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ΔΙΠΛΩΜΑΤΙΚΗ ΕΡΓΑΣΙΑ

ΟΙ ΟΞΕΙΕΣ ΕΠΙΔΡΑΣΕΙΣ ΤΩΝ DROP JUMPS ΜΕ ΚΑΙ ΧΩΡΙΣ ΕΚΚΕΝΤΡΗ ΕΠΙΒΑΡΥΝΣΗ ΣΤΗΝ ΚΑΘΕΤΗ ΑΛΤΙΚΗ ΑΠΟΔΟΣΗ: ΑΞΙΟΛΟΓΗΣΗ ΜΙΑΣ ΝΕΑΣ ΜΕΘΟΔΟΥ ΕΚΚΕΝΤΡΗΣ ΑΣΚΗΣΗΣ

ΠΕΡΙΛΗΨΗ

Τα τελευταία χρόνια, ολοένα και περισσότεροι ερευνητές έχουν δείξει ενδιαφέρον σχετικά με την έκκεντρη φάση σε πολλά αθλήματα. Πρώτα από όλα, σε αυτή την έρευνα διεξήχθη μία διερεύνηση για το πώς να επιβαρυνθεί μόνο η έκκεντρη φάση σε κάθετα άλματα (στα DJ και στα DJ25). Επιπλέον, σε αυτό το πρότζεκτ συμμετείχαν έξι αθλήτριες [ηλικίας 20.67±1.37 (χρν)] με εμπειρία σε προπόνηση ταχύτητας και αλτικότητας. Επιπροσθέτως, η έρευνα αποτελείται από δύο μέρη: το πρώτο μέρος περιλαμβάνει κάποιες ανθρωπομετρικές μετρήσεις (μάζα σώματος, ύψος σώματος, σωματικό λίπος, μήκος βραχίονα και ποδιού, sit and reach τεστ) και εξοικείωση με τα άλματα– το δεύτερο μέρος περιλαμβάνει δύο διαφορετικές ασκήσεις πρωτοκόλλου. Σε κάθε πρωτόκολλο περιλαμβάνεται ζέσταμα και πέντε λεπτά ξεκούρασης. Μετά από αυτό, οι συμμετέχοντες αξιολογήθηκαν σε δύο μέγιστες προσπάθειες στο CMJ με τρία λεπτά ξεκούρασης μεταξύ τους και, μετά, οι αθλήτριες ξεκουράζονται για τέσσερα λεπτά πριν από κάθε διαφορετική άσκηση πρωτοκόλλου, μία διαφορετική άσκηση κάθε φορά. Στο τέλος από όλες τις ασκήσεις πρωτοκόλλου, οι αθλήτριες ξεκουράζονται για τρία λεπτά, πριν εκτελέσουν ξανά δύο μέγιστες προσπάθειες στο CMJ. Επιπλέον, υπήρχαν, το ελάχιστο, δύο μέρες ξεκούρασης μεταξύ των δύο πρωτοκόλλων για να προετοιμαστούν οι συμμετέχοντες για το επόμενο. Λοιπόν, οι δύο ασκήσεις πρωτοκόλλου είναι: στο πρώτο πρωτόκολλο, οι αθλήτριες πραγματοποιούν τέσσερα drop jumps (DJ) με ένα λεπτό αποκατάστασης μεταξύ τους–στο δεύτερο πρωτόκολλο, οι αθλήτριες πραγματοποιούν τέσσερα drop jumps (DJ) με έξτρα 25% επιβάρυνση από την σωματική μάζα και ένα λεπτό αποκατάστασης μεταξύ τους (DJ25). Η στατιστική ανάλυση έδειξε ότι δεν υπήρχαν σημαντικές στατιστικές διαφορές μεταξύ των προηγούμενων και των επόμενων CMJs στην απόδοση του ύψους άλματος (p=.302) και στην μυϊκή σκληρότητα των μυών (p=.166). Τέλος, υπήρξε σημαντική στατιστική διαφορά μεταξύ του πρωτοκόλλου DJ και του πρωτοκόλλου DJ25 στον μέσο όρο της έκκεντρης δύναμης (p=.011).

THE ACUTE EFFECTS OF DROP JUMPS WITH AND WITHOUT ECCENTRIC LOADS IN VERTICAL JUMP PERFORMANCE: EVALUATION OF A NEW METHOD OF ECCENTRIC EXERCISE

1) <u>ABSTRACT</u>

In the past few years, more and more researchers have showed an interest about the eccentric phase in many sports. First of all, in this research took place an investigation of how to overload only the eccentric phase on vertical jumps (DJ and DJ25). Furthermore, in this study was participated 6 female athletes [age: 20.67±1.37 (yrs)] with the experience of sprint and jump training. Additionally, the study constitutes of two sessions: the first session includes some of the anthropometric measurements (body mass, body height, body fat, arm and leg length, sit and reach test) and familiarization with jumps–the second session includes two different exercise protocols. In each exercise protocol were included a warm up and 5 min recovery period. After that, the participants assessed in two maximum effort in CMJ with 3 min recovery period between them and, then, athletes rested for 4 min prior to the two different exercise protocols, one different exercise at each time. At the end of all the exercise protocols, athletes rest for 3 min, before they execute again in 2 maximum CMJ efforts. In addition, there were, at least, 2 days rest between the 2 protocols for the participants to be prepared for the next one. Well, the two different exercise protocols are: the protocol 1, athletes performed 4 drop jumps (DJ) with 1 min recovery period between them–the protocol 2, athletes performed 4 drop jumps (DJ) loaded with extra 25% of their body mass and 1 min recovery time between them (DJ25). The statistical analysis showed that there were not significant statistical differences between the pre and post CMJs

in height jump performance (p=.302) and in muscle stiffness (p=.166). Finally, there were significant statistical difference between the DJ and the DJ25 protocol in ECC Mean Power (p=.011).

2) INTRODUCTION

Plyometric training is an important type of training for all sports. It is critical to determine the type of plyometric training that brings the highest enhancement on muscle power and jump ability. Lately, there is effort of a few researchers to investigate and find new methods of eccentric training. There are plenty of methods such as elastic bands (Aboodarda et al., 2013 and 2014), accentuated eccentric loading (Alexandra et al, 2018) and flywheel (Fernández et al, 2018) and (Timon et al, 2019), which are the most common techniques to increase the load of the eccentric phase.

The term post activation potentiation (PAP) refers as the acute stimulation of the neuromuscular system after a stimulus with maximal or submaximal muscle contractions (Tallin and Bishop, 2009). The caused acute stimulation has shown to improve the subsequent performance of the athlete in vertical jumping [counter movement jump (CMJ), squat jump (SJ) and drop jump (DJ)] as well as on the speed and, especially, in the acceleration phase. This improvement has shown to be due to the muscles being in a state of activation (Robbins et al., 2019). From a biochemical point of view, the effect of PAP related to the greatest extent as a result of phosphorylation of light chains with main myosin regulator during muscle contraction (Szczesna et al., 2003). In addition, another important factor is the optimal rest time between exercise and exercise performance that vary between 3 and 7min (Hodgson et al., 2005). Furthermore, investigations showed that PAP affects humans regardless of their gender (Jensen et al., 2003).

PAP and Sprint

Speed is, perhaps, the most important physical ability in sports. Most of the investigations evaluate distances about 60m sprint and focusing, also, on acceleration phase (0–15m), because is, directly, connected with PAP.

