25), enhanced strength (12), and greater agility (11) and therefore may be an attractive option to S&C coaches. It has also been proposed that the inclusion of a low volume of DJs may lead to subsequent enhancements in performance as the result of a postactivation potentiation (PAP) response (4,8).

Plyometric activities such as the DJ have previously been reported to result in a PAP response. This refers to the phenomenon by which muscular performance characteristics are improved due to their contractile history (17). As yet the mechanisms responsible for the PAP response are unclear, however, when using plyometric activities such as the DJ it has been proposed that the preferential recruitment of type II motor units may be responsible for the subsequent improvement in lower-body performance (see Maloney et al. (24) and Seitz and Haff (28) for a full review of the mechanisms associated with PAP during plyometric exercise).

Previously studies have investigated the effects of plyometric activities on PAP and its influence on acute performance (4,8,16,26,30,33). Bomfim Lima et al. (4) reported that 2 sets of 5 DJ (0.75 m) with professional strength trained athletes resulted in increased vertical jump performance (6% 15 minutes poststimulus) and improved 50 m sprint performance (2.4% and 2.7% 10 and 15 minutes poststimulus respectively). In a study investigating the acute effects of different DJ volumes and recovery times on subsequent CMJ performance in plyometric trained male volleyball athletes, Chen et al. (8) reported both 1 set of 5 repetitions and 2 sets of 5 repetitions resulted in improved CMJ height 2 minutes poststimulus. In a further study with professional male rugby players, Tobin and Delahunt (33) suggest that the use of plyometric exercises as a preload stimulus may be preferable to the use of heavy load stimulus as a result of the required rest periods to elicit a PAP being shorter. Although studies have reported that plyometric exercises have resulted in a PAP response others have reported no such effect (13,31). It is therefore suggested that the evidence supporting the use of the plyometric exercises as a PAP stimulus is controversial.

Although the intensity of the DJ exercise is usually dictated by drop height, previous research has suggested that another method for altering intensity is by manipulating the mass of an individual (23,34). An alternative to this constant additional load approach is the suggestion that dumbbells or bands provide accentuated eccentric loading (AEL) during the eccentric phase of the DJ exercise (27). Thus as an athlete reaches the bottom position of the CMJ they release the dumbbells or bands and perform the concentric phase without any additional load (27).

Currently, only one study has investigated the use of AEL during DJs. In this study, AEL was applied through the use of elastic bands which increased downward force by either 20% or 30% of BM (1). The results of this study using highly resistance-trained subjects indicated that additional eccentric load significantly enhanced eccentric impulse ($p \leq 0.05$), rate of force development ($p < 0.001$), and resulted in small to moderate effect size (ES) increases in integrated electromyography (iEMG) across the eccentric phase (ES = 0.23–0.51), however, no increases in jump height or concentric muscle activation were reported (1). Due to the finding that the AEL resulted in improved quadriceps iEMG, it is proposed by the authors that the AEL may result in greater recruitment of type II motor units and thus may result in a greater PAP stimulus than that provided by unloaded DJs alone.

At present there is no research, which has investigated the effects of using dumbbells to provide an AEL during the DJ exercise and its ability to improve subsequent lower body performance as a result of the PAP phenomenon. Therefore, the aims of this study were to (1) investigate the effects of AEL DJ on DJ performance (jump height, flight time, contact time, and ground reaction force [GRF]) and (2) to investigate the acute effects of completing AEL DJs on subsequent CMJ performance (jump height, peak power, and GRF). It was hypothesized that the addition of the eccentric load (10, 20, and 30% of participants BM) during the DJs would result in a significant increase in jump height and peak power in the subsequent CMJs in comparison with DJs completed without any additional load.

