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Original Article

The effects of different conditioning contraction protocols of post-activation performance enhancement on variables of eccentric phases and concentric phase of vertical jumps

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Abstract
Purpose Investigation of the influence of different conditioning contraction protocols on the eccentric variables in terms depth of descent of body centre of mass at countermovement jump as well as capacity of muscle force, power, and velocity at countermovement jump, and depth jump, i.e., velocity at time of rebound both mentioned jumps. Methods In a sample of 29-students (age: 19.6 ± 0.8), 1 repetition maximum was determined by estimating 10 repetition maximum, to be stratified in a six-week workout. Static group practiced hold back squat at 120° for 12 seconds, dynamic group practiced back squat at 120° (x8) for 12 seconds, and combined group practiced 2 back squat at 120° and 2 seconds endurance (x2) for 12 seconds. Control group had a 6 to 8 hours of activity per week. After the pre-contractions, they continuously performed shock-plyometrics (50 cm box), triple jump and 5-meter sprint. Training load was 80% of 1 repetition maximum. Results A statistically significant increase (13.3, and 9.3%) was found in spontaneous descent of body centre of mass at static and dynamic group, unlike in combined and control group (4.4, and 5.5%). In variables force, power, and velocity eccentric phases of countermovement jumps, significant performance ranges of experimental groups from 5.9 to 13.3% were found, unlike in depth jump variables for which there was no significance. Concentric variable in terms velocity time of rebound countermovement jump exhibits significance for dynamic and combined groups in values (3.4, and 4.3%), i.e., same variable of depth jump for static, dynamic, and combined groups in values (2.0, 2.9, 4.1%, respectively; p≤0.05). Conclusion The most indicated increases in variable, velocity at time of rebound at both jumps, were observed after the dynamic loads, referring to sublimated eccentric and concentric manifestations of muscular effects.
Key words: Neuro-muscular potentiation, eccentric muscular action, stretch-shortening cycle, muscular capacity.

Introduction

Any sports activity is generally determined as a combination of concentric and eccentric muscle action (Dickinson et al., 2000). Concentric locomotor activity in most cases, therefore, follows the eccentric, which is in the opposite direction, so this phenomenon refers to the storage and utilization of elastic energy, terminologically represented by the stretch-shortening cycle (SSC), (Ong et al., 2016). Actively contracted muscle opposes stretching if it occurs rapidly (Kubo et al., 2000), thereby accumulating a significant amount of energy in the elastic component of the tendon as the central site (Lichtwark & Wilson, 2007).

Evaluation of the effects of pronounced eccentric load (group I of participants without load vs. 20 kg of external load in group II), on consequent concentric-kinetic factors (CMJ), in elite athletes, was considered in the research (Sheppard et al., 2007). The obtained results showed improvement ratios of (4.3, 9.4, 3.9 and 3.1% at jump height and power peak, force peak and velocity peak, respectively), in favor of the conditioning contraction group. This is explained by the acute increase in critical abilities during the exercise of vertical jumps ($p<0.05$), since the stated load provided sufficient neuronal stimulation, i.e., appropriate myogenic changes in the participants.

The study (Gollhofer et al., 1992) under different elongation load conditions, electromyographically (EMG) showed the force-length relationships of the muscle-tendon complex (MTC), triceps surae and Achilles tendons, as well as m. soleus, gastrocnemius and tibialis anterior. Diagrams (EMG) stated individually high sensitivity of imposed loads. However, comparing (DJ) with (CMJ) indicates that the increase in eccentric muscle activity of deep jumps does not increase jump height due to incomplete absorbency in the muscle-tendon system.

The aim of the work presented in the study by Voigt et al. (1995) was the interaction between tendon elasticity, dynamics of muscle load activation, specific actions of biarticular muscles, conditioning contractions and jumping performance during maximal vertical jumps on a sample of six experienced athletes. The results showed that the best jumping performance was achieved with jumps of smaller conditioning contractions, such as (CMJ) and (DJ) from 0.3 meters, where a significant amount of energy before load elongation was stored in the tendons (26 ± 3%), thus preventing excessive elongation of muscle fibers in relation to changes in tendon

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length. Significant increase in m. rectus femoris activity indicates the transport of mechanical energy produced for the proximal monoarticular m. gluteus maximus, which increases the transformation of rotational joint work to translational work of the body centre of mass. During pre-extension and take-off, the motions of body segments induce forward and backward body rotation, respectively, creating a reciprocal change in the activities of biarticular m. rectus femoris and m. semitendinosus.