In the research of Okuno et al., (2013), analyzed the changes on repeated sprint ability (RSA) after heavy load exercise in elite handball players in 2 experimental training sessions. In session 1, the participants executed 30m shuttle sprints with a change of direction at 15m and, in session 2, they executed half squat with 1RM load (1X5 at 50%, 1X3 at 75%, 5X1 at 90%). Results demonstrated the correlation coefficient between 1RM load and magnitude of change for RSA best sprint time after the conditioning activity was very low. Also, showed the previous heavy load exercise can be used to improve the RSA performance with a small moderate change.

In another study, Matusinski et al., (2021), examined the acute effects of resisted activation in 20m sprint with loads of body mass on sprint and flying start sprint performance in elite female sprinters using a resisted drag technology system (SPRINT 1080 device). Participants performed two unresisted 20m sprints (from a crouched and flying start) before and after a single resisted sprint loaded with 5, 10, or 15% body mass to verify the effectiveness of the activation stimulus. Results demonstrated that using a SPRINT 1080 resistance device (1080 Motion AB, Stockholm, Sweden), showed a decrease of sprint time and an increase in peak velocity values after the 10% body mass resisted conditioning activity, when compared with pre conditioning activity values. Therefore, using 10% resisted loads of body mass is effective and inducing a potentiating effect on subsequent 20m flying start sprint performance in elite female sprinters.

Additionally, Sarramian et al., (2015), examine the effect of PAP on 50m freestyle in national level swimmers. Subjects performed 2 testing protocols, where examined the effect of the pulls ups (PU) and jump box (JB) as conditioning activities to produce potentiation on sprint swimming. Participants performed a medicine ball throw after the upper body PAP conditioning activity (1 set of 3RM of the PU) and a counter movement jump (CMJ) on a jump mat after a PAP stimulus (1 set of 5 jumps to the box wearing a weighted vest loaded with 10% of their bodyweight). Also, subjects performed with 4 types of warm up including race specific warm up (RSWU), upper body PAP (UBPAP), lower body PAP (LBPAP) and combined PAP warm up (CPAP). The results showed the performance of swim time decreased in RSWU (29.00 ± 2.05s vs 29.36 ± 1.88s) and compared UBPAP warm up protocol in relationship with 2 testing protocols.

PAP and Strength

Comyns et al., (2010), analyzed the effect of squatting on sprint performance and repeated exposure to complex training in male rugby players. This study involved the subjects performing a 30m sprint before and after 3RM back squatting with a 4 minute rest between the lifting and the post 30m sprint. This procedure was repeated in 4 separate testing sessions. In session 1, there was a significant increase in 30m time and a significant reduction in average 30m velocity and maximum velocity. In general, for session 2, the mean posttest scores for the dependent variables were similar to the pretest scores and for sessions 3 and 4, mean posttest scores were slightly higher. It is important to note that taken, separately, no session showed a significant enhancement in sprinting performance.

Moreover, Alves et al., (2019), analyzed the influences of post activation and potentiation (PAP) on performance after a resistance training (RT) session in trained individuals. Subjects performed 3 sessions. In first session, participants executed a 1RM test on the bench press. In second and third session executed with randomized PAP and without post activation potentiation

CON protocols. CON: performed 3 sets on the bench press to concentric failure as, previously, defined with 75% of 1RM. PAP: performed one set of 3 repetitions with 90% of 1RM and, after a 10 minute recovery, they performed 3 sets to concentric failure, similarly, to the CON protocol. Results demonstrated that the PAP protocol resulted in a greater total work than CON protocol. Therefore, the number of repetitions during PAP and CON reduced, significantly, from set 1 to set 2 and set 2 to set 3.

Accentuated Eccentric Exercise

Firstly, Aboodarda et al., (2013), examined the effect of additional elastic force on the magnitude of leg stiffness, during the performance of accentuated counter movement jumps. Subjects performed 3 types of CMJ, including FCMJ (free–only body weight), ACMJ–20 (accentuated eccentric CMJ with downward tensile force equivalent to 20% of body weight) and ACMJ–30 (accentuated eccentric CMJ with downward tensile force equivalent to 30% of body weight). Concentric phase increased maximal concentric VGRF (6.34%), power output (23.21%), net impulse (16.65%) and jump height (9.52%) in ACMJ–30 compared with FCMJ. The results indicate that using downward recoil force of the elastic material during the eccentric phase of a CMJ could be an effective method to enhance jump performance.

Also, Aboodarda et al., (2014), was examined the effect of increased eccentric phase loading, as delivered using an elastic device, on DJs performed from different drop heights. Participants performed DJs from three heights (20, 35 and 50 cm) under three different conditions of FDJ (free–only body weight), 20DJ (DJ with elastic bands 20% of body weight) and 30DJ (DJ with elastic bands 30% of body weight). All participants performed 3 trials for each type of jump and the order of the measurements was randomized across the exercise conditions [(3 heights)X(3 loads)]. Results demonstrated that using additional tensile load during the airborne and eccentric phases of the drop jump could enhance eccentric impulse and rate of force development. They observed faster eccentric loading, however, did not, immediately, alter concentric kinetics and jump height.

Additionally, Alexandra et al., (2018), examined the differences in the bench press between traditional loading with a weight of 80% of the subjects, accentuated eccentric loading (AEL) using weight releasers and cluster set loading with a weight of 80% of the subjects. Subjects performed five sessions, which consisted of a 1 repetition maximum (1RM) testing session and four experimental conditions. The first session was used to determine the 1RM of the subjects to define their maximal strength and provide eccentric and concentric prescription. Four randomized loading conditions were implemented to investigate the performance differences between AEL, clusters and traditional loading using a 3X5 rep scheme for each condition. Traditional loading (TRD) was completed with a weight of 80% of the subjects 1RM with no rest between repetitions and three minutes of rest between sets. The traditional cluster set loading condition (TRDC) provided the same 80% prescription as TRD loading, but provided 30 seconds of passive rest between repetitions and three minutes of rest between sets. In the AEL cluster (AELC) loading condition, all five repetitions in the set received an eccentric overload, but 30 seconds of passive rest was provided between repetitions to load the hooks back on the barbell and 3 minutes rest between sets. During the AEL straight set (AEL1) condition, the hooks were only applied during the first repetition, while the subsequent reps were completed in a traditional manner with no rest between repetitions and three minutes rest between sets. The loading prescription during AELC and AEL1 was 105% of the concentric 1RM for the eccentric portion and 80% for the concentric portion of the lift for all subjects. The results of this study showed that cluster set loading provided favorable outcomes compared with traditional loading and eccentric overload. The results, also, indicated that cluster repetitions yield greater concentric outcomes in every set compared with a traditional load, thus suggesting that inter repetition rest had an influence on concentric performance and may be favorable, when using higher loads.

In another study, Fernández et al., (2018), analyzed the effect of flywheel (eccentric exercise devise) exercise on swim start. The aim of the current study was to assess the effects of PAP conditioning exercise based on eccentric flywheel maximal repetitions in swim start and to compare differences between USUAL and PAP warm up conditions. In the first condition, swimmers performed a dynamic stretching protocol, which consisting of specific exercises for jump performance. After 6 min of rest, swimmers performed three kick starts with 6 min intervals in between. In the second condition, swimmers performed PAP warm up, which consisted of five maximum squat repetitions with the flywheel squat device. The results did not show in the peak horizontal force and vertical force differences between the USUAL and PAP warm up conditions. Nevertheless, the results in vertical impulse have differences between the USUAL and PAP warm up conditions.