Methods

Experimental Approach to the Problem

A repeated measures design was used to investigate the acute effects of AEL DJ on DJ performance and subsequent CMJ performance in strength-trained athletes. Initially, subject's baseline CMJ performance and optimum drop height were established. After 2 weeks, DJ and CMJ performance were assessed during and after 4 protocols: (a) a DJ protocol with BM only, (b) a DJ protocol with an additional dumbbell load of 10% during the eccentric phase, (c) a DJ protocol with 20% additional load, and (d) a DJ protocol with 30% additional load. The additional loads used during the AEL DJs were calculated as a percentage of each subjects' individual BM. These loads were selected based on the previous findings by Aboodarda et al. (1) that both a 20% and 30% additional AEL load resulted in enhanced eccentric impulse and rate of force development. During each protocol, the subjects completed one set of 5 repetitions before completing 3 CMJs at each of the following recovery times: (a) 2 minutes, (b) 6 minutes, and (c) 12 minutes post.

Subjects

Twelve male strength trained athletes (mean age: 25.4 ± 3.5 years; mean height: 177.2 ± 4.5 cm; mass: 84.0 ± 10.1 kg and 1RM squat relative to body weight [BW, 1.89 ± 0.27]) with previous experience of plyometric training volunteered to participate in this study. All subjects had at least 2 years strength training experience and were able to squat at least 1.5 times BW. The sample size in this study was based on previous studies, which have used a similar study design and number of subjects (4,8). Before commencing testing, all subjects were fully informed about the procedures, possible risks, and purpose of the study. All subjects also provided informed written consent. The Auckland University of Technology Ethics Committee approved this study.

Procedures

Subjects were asked to refrain from training in the 48 hours before any testing session. In testing session 1, the subjects completed a 5-minute warm up on a stationary exercise bike (95C Lifecycle; Life Fitness, Hamilton, New Zealand) followed by 10 BW squats. On completion of the warm up, subjects completed 3 maximal CMJ (15 seconds between jumps). During the CMJ all subjects squatted to a self-selected depth and were permitted to use their arms whilst the tester provided verbal encouragement. During the baseline, 3 CMJ testing within the session reliability was assessed through intraclass correlation coefficients (ICCs) and coefficients of variation (CV) using an excel reliability spread sheet found at www.sportsci.org (21). The results of this analysis based on Bradshaw et al. (5) classification indicated a small variability between the 3 trials (jump height, CV = 3.6% and ICC = 0.90, peak power CV = 2.7% and ICC = 0.98 and GRF (normalized for BM) CV = 7.8% and ICC = 0.71).

On completion of the CMJ testing, subjects then did 5 warm-up DJ from plyometric boxes (38 and 62 cm, 15 seconds between jumps and 3 minutes between drop heights). Subjects then attempted 3 maximal DJ with no additional load from the following plyometric box drop heights 28, 38, 52, 62, and 70 cm (15 seconds between each

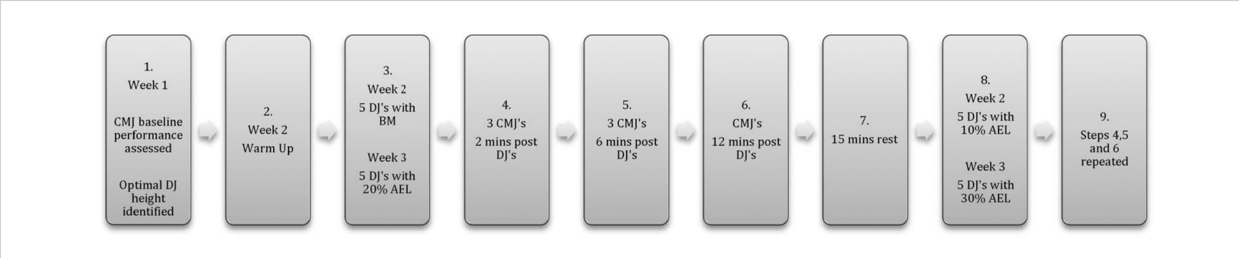

Figure 1. Schematic design for drop jump and countermovement jump testing.

jump and 3 minutes rest between different heights). These heights were selected to provide a range of drop heights from low to high in line with previous research investigating the use of the DJ exercise (2,8). During these DJs the subjects were instructed to step off the box and immediately on contact with the ground complete a CMJ (use of arms permitted). From these trials, each subject's individual optimal drop height was determined as the drop height that elicited the best maximal jump height (MJH) (2). Finally, at the end of this testing session, subjects were familiarized with AEL DJ protocol using dumbbells (Hammer Strength; Life Fitness) to provide the additional load.