Training research method, which involves inducing the effect of post-activation potentiation (PAP), or the after-effect phenomenon, leading to an acute increase in muscle contraction capacity after conditioning contraction (Xenofondos et al., 2010), is contrast (CT) training (Alves et al., 2010; Mujika et al., 2009). The many researchers like (Cuenca-Fernandez et al., 2017) would benefit by adopting terminology which clearly distinguishes postactivation performance enhancement of voluntary activations (PAPE) from postactivation potentiation seen in electrically evoked contractions (PAP).

Just, this current research trying to determine whether increasing loads in terms of muscle conditioning contractions (static, dynamic or combined static-dynamic) and activity of eccentric muscle phase during vertical jumps can significantly improve the performance of concentric phases (CMJ and DJ).

Methods

Experimental Approach to the Study Problem

By comparing the effects of three different intra-sessions of training treatment in this study, as well as the combination of shock plyometrics - plyometrics on maximal output of rapid movements i.e., velocity time of rebound in the student athlete population, selected eccentric phases (CMJ and DJ) were evaluated. The pre- and post-protocol measurements were taken over a period of 5-7 days, including 3 experimental and 1 control group. Contrast (CT) training lasted six weeks. Measurements, as well as conditioning contraction sessions, were carried out in the laboratory of the Faculty of Sports and Physical Education, University of Belgrade, while the subsequent conditioning contraction exercises were carried out in the hall of the Faculty.

Participant Sample

Data were collected from 29 students of the first and second year of studies (age 19.6 ± 0.8 years; body height 182.7 ± 6.6 cm and body weight 77.7 ± 8.1 kg). The academic curriculum included 6-8 hours of physical activity per week (Taylor-Piliae et al., 2006). Through an estimate of 10 repetition maximum, 1 RM was determined for each of them individually, so based on the equal distribution, the groups were homogenized (values - from the highest to the lowest). The participants were divided into groups (experimental-static ES, n = 9), (experimental-dynamic ED, n = 9), (experimental-combined EC, n = 5), and (control C, n = 6).

The experimental participants had to be healthy, without chronic diseases, heart failure or injury to the locomotor system, which would affect the health condition and evaluation of the tests. Everyone was acquainted with the measurement protocol, testing, training sessions, the subject and aim of the research, i.e., the benefits and risks. This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Faculty of Sports and Physical Education, University of Belgrade (02 -04-2021 / 02 536/21-2).

Experiment Protocol

Initial testing, programmed 6-week training (November-December 2019) and final testing were performed. Anthropometry, 10 RM and familiarization i.e., back-squat motoric-training tasks at 120º, shock plyometrics, triple jump and sprint were performed on day one. Height of body was measured wusing a Martin anthropometer with an accuracy of 0.1 cm (Norton et al., 2000), on all students before start experiment, so that's why was not repeat in protocol, while mass was estimated by bioelectric impedance (InBody720, Cerritos, CA, USA). The maximum ten times lifted weight on the modified Smith machine was 10 RM or 75% max load (Baechle & Earle, 2008). The order of the participants in the testing was random.

On day two, students were tested by the tensiometric method (AMTI BP600400; USA), when signals of the ground reaction force were recorded in countermovement and depth jump. The posttest was performed in one day, with repeated anthropometry and vertical jump tests. Warming up and dynamic stretching lasted 20 minutes, and the completion of the evaluation was followed by static stretching of 10-15 minutes.

Training Procedures

The three training was held in the interval of 48h between sessions in the first 3 weeks and two training in the interval of 72h in the remaining 3 weeks with circadian rhythm evaluation. Raising neuromuscular activation in the introduction lasted 20 minutes and included jogging, change of direction, various leaps, half-squat walking and then dynamic stretching. Two access series of warm-ups with 10 to 15 repetitions were also practiced, using a load of 40 and 60% 1 RM. The training load applied was 80% at 1 repetition maximum (Shimano et al., 2006; Wilson et al., 2006). Every other week, the training stimulus was progressively increased by 5% in exercises with external load, and coupling time was reduced by ~ 30-40 ms for shock plyometrics and ~ 10 ms for plyometrics in triple jump, using fast SSC classifications (Walker, 2016). In the first four weeks, six training series were performed, and in the fifth and sixth weeks, eight series were performed.