In addition, the research of Timon et al., (2019), examined the PAP effect on squat jump (SJ) performance, after an inertial flywheel protocol and a traditional protocol performed with a guided barbell machine. Both protocols consisted of 3X6 reps at the load that maximized power, with a 3 minute rest interval between sets. The squat jump (SJ) was measured after four, eight and twelve minutes after the PAP stimulus. There were significant increases of SJ height, velocity and power from the base line after the inertial flywheel protocol, more specifically at 4 and 8 minutes after the PAP stimulus. Furthermore, no improvements were observed after PAP for any of the horizontal variables derived from the force plates: ground reaction forces, acceleration and impulse (average and peak). Meanwhile, vertical forces improved as a result of the PAP stimulation and this was transferred to all the dependent variables of vertical force (average and peak).

The aim of our investigation is to examine the acute effects of drop jumps (DJ) and drop jumps with additional 25% of body mass (DJ25) during the eccentric phase on vertical jump performance (CMJ). An additional aim was to evaluate the operation and the validity of a smith machine that converted to execute extra weight load only during the eccentric phase of the drop jumps. Finally, to compare our results with the other studies' results and examine, if accentuated eccentric exercise constitutes an essential plyometric training to improve vertical jump performance.

3) METHODS

Subjects

The study was conducted with six female track and field athletes [age: 20.67±1.37 (yrs), body mass: 58.78±3.42 (kg), body height: 1.67±0.06 (m), body fat (skinfold): 15.04 ±0.06 (%), arm length: 1.67±0.08 (m), right leg length: 0.89±0.03 (m), left leg length: 0.89±0.02 (m)] (Table 1). The athletes were experienced of sprint and jump training in the past 2 years, so they were familiar with counter movement jump (CMJ) and with drop jump (DJ) technique. None of the participants had taken medication in the past and there were no reports of musculoskeletal injuries or metabolic disorders.

	Age (yrs)	Body mass (kg)	Body height (m)	Body fat (%)	BMI	Arm Length (m)	Right Leg Length (m)	Left Leg Length (m)
Mean	20.67	58.78	1.67	15.04	20.74	1.67	0.89	0.89
STDEV	1.37	3.42	0.06	0.06	1.23	0.08	0.03	0.02

Table 1. Track and Field athlete's anthropometric characteristics

Procedures

The measurements took place at municipal stadium of Trikala, inside the indoor track and field's facilities. The experiment was consisted of 2 sessions:

i) In the first session was included some of the anthropometric measurements (body mass, body height, body fat, arm and leg length, sit and reach test) and familiarization with the jumps (DJ, DJ25).

ii) In sessions 2 was included two different exercise protocols. In each exercise protocol were included a warm up and 5 min recovery period. After that, the participants assessed in two maximum effort in CMJ with 3 min recovery period between them. After the two CMJ maximum efforts athletes rested for 4 min prior to the two different exercise protocols (explained below), one different exercise at each time. At the end of all the exercise protocols, athletes rest for 3 min, before they execute again in 2 maximum CMJ efforts. In addition, there were, at least, 2 days rest between the 2 protocols for the participants to be prepared for the next one. The two different exercise protocols are:

iia) Protocol 1: In this protocol, athletes performed 4 drop jumps (DJ) with 1 min recovery period between them.

iib) Protocol 2: In this protocol, athletes performed 4 drop jumps (DJ) loaded with extra 25% of their body mass and 1 min recovery time between them (DJ25).

Measurements

Body Mass: was measured by using a standard scale (Seca, 777).

Body Height: was measured using a standard tape.

Body Fat: was calculated utilizing the measurements of seven skin folds (chest, sub scapular, triceps, sub scapula, abdominal, suprailiac, quadriceps, biceps brachii) by using a skinfold (Harpenden Skinfold Caliper). We used SIRI equation (0,00043499*SUMSKIN)+(0,00000055*SUMSKIN^2)-(0,00028826*AGE) to calculate body fat and the following equation to calculate body density [body fat %=(495/BODY DENSITY)-450].

Arm and Leg length: was deducted by using the measurement from the acromiale (lateral edge of the acromion process, e.g., bony tip of shoulder) to the top of the little finger. Leg length was measured from the ambilicus to the medial malleoli of the ankle.

Sit and Reach test: The participants sat on the floor with legs stretched out straight ahead and they removed their shoes. The soles of the feet are placed flat against the box. Both knees were locked and pressed flat to the floor. With the palms were facing downwards and the hands on top of each other or side by side, the subject reached forward along the measuring line, as far as possible. After some practice in this position, the subject reached out and held that position for, at least, one or two seconds, while the distance was recorded.

Drop Jumps: The participants dropped off with both feet simultaneously from a 30cm platform, they landed on a force plate and performed a very quick vertical jump, immediately, after the landing in all jumps. We instructed to keep their feet parallel and their hands in the middle of the body, on their hips, during the whole jump and were giving them maximum effort during the jumps. Also, the participants instructed to minimize lateral and frontal displacements by jumping vertically and landing directly on the force plate.

Force Plate: All data collected by using a 60X90cm force plate (Bertec, Columbus, Ohio USA).

Smith Machine with resistance bands: In the second session (DJ25 protocol), the DJ25s were performed on a Converted Smith Machine, where weights were loaded through belts and pulleys on a weightlifting belt that were wear from athletes (photo 1). In the DJ25s, weights were loaded only during the eccentric phase and released during the concentric phase. Moreover, the weight's load released at the end of the eccentric phase (photo 2) by using a car's block release seat belt mechanism. We examined the Converted Smith Machine function by performing a wide number of jump trails (DJ and DJ25).

Photo 1. Starting phase in DJ25s (Converted Smith Machine)

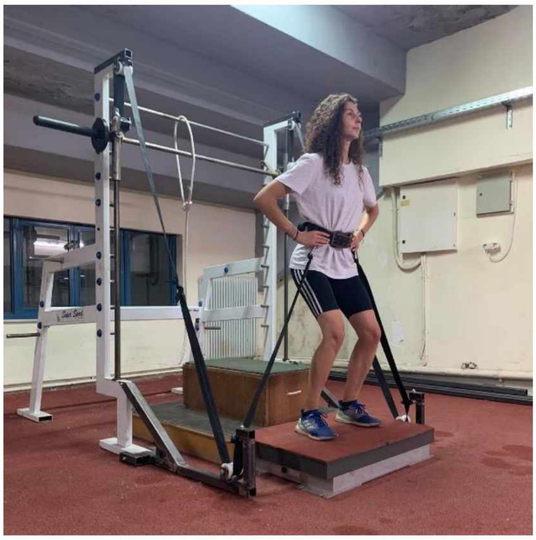


Photo 2. Eccentric phase in DJ25s (Converted Smith Machine)

Video Analysis: At a distance of 2 meters sideways from the Converted Smith Machine we placed a camera (GoPro Hero 7 Silver) to record every trial and to evaluate the starting and the ending points of eccentric and concentric phase during the 2 protocols [drop jump (DJ) and drop jump (DJ25)]. This procedure done with purpose to verify the validity of the working process of the Converted Smith Machine and the correct technique of the jumps.