One week after the initial testing session, the subjects returned to the lab and completed the same warm up as described previously. Subjects then completed 5 DJs from their individual optimal drop height. These DJs were completed as normal but when each subject hit the bottom position of the CMJ (thighs parallel to the ground) the dumbbells were released allowing the subjects to complete the concentric phase without any additional load. Two minutes after the completion of these jumps the subjects completed 3 CMJs (30 seconds between each jump). This process was repeated 6 and 12 minutes after the 5 initial DJs (Figure 1). These recovery times were selected based on the finding by Chen et al. (8) that CMJ height was greater 2 minutes after completing a low volume DJ protocol than during the pretest, 6 minutes, and 12 minutes. In addition, 6 minutes recovery was also found to result in greater CMJ height than 12 minutes post (8). A review by Maloney et al. (24) also reported that when using ballistic exercises as a PAP stimulus, rest periods of 1–6 minutes have been successfully prescribed.

During the first week of DJ testing, the subjects initially complete the DJs with no additional load and then after a 15 minutes rest (post the final CMJ) subjects completed 5 DJs with an additional dumbbell load of 10% BM. After a further weeks' recovery, the subjects returned to the lab for the final time. As before the subjects initially warmed up, beforecompleting 5 DJs with an additional dumbbell load of 20% BM followed by the CMJ testing previously described. Finally, after a further 15 minutes rest the subjects completed 5 DJs with an additional dumbbell load of 30% BM before completing the CMJ testing.

During the DJs, the variables of interest were jump height (cm), contact time (s), flight time (s), and peak

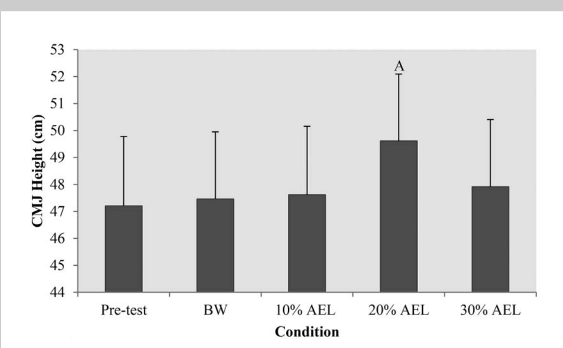

Figure 2. CMJ height (mean ± *SD*) at baseline and after completing each DJ condition. A–indicates significant differences between CMJ height in the 20% AEL condition compared with all other conditions ($p < 0.001$). CMJ, countermovement jump; DJ, drop jump, AEL, accentuated eccentric loading; BW, body weight.

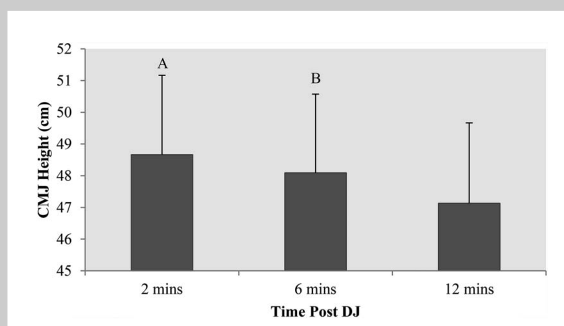

Figure 3. CMJ height (mean ± *SD*) each time point on completion of DJ. A– indicates significant differences between CMJ height 2 minutes post-DJ and 12 minutes ($p < 0.001$). B–indicates significant differences between CMJ height 6 minutes post-DJ and 12 minutes ($p \leq 0.05$). CMJ, countermovement jump; DJ, drop jump.