The back squat was performed with the proper technique on a standard Smith machine (Newton et al., 1997) following the procedure (Riebe et al., 2018). On that occasion, the most loaded muscles were m. vastus lateralis, m. vastus medialis, m. rectus femoris, m. biceps femoris, m. semitendinosus and m. triceps surae, and also m.

gluteus maximus and m. erector spinae due to muscular activation. The depth of the squat was interrupted when the parallel position of the back thigh and the surface was occupied, i.e. when the vertical projection of the sliding bar passed through the middle of the foot, and then with the lower third of the lower leg and thigh slightly closer to the knee joint. The participant was in a deep squat position, i.e., knee joint flexion at an angle of approximately 120 degrees° (Bazyler et al., 2015; Trindade et al., 2020).

Each participant with weight sets had 12 seconds of workout (Table 1), and the time was measured with a stopwatch (CATIGA CG-503). Static group represented of 9 students who applied 80% 1 RM in static endurance of the back squat at 120°. Dynamic group represented of 9 students who applied 80% 1 RM with 8 back-squats in a dynamic repetition at a knee joint angle of 120°. And combined group represented of 5 students who applied 80% 1 RM with 2 back squats and 2 seconds of endurance at 120° with full knee joint extensions (x2).

After the applied conditioning contraction protocols, the experimental participants took a rest 2 minutes (Wilson et al., 2013), and then successively performed jumps on a 50 cm high box (shock plyometrics), a continuous triple jump and a five-meter sprint (x3), with a rest interval of one-minute between each repetition. The surface on which the subsequent conditioning contraction exercises were performed was hard ceramic support (Arampatzis et al., 2004; Moritz & Farley, 2005), with the participants wetting the soles of the sneakers well before each start to avoid possible slipping and injuries. Emphasized proper technique of the take off – land off within the mentioned applicable surface should have had the purpose of the positive effect of the elastic component of the muscle-tendon unit and kinetic energy of the body.

The rest between sets was 5 minutes in the first four weeks, and 6 minutes in the fifth and sixth weeks, with active rest and stretching of the muscles (as described in Table 1). The final part of the training sessions lasted 15 minutes and included body cooling, relaxation and light static stretching. The participants from the control group were instructed to maintain the level of physical activity they had been practicing throughout the experiment.

Table 1. Presentation of practicing conditioning contractions as part of contrast training sessions.

Work week 1, 2, 3, 4, 5, 6	† nts	†† rble&swj	††† nrjews	†††† rbts
	6, 6, 8	2, 2, 2 min.	3, 3, 3	5, 5, 6 min.

Static load (ES)	Dynamic load (ED)	Combined load (EC)	↔	Plyometric method
12 sec. endurance 80% 1 RM knee angle 120°	8 reps. in 12 sec. 80% 1 RM knee angle 120°	2 back squat + 2 sec. endurance (x2) 12 sec. on 80% 1 RM knee angle 120°		shock plyometrics (box 50cm) + triple jump + 5 met. max sprint (rest between exercise 1 min.)

Note: † nts number of training series in the first 4 weeks was six and in the last 2 weeks was eight, †† rble&swj rest between load exercises and sprint with jumps was 2 minutes, ††† nrjews number of repetitions of jumping exercises with sprint, †††† rbts rest between of the training series was 5 and 6 minutes.

Testing procedures of kinetic and kinematic characteristics

Countermovement jumps (Young et al., 1995), included max performance after a quick squat with fists resting on the hips. Depth jumps (Young et al., 1995) included absorbing landing with a 50 cm box high (Geraldo et al., 2019), i.e., were from the squat position and with free arms swing. Using the record of the ground reaction force in time, the variables were calculated: spontaneous descent depth of the body mass centre during the eccentric phase at CMJ, maximum ground reaction force, maximum power, and maximum velocity of the body mass centre in eccentric phases CMJ and DJ i.e., the maximum velocity achieved by the centre mass of the body at the time of rebound.

Both jumps were tested three times with the maximum achievements of each student at the initial and final measurement. During further statistical analysis, the average group values of mentioned variables were taken. There was a 30-second rest between jumps and a 5-minute rest between two different applied jumps.

Data gathering and processing

Tensiometric platform was calibrated at 1000 Hz. LabVIEW software (version 19.0; National Instruments, Austin, TX, USA) was used for data processing. First, the signals of the vertical component of the ground reaction force (F) were processed with a low-pass recursive filter "Butterworth" of the fourth order at a cutting frequency of 10 Hz, and then with the help of the resulting record, the acceleration data directly proportional to the force was obtained. By integrating the acceleration, repercussion of velocity was obtained, i.e. the next integration of the position of the body centre of mass during the jump (Vanrenterghem et al., 2001), which obtained the appropriate kinematic variables. The kinetic variable forces were calculated from signal (F), with the product of force and velocity being power. These procedures calculated the eccentric phases of two different types of jumps, as well as the parameter in the concentric phase, i.e. velocity at the time of rebound.