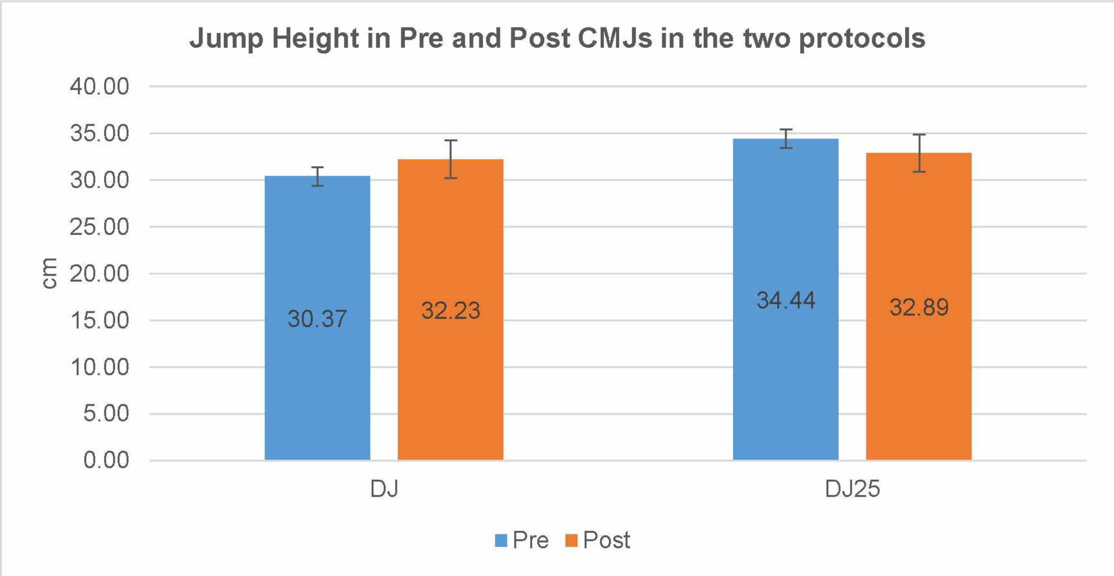
Statistical Analysis

SPSS statistical software (SPSS 21, Illinois USA) used for statistical analysis. The significance level was set at 0.05 and the data was presented as mean±SD. The pre and post vertical jump performance (CMJ) and the differences between the two protocol examined by using Paired t–test. The differences between the post CMJs following the two different protocols examined by One–Way repeated measures ANOVA. Furthermore, Pearson correlation used to examine the correlations between anthropometric measurements–post CMJs and, also, between post CMJs–DJs parameters (eccentric and concentric phase, contact time and post CMJs).

4) RESULTS

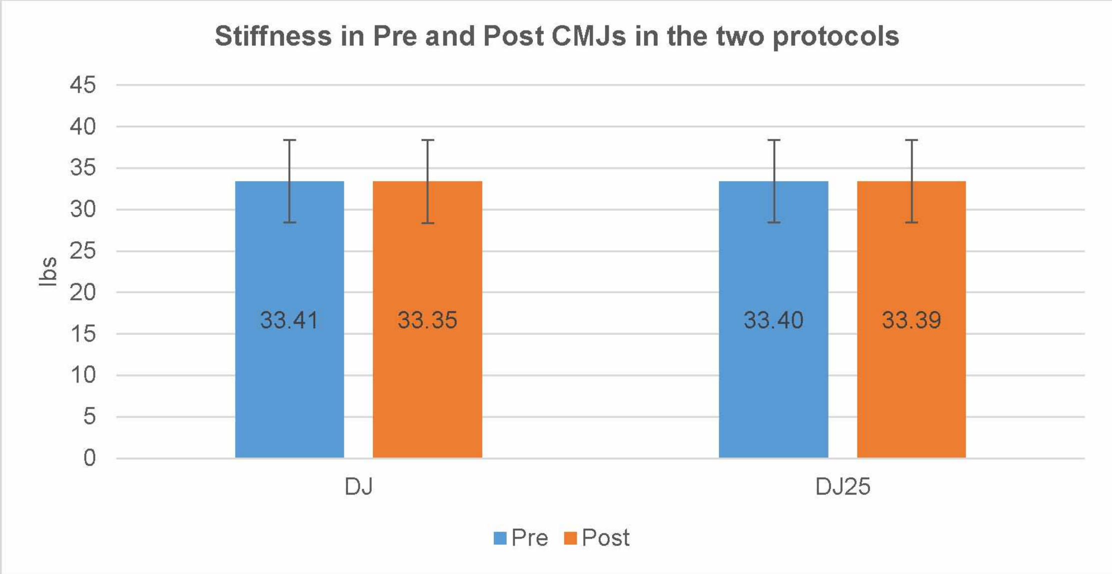
Counter Movement Jumps (Paired t–tests)

Jump Height in pre and post CMJs in the two protocols: Paired t–test did not find any significant difference between pre and post CMJs' jump height (t5=-1.86, p=.459) showing that there was no effect after the DJ protocol. In addition, paired t–test found that the DJ25 protocol did not cause any significant statistical difference between pre and post CMJs' jump height (t5=1.85, p=.302) (graph 1).



Graph 1. Pre and Post CMJ' Jump Height in the two protocols (DJ and DJ25)

Stiffness in pre and post CMJs in the two protocols: Paired t–test did not find any significant difference between pre and post CMJs' stiffness (t5=28.5, p=.263) showing that there was no effect after the DJ protocol. In addition, paired t–test found that the DJ25 protocol did not cause any significant statistical difference between pre and post CMJs' stiffness (t5=-9.59, p=.166) (graph 2).



Graph 2. Pre and Post CMJ' Stiffness in the two protocols (DJ and DJ25)

Training Jump Protocols (One–Way repeated measures ANOVA)

ECC Mean Power

DJ Protocol: One–Way repeated measures ANOVA showed that there was not any significant difference between the mean values of the four DJs' Mean Power ECC phase and showing that there was no effect after the DJ protocol (Table 2).

Pairwise Comparisons

Measure: ECC

(I) ECC POWER MEAN	(J) ECC POWER MEAN	Mean Difference (I–J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
DJ 1	2	-5.435	5.584	1.000	-28.995	18.125
	3	.448	3.727	1.000	-15.277	16.174
	4	1.242	3.064	1.000	-11.687	14.170
DJ 2	1	5.435	5.584	1.000	-18.125	28.995
	3	5.883	3.916	1.000	-10.638	22.405
	4	6.677	3.503	.690	-8.103	21.457

DJ 3	**1**	-.448	3.727	1.000	-16.174	15.277
	2	-5.883	3.916	1.000	-22.405	10.638
	4	.793	2.025	1.000	-7.749	9.336
DJ 4	**1**	-1.242	3.064	1.000	-14.170	11.687
	2	-6.677	3.503	.690	-21.457	8.103
	3	-.793	2.025	1.000	-9.336	7.749

Based on estimated marginal means

Adjustment for multiple comparisons: Bonferroni

Table 2. Pairwise Comparisons between the four DJs

DJ25 Protocol: One–Way repeated measures ANOVA showed that there was not any significant difference between DJs' Mean Power ECC phase and showing that there was no effect after the DJ25 protocol (Table 3).

Pairwise Comparisons

Measure: ECC

(I) ECC POWER MEAN	(J) ECC POWER MEAN	Mean Difference (I–J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
DJ 1	**2**	-1.843	1.185	1.000	-6.842	3.155
	3	-5.212	6.866	1.000	-34.182	23.759
	4	1.223	2.428	1.000	-9.021	11.468
DJ 2	**1**	1.843	1.185	1.000	-3.155	6.842
	3	-3.368	6.324	1.000	-30.051	23.314
	4	3.067	1.959	1.000	-5.198	11.331
DJ 3	**1**	5.212	6.866	1.000	-23.759	34.182
	2	3.368	6.324	1.000	-23.314	30.051
	4	6.435	4.549	1.000	-12.759	25.629
DJ 4	**1**	-1.223	2.428	1.000	-11.468	9.021
	2	-3.067	1.959	1.000	-11.331	5.198
	3	-6.435	4.549	1.000	-25.629	12.759