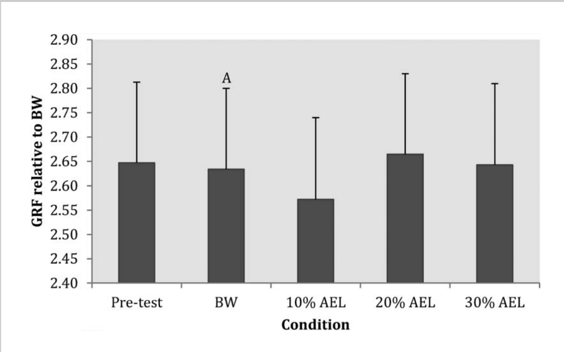

Figure 4. GRF relative to BW (mean ± *SD*) during CMJ at baseline and after completing each DJ condition. A–indicates significant differences between CMJ GRF between the BW and 10% AEL conditions ($p < 0.001$). GRF, Ground reaction force; BW, body weight; AEL, accentuated eccentric loading; CMJ, countermovement jump; DJ, drop jump.

ground reaction force (GRF[N]). During CMJ testing, jump height, peak power, and GRF (normalized for BM) were the variables of interest. All variables were measured using a force plate (400S; Fitness Technology, South Australia, Australia) sampling at 600 Hz. The mean values of each of the variables of interest during the DJs in each AEL condition and the subsequent CMJs were used during further statistical analysis.

Statistical Analyses

During this study, all statistical analysis was completed using the SPSS software (Version 12.0; SPSS Inc, Chicago, IL, USA). Freidmann ANOVA was used to compare the DJ variables across the 4 different loads with significance set at $p \leq 0.05$. When differences were found, post hoc testing used the Wilcoxon signed ranked test to investigate where these differences occurred.

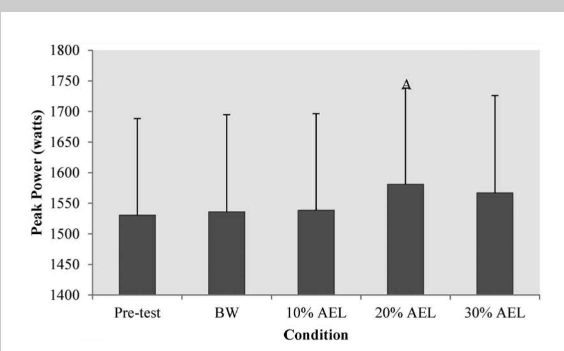

Figure 5. Peak power (mean ± *SD*) during CMJ at baseline and after completing each DJ condition. A–indicates significant differences in CMJ peak power between the 20% AEL condition, baseline, BW, and 10% AEL conditions ($p \leq 0.05$). CMJ, countermovement jump; DJ, drop jump; AEL, accentuated eccentric loading; BW, body weight.

Adjusting for multiple comparisons the alpha level was set at $p = 0.008$ during post hoc testing (0.05 divided by number of conditions). A generalized linear mixed model was used to investigate the effects of load and time on jump height, peak GRF, and peak power after completion of the DJ conditions with subjects as the random effect. This generalized mixed model was chosen to analyze the data as they were found to be nonparametric.

Where statistical differences were identified effect sizes (90% confidence interval) were calculated using an Excel spreadsheet (*Post-only crossover*) found at Sportsci.org (19). For assessing the magnitude of standardized effects, threshold values of <0.2, 0.2, 0.6, and 1.2 represent trivial, small, moderate, and large differences, respectively (20).