Statistical analysis of data

Participants' achievements through variables were represented by mean values and standard deviations. All data were examined for normal distribution and the variance homogeneity test (Shapiro-Wilk test, and Levene Statistic test). The eccentric phases and the criterion of their reliability (95% confidence interval) were determined with the help of standard error of measurement (SEM), the coefficient of variation (cV%) and intraclass correlation coefficient (ICCs).

Comparative statistics included 2-factor (group "ES, ED, EC and C", and time "pretest - posttest") analysis of variance with repeated measures in terms of assessment of training effects on the outcomes of eccentric phases and concentric phase of vertical jumps i.e., indicators of their interaction. Significance was represented by the Tukey's HSD post hoc test. The criterion of statistical significance is presented as p-value at the level of ($p \leq 0.05$). The processing of all data was performed in the SPSS program for Windows (version 20.0; IBM Corp., Armonk, NY, USA), while the figure presentations were made using GraphPad Prism Software (version 8.0.1; San Diego, CA, USA).

Results

Mean values and standard deviations of three experimental groups and one control on the pretest and posttest, along with other significant indicators of spontaneous depth of descent of the body centre of mass in the eccentric phase countermovement jump are presented, i.e., the addition of interaction impact assessment (as described in Tables 2 and 3).

Table 2. Descriptive indicators of the countermovement jumps.

Hdd (cm)	Jump 1	Jump 2	Jump 3	Jump 1	Jump 2	Jump 3
			mean±sd			
CMJ (ES)	34.0±4.5	34.6±3.1	34.8±5.3	38.5±5.0	38.8±5.8	39.9±4.4
CMJ (ED)	34.7±4.9	37.3±6.3	35.7±6.4	39.2±6.2	38.7±5.6	39.8±5.5
CMJ (EC)	30.3±5.9	31.9±4.1	33.4±5.1	32.1±5.0	32.8±4.2	35.0±2.4
CMJ (C)	33.8±4.7	33.3±5.6	34.1±5.8	35.6±3.5	35.8±8.5	35.4±5.8

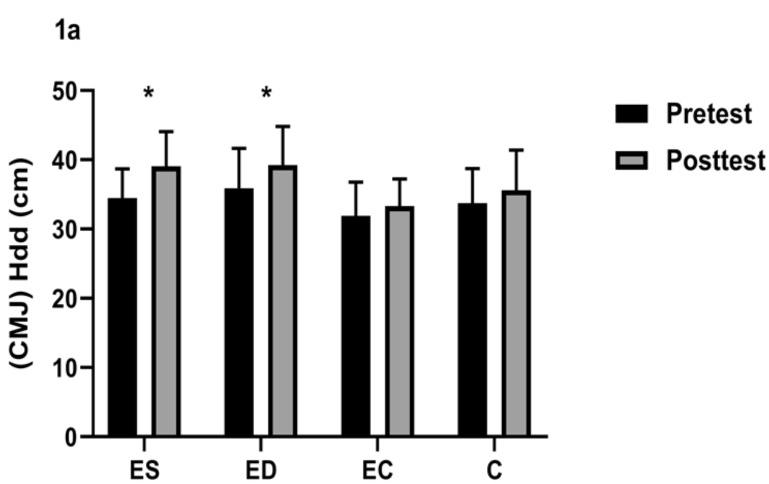
Table 3. Reliability results of spontaneous Hdd (cm) i.e., 2-factor analysis of variance.

Hdd (cm)	SEM	cV(%)	ICC (95%CI)	SEM	cV(%)	ICC (95%CI)
CMJ (ES)	0.81	12.22	0.58(0.18-0.87)	0.96	12.73	0.70(0.35-0.92)
CMJ (ED)	1.11	16.03	0.53(0.12-0.85)	1.08	14.24	0.89(0.69-0.97)
CMJ (EC)	1.26	15.35	0.88(0.55-0.99)	1.02	11.81	0.66(0.11-0.95)
CMJ (C)	1.29	14.85	0.94(0.72-0.99)	1.50	16.29	0.76(0.27-0.97)
interactions – time*group - Wilks' Lambda= 0.682; F = 0.551; p = 0.899; pŋ²= 0.120;						

The figures on the left show the mean values groups with significant differences on the t-test of the dependent samples, and the right ones show the absolute differences of the parameters groups observed between the two measurements, with the help of one-way analysis of variance and the Tukey's HSD post hoc test (as shown in Figures 1a-7b).