Based on estimated marginal means

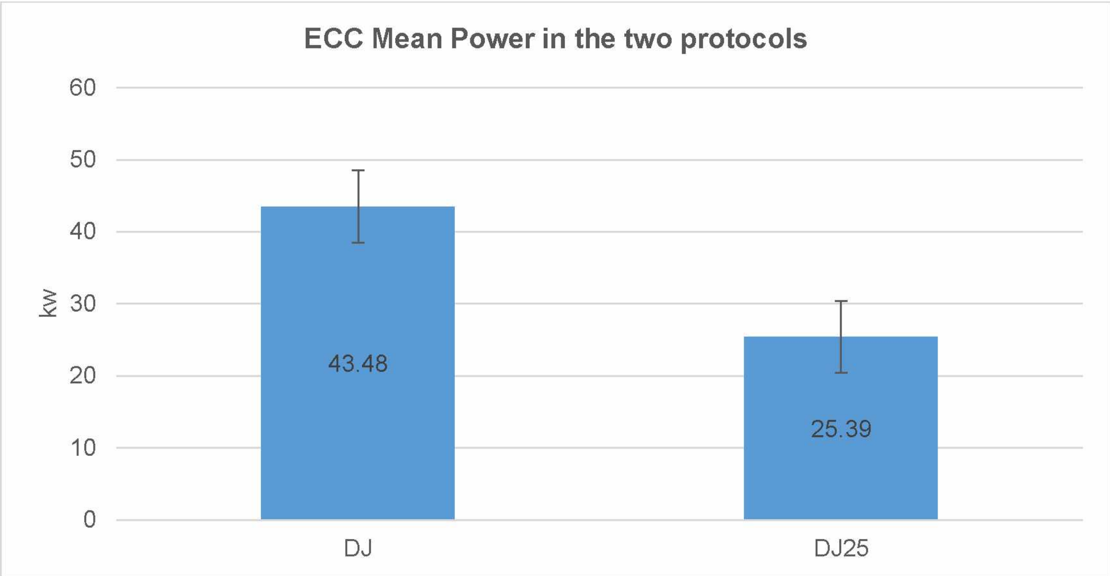
Adjustment for multiple comparisons: Bonferroni

Table 3. Pairwise Comparisons between the four DJ25s

DJ and DJ25 protocols: Paired t–test showed that there was a significant difference in ECC Mean Power between the two protocols (DJ, DJ25). There was a significant difference between DJ and DJ25 protocols (p=.011) (Table 4 and Graph 3).

(I) MEAN POWER MEAN	(J) MEAN POWER MEAN	Mean Difference (I–J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
DJ	**DJ25**	-18.085*	3.553	.011	-30.640	-5.530
DJ25	**DJ**	18.085*	3.553	.011	5.530	30.640

Table 4. ECC Mean Power's difference between the two protocols (DJ and DJ25)



Graph 3. ECC Mean Power in the two protocols (DJ and DJ25)

ECC Peak Power

DJ Protocol: One–Way repeated measures ANOVA showed that there was not any significant difference between DJs' Peak Power ECC phase and showing that there was no effect after the DJ protocol (Table 5).

Pairwise Comparisons

Measure: ECC

(I) ECC PEAK POWER	(J) ECC PEAK POWER	Mean Difference (I–J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
DJ 1	**2**	-9.033	7.931	1.000	-42.496	24.429
	3	-14.082	11.862	1.000	-64.132	35.969
	4	-5.725	11.124	1.000	-52.663	41.213
DJ 2	**1**	9.033	7.931	1.000	-24.429	42.496
	3	-5.048	11.510	1.000	-53.612	43.515
	4	3.308	9.314	1.000	-35.991	42.608
DJ 3	**1**	14.082	11.862	1.000	-35.969	64.132

	2	5.048	11.510	1.000	-43.515	53.612
	4	8.357	4.893	.890	-12.289	29.002
DJ 4	**1**	5.725	11.124	1.000	-41.213	52.663
	2	-3.308	9.314	1.000	-42.608	35.991
	3	-8.357	4.893	.890	-29.002	12.289

Based on estimated marginal means

Adjustment for multiple comparisons: Bonferroni

Table 5. Pairwise Comparisons between the four DJs

DJ25 Protocol: One–Way repeated measures ANOVA showed that there was not any significant difference between DJs' Peak Power ECC phase and showing that there was no effect after the DJ25 protocol (Table 6).

Pairwise Comparisons

Measure: ECC

(I) ECC PEAK POWER	**(J) ECC PEAK POWER**	**Mean Difference (I–J)**	**Std. Error**	**Sig.[a]**	**95% Confidence Interval for Difference[a]**	
					Lower Bound	**Upper Bound**
DJ 1	**2**	7.666	6.587	1.000	-24.289	39.621
	3	2858	9.197	1.000	-41.758	47.474
	4	-2.740	7.131	1.000	-37.332	31.852
DJ 2	**1**	-7.666	6.587	1.000	-39.621	24.289
	3	-4.808	3.611	1.000	-22.325	12.709
	4	-10.406	7.578	1.000	-47.167	26.355
DJ 3	**1**	-2.858	9.197	1.000	-47.474	41.758
	2	4.808	3.611	1.000	-12.709	22.325
	4	-5.598	9.032	1.000	-49.412	38.216
DJ 4	**1**	2.740	7.131	1.000	-31.852	37.332
	2	10.406	7.578	1.000	-26.355	47.167
	3	5.598	9.032	1.000	-38.216	49.412

Based on estimated marginal means

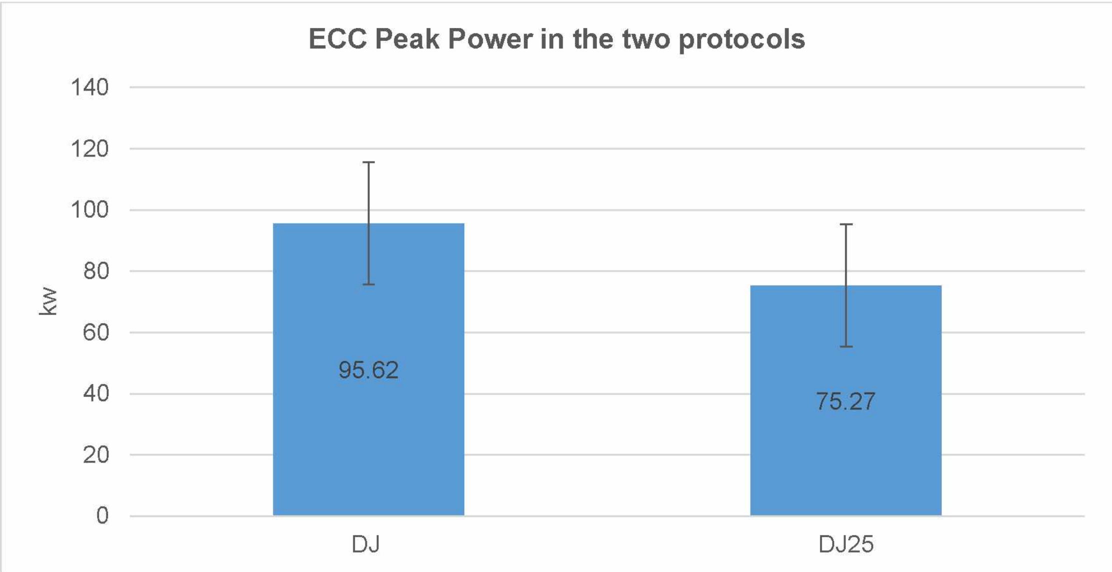
Adjustment for multiple comparisons: Bonferroni

Table 6. Pairwise Comparisons between the four DJ25s

DJ and DJ25 protocols: Paired t–test showed that there was not any significant difference between the mean values of the 2 protocols (DJ, DJ25) (p=.059) (Table 7 and Graph 4).