Results

Drop Jump Analysis

Although significant main effects were found for DJ variables, post hoc testing taking into account multiple comparisons did not find any significant differences ($p > 0.008$) between the conditions. However, effect size analysis identified small differences between the conditions. DJ jump height was found to be greater in the BW condition compared with the 10% and 30% AEL conditions ($p = 0.012$, ES = 0.39 [0.17–0.60] and $p = 0.023$, ES = 0.34 [0.11–0.56], respectively). It was also found that DJ jump height was greater in the 20% condition compared with the 10% and 30% AEL conditions ($p = 0.012$, ES = 0.37 [0.20–0.55] and $p = 0.019$, ES = 0.32 [0.12–0.52]). Significant main effects were also found for DJ flight time ($p \leq 0.05$). Post hoc analysis revealed greater DJ flight time in the BW condition compared with the 10 and 30% AEL conditions ($p = 0.019$, ES = 0.38 [0.16–0.59] and $p = 0.018$, ES = 0.34 [0.11–0.56]). In addition, greater flight time was found in the 20% AEL DJ condition compared with the 10 and 30% AEL DJ conditions ($p = 0.019$, ES = 0.36 [0.20–0.52] and $p = 0.010$, ES = 0.32 [0.12–0.52]).

Post Drop Jump Analysis

A generalized linear mixed model found significant main effects of load and time on CMJ height ($p < 0.001$), no significant load and time interaction was demonstrated. Post hoc testing indicated that the 20% AEL DJ condition resulted in significantly greater CMJ height in comparison with baseline (ES = 0.47 [0.24–0.71]), the BW (ES = 0.48 [0.30–0.66]) and the 10% (ES = 0.37 [0.17–0.57]) and 30% (ES = 0.34 [0.17–0.51]) AEL DJ conditions ($p < 0.001$) (Figure 1).

Post hoc testing indicated significantly greater CMJ height 2 minutes and 6 minutes post-DJs compared with 12 minutes post-DJ ($p < 0.001$, ES = 0.64 [0.48–0.80] and $p \leq 0.05$, ES = 0.17 [0.09–0.25], respectively, Figure 2). A main effect was found for load on ground reaction force relative to BW ($p \leq 0.05$). Post hoc testing indicated a significantly greater GRF during CMJ at baseline compared with post the 10% AEL DJ condition ($p \leq 0.05$, ES = 0.29 [0.02–0.56], Figures 3 and 4).

A main effect was also found for load on peak power ($p \leq 0.05$). Post hoc testing indicated significantly greater peak power ($p \leq 0.05$) in the CMJs after completion of the 20% AEL DJ condition in comparison with baseline (ES = 0.17 [0.09–0.26]), BW (ES = 0.17 [0.09–0.26]), and 10% AEL DJ (ES = 0.14 [0.06–0.22]) (Figure 5).

Discussion

The main findings of this study were that one set of 5 DJs using an AEL of 20% BM resulted in significantly greater CMJ height in comparison with baseline and all other DJ conditions. The 20% AEL condition also produced greater peak power outputs during the subsequent CMJs in comparison with baseline and the BW DJs and the 10% AEL DJs. In addition, it was found that CMJ height was significantly greater after 2 minutes recovery compared with 12 minutes and after 6 minutes compared with 12 minutes. The results of this study are in agreement with other studies that have found that low volume DJs can enhance lower body performance (4,8,16,26).

Plyometric activities such as the DJ have been reported to carry a greater potential to induce a PAP response than traditional resistance exercises (back squat) due to their high intensity (24,28). This increase in PAP potential may be the consequence of plyometric exercises leading to preferential recruitment of type II motor units which is one of the premises that underpin PAP (15,28) and may lead to improvements in CMJ performance (8). In addition, eccentric contractions that occur during DJs have been reported to result in increased muscle temperature leading to high muscular activation, increased storage and recoil of elastic energy and enhanced phosphorylation of the myosin light chain (MLC) all of which may contribute to increased subsequent CMJ performance (8). Thus in this current study, it is suggested that the 20% AEL DJ condition was the optimal additional eccentric load required by the subjects to take advantage of the PAP response.