Differences between groups in the pretest:

- (CMJ) Hdd (/); (CMJ) F ecc (/); (CMJ) P ecc (/); and (CMJ) V ecc (ED↔EC; and ED↔C),
- (DJ) F ecc (/); (DJ) P ecc (ES↔C; and EC↔C); and (DJ) V ecc (/).



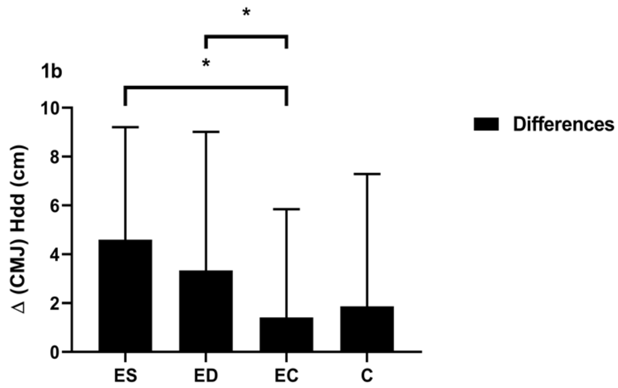


Fig. 1a and 1b. Countermovement jump results of average values spontaneous descent depth of the body centre of mass (cm; mean ± SD and mean 2 – mean 1 ± SD pooled) in eccentric phase for experimental groups and control participants in pretest and posttest. *Statistical significant (p≦0.05).

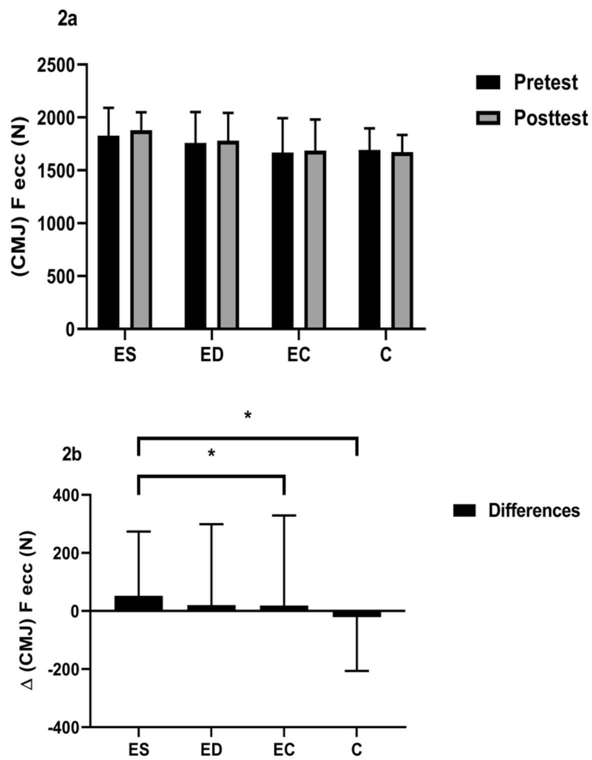
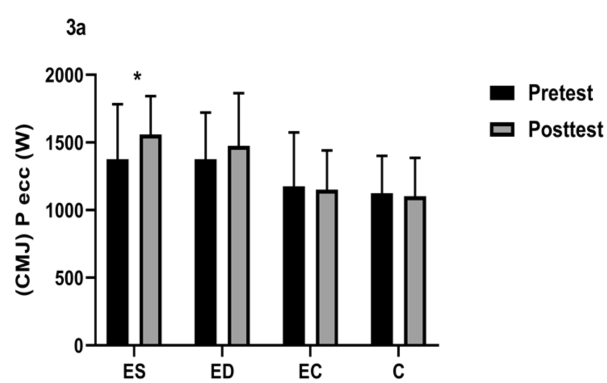


Fig. 2a and 2b. Countermovement jump results of average values muscle force (N; mean ± SD and mean 2 – mean 1 ± SD pooled) in eccentric phase for experimental groups and control participants in pretest and posttest.