(I) PEAK POWER MEAN	(J) PEAK POWER MEAN	Mean Difference (I–J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
DJ	**DJ25**	-20.343	6.022	.059	-41.626	.939
DJ25	**DJ**	20.343	6.022	.059	-.939	41.626

Table 7. ECC Peak Power's difference between the two protocols (DJ and DJ25)



Graph 4. ECC Peak Power in the two protocols (DJ and DJ25)

ECC Peak GRF

DJ Protocol: One–Way repeated measures ANOVA showed that there was not any significant difference between DJs' Peak GRF ECC phase and showing that there was no effect after the DJ protocol (Table 8).

Pairwise Comparisons

Measure: ECC

(I) ECC PEAK GRF	(J) ECC PEAK GRF	Mean Difference (I–J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
DJ 1	**2**	506.458	341.258	1.000	-933.413	1946.330
	3	246.902	386.751	1.000	-1384.920	1878.724
	4	114.413	369.951	1.000	-1446.526	1675.353
DJ 2	**1**	-506.458	341.258	1.000	-1946.330	933.413

	3	-259.557	311.389	1.000	-1573.404	1054.290
	4	-392.045	233.121	.921	-1375.655	591.565
DJ 3	1	-246.902	386.751	1.000	-1878.724	1384.920
	2	259.557	311.389	1.000	-1054.290	1573.404
	4	-132.488	197.839	1.000	-967.232	702.255
DJ 4	1	-114.413	369.951	1.000	-1675.353	1446.526
	2	392.045	233.121	.921	-591.565	1375.655
	3	132.488	197.839	1.000	-702.255	967.232

Based on estimated marginal means

Adjustment for multiple comparisons: Bonferroni

Table 8. Pairwise Comparisons between the four DJs

DJ25 Protocol: One–Way repeated measures ANOVA showed that there was not any significant difference between DJs' Peak GRF ECC phase and showing that there was no effect after the DJ25 protocol (Table 9).

Pairwise Comparisons

Measure: ECC

(I) ECC PEAK GRF	(J) ECC PEAK GRF	Mean Difference (I–J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
DJ 1	2	-252.036	239.696	1.000	-1414.802	910.730
	3	-134.264	307.042	1.000	-1623.725	1355.197
	4	71.734	198.232	1.000	-889.892	1033.360
DJ 2	1	252.036	239.696	1.000	-910.730	1414.802
	3	117.772	135.045	1.000	-537.332	772.876
	4	323.770	233.117	1.000	-807.085	1454.625
DJ 3	1	134.264	307.042	1.000	-1355.197	1623.725
	2	-117.772	135.045	1.000	-772.876	537.332
	4	205.998	309.012	1.000	-1293.024	1705.020
DJ 4	1	-71.734	198.232	1.000	-1033.360	889.892
	2	-323.770	233.117	1.000	-1454.625	807.085
	3	-205.998	309.012	1.000	-1705.020	1293.024

Based on estimated marginal means

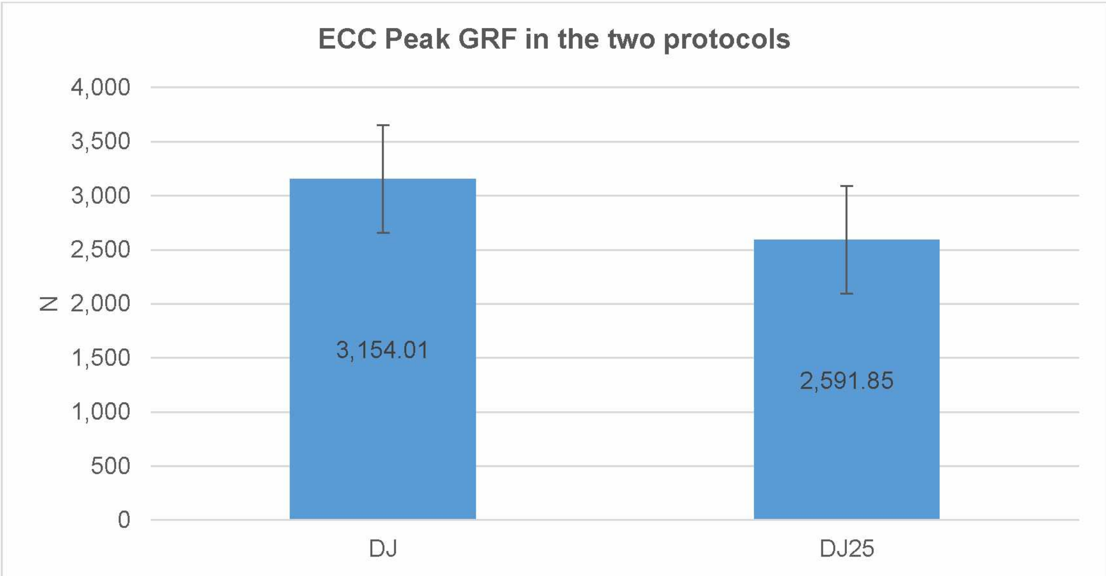
Adjustment for multiple comparisons: Bonferroni

Table 9. Pairwise Comparisons between the four DJ25s

DJ and DJ25 protocols: Paired t–test showed that there was not any significant difference between the mean values of the two protocols (DJ, DJ25) (p=.444) (Table 10 and Graph 5).

(I) PEAK GRF MEAN	(J) PEAK GRF MEAN	Mean Difference (I–J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
DJ	**DJ25**	562.153	328.785	.444	-599.808	1724.114
DJ25	**DJ**	-562.153	328.785	.444	-1724.114	599.808

Table 10. ECC Peak GRF's difference between the two protocols (DJ and DJ25)



Graph 5. ECC Peak GRF in the two protocols (DJ and DJ25)

ECC FGR

DJ Protocol: One–Way repeated measures ANOVA showed that there was not any significant difference between DJs' FGR ECC phase and showing that there was no effect after the DJ protocol (Table 11).

Pairwise Comparisons

Measure: ECC

(I) ECC FGR	(J) ECC FGR	Mean Difference (I–J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	**2**	833.333	6493.159	1.000	-26563.311	28229.977
	3	-7333.333	4112.312	.808	-24684.449	10017.783
	4	1333.333	8183.995	1.000	-33197.472	35864.139
2	**1**	-833.333	6493.159	1.000	-28229.977	26563.311

	3	-8166.667	7006.743	1.000	-37730.280	21396.947
	4	500.000	7978.095	1.000	-33162.049	34162.049
3	1	7333.333	4112.312	.808	-10017.783	24684.449
	2	8166.667	7006.743	1.000	-21396.947	37730.280
	4	8666.667	5736.821	1.000	-15538.753	32872.086
4	1	-1333.333	8183.995	1.000	-35864.139	33197.472
	2	-500.000	7978.095	1.000	-34162.049	33162.049
	3	-8666.667	5736.821	1.000	-32872.086	15538.753

Based on estimated marginal means

Adjustment for multiple comparisons: Bonferroni

Table 11. Pairwise Comparisons between the four DJs

DJ25 Protocol: One–Way repeated measures ANOVA showed that there was not any significant difference between DJs' FGR ECC phase and showing that there was no effect after the DJ25 protocol (Table 12).