Repeated contractions can lead to fatigue and impaired performance but also may result in potentiation and improved performance (7,22). Initially on completion of exercise, fatigue effects are proposed to dominate, however, potentiation has been reported to last longer (32). Thus getting the balance right between recovery to allow the effects of fatigue to recede and potentiation to be in the ascendancy is crucial for performance enhancements (17). A review by Maloney et al. (24) into the use of ballistic exercises such as the DJ reported that currently there is no agreement on the required recovery times to produce an optimal PAP response. However, plyometric activities have also been proposed to result in less fatigue in comparison with traditional resistance exercises despite their high intensity and thus result in a greater subsequent state of potentiation (28).

In relation to vertical jump performance Bomfim Lima et al. (4) reported that vertical jump performance was potentiated 15 minutes after a bout of DJ. However, in contrast, Chen et al. (8) reported greatest increases in vertical jump performance 2 minutes after a bout of DJ in comparison with 6 and 12 minutes recovery. Tobin and Delahunt (33) also reported improvements in vertical jump performance at 1, 3, and 5 minutes after a bout of ballistic jumping exercise. Based on these findings and the results of other studies, investigating ballistic exercise to induce PAP Maloney et al. (24) concluded that the recovery duration needed to induce a PAP response may be reduced compared with heavy resistance exercise (such as the squat) due to reductions in system mass.

In this current study, a rest period of 2 (moderate ES) and 6 minutes (trivial ES) resulted in greater CMJ performance than 12 minutes. Thus, in agreement with the findings of Chen et al. (8) by 12 minutes, it is speculated that the PAP response from completing the DJs was starting to diminish and as a consequence, CMJ performance declined. Although there were no significant differences in CMJ performance between 2 and 6 minutes, 2 minutes recovery resulted in the greatest CMJ performance. Based on the findings of this current study and in agreement with previous research by Chen et al. (8), it would seem that 2 minutes would be the most effective rest period to enhance CMJ performance after a bout of DJs.

One potential limitation to this study was that the optimal drop height for each subject was identified with no additional load. Thus although the drop height identified initially may have resulted in MJH with no extra load the addition of the AEL may have resulted in a different optimal drop height. Therefore, future research may be required to investigate the effect of AEL on optimal drop height during the DJ and how this influences the subsequent PAP response. Additionally, the subjects in this study initially completed 5 DJs without any load followed by 15 minutes after the last CMJ (30 minutes post the initial bout of DJs) by a further set of DJs with 10% additional load. The following week the subject initially completed the DJs with 20% followed by 30% additional load. It may therefore be argued that the initial bout of DJs may have had a negative effect on the subsequent bout of DJs ability to produce a PAP response and therefore enhance CMJ performance and this may be a limitation to this current study. The authors, however, suggest that the 30 minutes time between bout of DJs is adequate to allow recovery in agreement with the research of Maloney et al. (24) on recovery times after ballistic exercise. In addition, baseline CMJ performance was assessed during week 1 and thus there may have been a change in subjects' baseline performance across the 2 weeks testing period. However, a recent review suggests that in strength trained individuals such as those in the current study the degree to which alterations in strength influences performance may be reduced (29). Therefore it is suggested that the initial baseline performance is still valid when used as a comparison on completion of the DJs.

In conclusion, one set of 5 DJs using dumbbells to provide an AEL of 20% BM resulted in the greatest subsequent CMJ performance. A 2 minutes recovery period after the DJs seems to result in optimal subsequent CMJ performance.

Practical Applications

This study was the first to show that AEL during the DJ exercise can potentiate subsequent CMJ performance. Five DJs using dumbbells to provide an additional eccentric load equal to 20% of each subjects' BM resulted in the greatest acute improvements in CMJ height. In addition, 2 minutes recovery was found to be the optimal rest period necessary to enhance CMJ performance. Therefore it is suggested that athletes wishing to enhance their vertical jump performance may benefit from using an AEL DJ protocol. Based on the findings of this current study, S&C coaches should initially identify the optimal drop height for each athlete based on the MJH method. Athletes would then (approximately, 2 minutes before competing) complete 5 AEL DJs during their warm up (from the drop height previously identified) with an additional load of 20% BM to potentiation subsequent vertical jump performance.

Acknowledgments

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