Pairwise Comparisons

Measure: ECC

(I) ECC FGR	(J) ECC FGR	Mean Difference (I–J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
DJ 1	2	7500.000	5515.131	1.000	-26867.777	41867.777
	3	3000.000	8831.761	1.000	-52035.502	58035.502
	4	1500.000	8665.064	1.000	-52496.723	55496.723
DJ 2	1	-7500.000	5515.131	1.000	-41867.777	26867.777
	3	-4500.000	5041.494	1.000	-35916.292	26916.292
	4	-6000.000	5000.000	1.000	-37157.717	25157.717
DJ 3	1	-3000.000	8831.761	1.000	-58035.502	52035.502
	2	4500.000	5041.494	1.000	-26916.292	35916.292
	4	-1500.000	1443.376	1.000	-10494.458	7494.458
DJ 4	1	-1500.000	8665.064	1.000	-55496.723	52496.723
	2	6000.000	5000.000	1.000	-25157.717	37157.717
	3	1500.000	1443.376	1.000	-7494.458	10494.458

Based on estimated marginal means

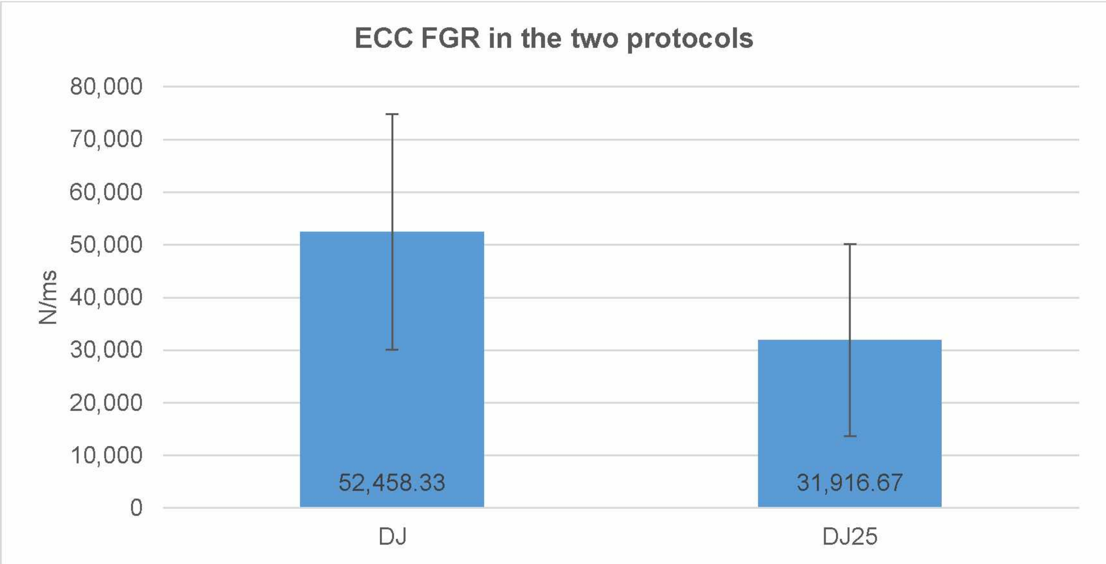
Adjustment for multiple comparisons: Bonferroni

Table 12. Pairwise Comparisons between the four DJ25s

DJ and DJ25 protocols: Paired t–test showed that there was not a significant difference in ECC FGR between the two protocols (DJ, DJ25). There was not a significant difference between DJ and DJ25 protocols (p=.757) (Table 13 and Graph 6).

(I) FGR MEAN	(J) FGR MEAN	Mean Difference (I–J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
DJ	DJ25	8458.333	6536.888	.757	-14643.752	31560.419
DJ25	DJ	-8458.333	6536.888	.757	-31560.419	14643.752

Table 13. ECC FGR's difference between the two protocols (DJ and DJ25)



Graph 6. ECC FGR in the two protocols (DJ and DJ25)

CT–ECC CT–CON CT

DJ Protocol: One–Way repeated measures ANOVA showed that there was not any significant difference between DJs' CT ECC phase and showing that there was no effect after the DJ protocol (Table 14).

Pairwise Comparisons

Measure: ECC

(I) ECC CT	(J) ECC CT	Mean Difference (I–J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
DJ 1	2	-.014	.011	1.000	-.061	.034
	3	.005	.011	1.000	-.039	.050
	4	.004	.011	1.000	-.042	.050
DJ 2	1	.014	.011	1.000	-.034	.061
	3	.019	.012	1.000	-.031	.069

	4	.018	.013	1.000	-.036	.071
DJ 3	**1**	-.005	.011	1.000	-.050	.039
	2	-.019	.012	1.000	-.069	.031
	4	-.001	.005	1.000	-.023	.021
DJ 4	**1**	-.004	.011	1.000	-.050	.042
	2	-.018	.013	1.000	-.071	.036
	3	.001	.005	1.000	-.021	.023

Based on estimated marginal means

Adjustment for multiple comparisons: Bonferroni

Table 14. Pairwise Comparisons between the four DJs

DJ25 Protocol: One–Way repeated measures ANOVA showed that there was not any significant difference between DJs' CT ECC phase and showing that there was no effect after the DJ25 protocol (Table 15).

Pairwise Comparisons

Measure: ECC

(I) ECC CT	(J) ECC CT	Mean Difference (I–J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
DJ 1	**2**	-.008	.008	1.000	-.046	.029
	3	-.020	.019	1.000	-.112	.071
	4	-.049	.015	.182	-.122	.024
DJ 2	**1**	.008	.008	1.000	-.029	.046
	3	-.012	.014	1.000	-.082	.058
	4	-.041	.017	.466	-.125	.043
DJ 3	**1**	.020	.019	1.000	-.071	.112
	2	.012	.014	1.000	-.058	.082
	4	-.029	.016	.846	-.107	.048
DJ 4	**1**	.049	.015	.182	-.024	.122
	2	.041	.017	.466	-.043	.125
	3	.029	.016	.846	-.048	.107

Based on estimated marginal means

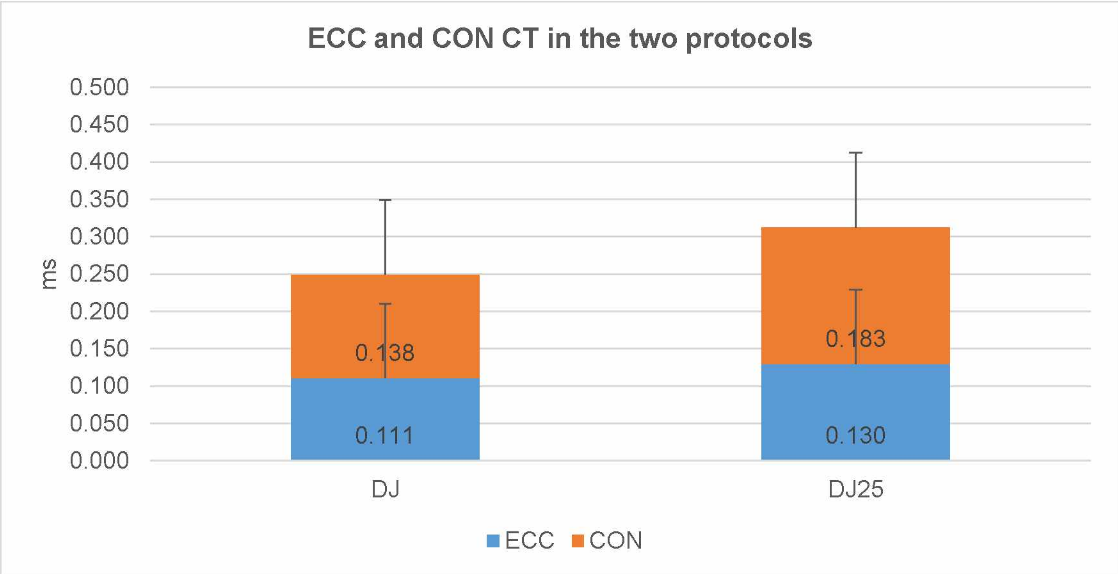
Adjustment for multiple comparisons: Bonferroni

Table 15. Pairwise Comparisons between the four DJ25s

DJ and DJ25 protocols: Paired t–test showed that there was not a significant difference in ECC CT between DJ and DJ25 protocols (DJ, DJ25) ($p=.360$) (Table 16 and Graph 7).

(I) CT MEAN	(J) CT MEAN	Mean Difference (I–J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
CT DJ	**CT DJ25**	-.025	.013	.360	-.072	.022
CT DJ25	**CT DJ**	.025	.013	.360	-.022	.072

Table 16. ECC CT's difference between the two protocols (DJ and DJ25)



Graph 7. ECC CT in the two protocols (DJ and DJ25)

Training Jump Protocols (Correlations)

<u>DJ Protocol</u>: Pearson correlation showed that there was a positive significant correlation between ECC Mean Power, ECC Peak Power (r=.82, p=.45) and ECC CT (r=.84, p=.36). Also, there was a negative correlation between ECC Peak GRF, ECC Mean Power (r=-.86, p=.27) and ECC Peak Power (r=-.87, p=.23). Also, there was no statistical significance correlations between the other parameters (Table 17).

	ECC Mean Power	ECC Peak Power	ECC Peak GRF	ECC CT	CON CT	CT
ECC Mean Power	1	.821*	-.862*	.842*	.566	.752
Sig. (2-tailed)		.045	.027	.036	.241	.085
N	6	6	6	6	6	6

ECC Peak Power	.821*	1	-.873*	.691	.034	.755
Sig. (2-tailed)	.045		.023	.128	.949	.083
N	6	6	6	6	6	6
ECC Peak GRF	-.862*	-.873*	1	-.611	-.187	-.766
Sig. (2-tailed)	.027	.023		.197	.722	.075
N	6	6	6	6	6	6
ECC CT	.842*	.691	-.611	1	.475	.513
Sig. (2-tailed)	.036	.128	.197		.341	.298
N	6	6	6	6	6	6
CON CT	.566	.034	-.187	.475	1	.380
Sig. (2-tailed)	.241	.949	.722	.341		.458
N	6	6	6	6	6	6
CT	.752	.755	-.766	.513	.380	1
Sig. (2-tailed)	.085	.083	.075	.298	.458	
N	6	6	6	6	6	6

Table 17. Correlations between ECC Mean Power, ECC Peak Power, ECC Peak GRF, ECC CT, CON CT and CT in the DJ protocol

DJ25 Protocol: Pearson corelation showed that there was a positive significant correlation between ECC CT DJ25 and CON CT DJ25 (r=.98, p=.000). Also, there was a negative correlation between ECC Peak GRF DJ25 and ECC Peak DJ25 (r=.-94, p=.005). Also, there was no statistical significance in the other correlations (Table 18).

	ECC Mean Power	**ECC Peak Power**	**ECC Peak GRF**	**ECC CT**	**CON CT**	**CT**
ECC Mean Power	1	.111	-.212	-.380	-.293	-.452
Sig. (2-tailed)		.834	.686	.457	.573	.368
N	6	6	6	6	6	6
ECC Peak Power	.111	1	-.984**	-.137	-.576	.174
Sig. (2-tailed)	.834		.000	.796	.232	.742
N	6	6	6	6	6	6
ECC Peak GRF	-.212	-.984**	1	.246	.653	-.046
Sig. (2-tailed)	.686	.000		.638	.160	.931
N	6	6	6	6	6	6
ECC CT	-.380	-.137	.246	1	.878*	.769
Sig. (2-tailed)	.457	.796	.638		.021	.074
N	6	6	6	6	6	6
CON CT	-.293	-.576	.653	.878*	1	.475
Sig. (2-tailed)	.573	.232	.160	.021		.341
N	6	6	6	6	6	6

CT	-.452	.174	-.046	.769	.475	1
Sig. (2-tailed)	.368	.742	.931	.074	.341	
N	6	6	6	6	6	6

Table 18. Correlations between ECC Mean Power, ECC Peak Power, ECC Peak GRF, ECC CT, CON CT and CT in the DJ25 protocol

5) <u>DISCUSSION</u>

The purpose of this investigation was to explore the acute effects of drop jumps (DJ) and drop jumps with additional 25% of body mass (DJ25) during the eccentric phase on vertical jump performance (CMJ). There was, also, an another significant goal, which was to evaluate the operation and the validity of a Converted Smith Machine that transformed to execute extra weight load only during the eccentric phase of the drop jumps.

Specifically, in this study, we aimed to determine the effects of DJ and DJ25 protocol, so in the jump height performance, as in the muscle stiffness of the female athletes. The procedure presented that there were no significant difference between pre and post CMJs' jump height and stiffness showing that there was no effect after the two protocols. This may be due to the fact that only one minute of rest time was used between the four drop jumps (DJ protocol, DJ25 protocol) or the eccentric load of 25% of the body mass that was used in the four drop jumps in the second protocol (DJ25 protocol) was very large for the contestants' abilities. In comparison with previous literature, Alexandra et al., (2018), examined the differences in the bench press between the traditional loading–the accentuated eccentric loading (AEL)–the cluster set loading with three minutes rest between the sets of each protocol and indicated that this rest had an influence on the performance and ,may, be favorable, when using higher loads.

In addition, the statistical analysis showed that in the DJ and DJ25 protocol, all the measurable parameters (ECC Mean Power, ECC Peak Power, ECC GRF, ECC FGR and ECC CT), which were examined between the four DJs in each protocol, have no significant statistical difference. This factor appears to be, mainly, driven by the large overload in eccentric phase (25% of body weight). This is why the contestants have no fast contact time with the Force Plate as a result the ECC CT was giant in both protocols. Further, according to Matusinski et al., (2021), examined the acute effects of resisted activation in 20m sprint with loads of body mass on sprint and flying start sprint performance in elite female sprinters. Therefore, the statistical analysis showed that using 10% resisted loads of body mass is effective and inducing a potentiating effect on subsequent 20m flying start sprint performance.

Moreover, these parameters does not appear to provide significant difference in the two protocols in vertical jump performance, but there is significant difference, if compare these parameters between the two protocols

(DJ, DJ25). So, there are significant statistical difference in ECC Mean Power (p=.011) between the DJ protocol and the DJ25 protocol. Also, in agreement with the project of Aboodarda et al., (2014), was examined the effect of increased eccentric phase loading, as delivered using an elastic device, on DJs performed from different drop heights. In this case the results demonstrated that using additional tensile load during the airborne and eccentric phases of the drop jump could enhance eccentric impulse and rate of force development.

In the one hand, the DJ protocol constitutes a typical example of plyometric exercise that could help to increase the power–speed of the athletes and, generally, the plyometric performance. In the other hand, the DJ25 protocol is an ideal eccentric load program, which has the advantage that the eccentric load is controllable and can be determined based on the ability of the athletes. It is, also, an exercise program to increase the athletes' power–strength, if there was a large eccentric load.

6) CONCLUSION

The results of the current investigation demonstrate that there is significant difference between DJ protocol and DJ25 protocol in ECC Mean Power, but, neither of the two protocols appear to provide a potentiating effect in the participants' performance. In addition, potentiation was not detected in the current search, so future study should focus on different eccentric load protocols and a new rest time between sets using a more developed Converted Smith Machine. Finally, the athletes must have more familiarization with the DJs and the DJ25s in the Converted Smith Machine to have maximum level in their jump efforts. After all, investigations will might need to be completed with more participants, both male and female in different ages, to determine, if eccentric potentiation is a better kind of training, rather than the classics methods, in vertical jump performance. However, this was a resolute aspect of the project in order to make it a more practical comparison.

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