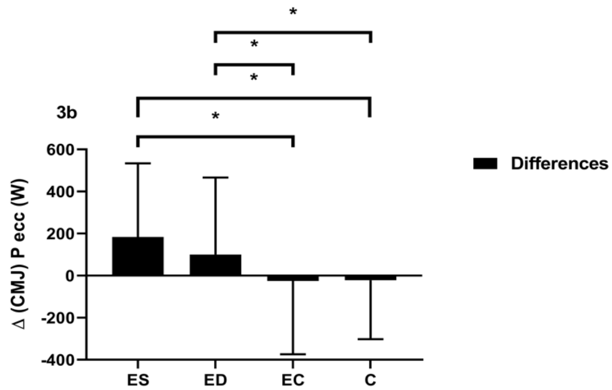


Fig. 3a and 3b. Countermovement jump results of average values muscle power (W; mean ± SD and mean 2 – mean 1 ± SD pooled) in eccentric phase for experimental groups and control participants in pretest and posttest.

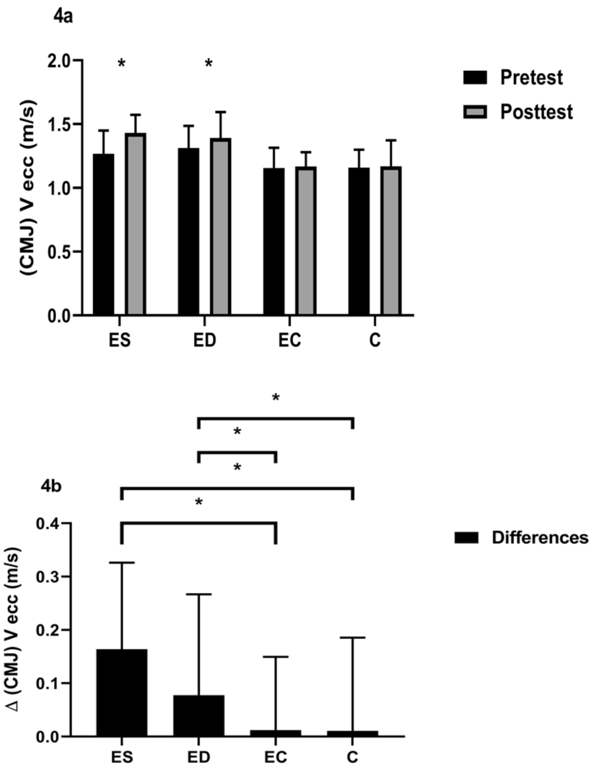
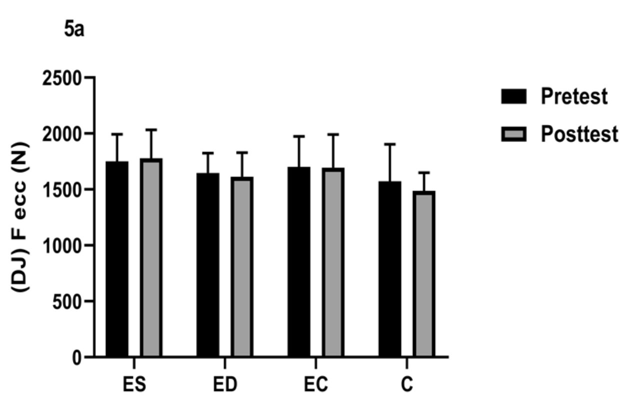


Fig. 4a and 4b. Countermovement jump results of average values muscle velocity (m/s; mean ± SD and mean 2 – mean 1 ± SD pooled) in eccentric phase for experimental groups and control participants in pretest and posttest.



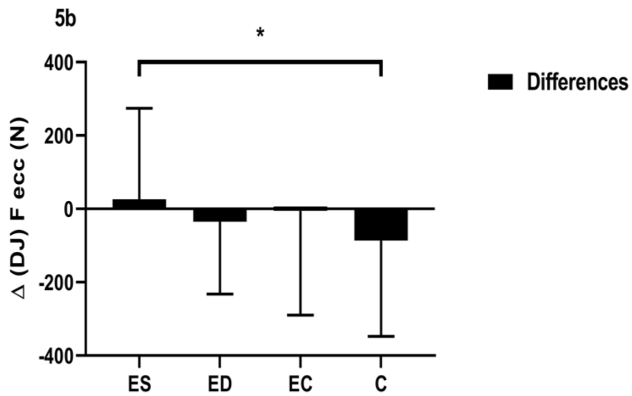


Fig. 5a and 5b. Depth jump results of average values muscle force (N; mean ± SD and mean 2 – mean 1 ± SD pooled) in eccentric phase for experimental groups and control participants in pretest and posttest.

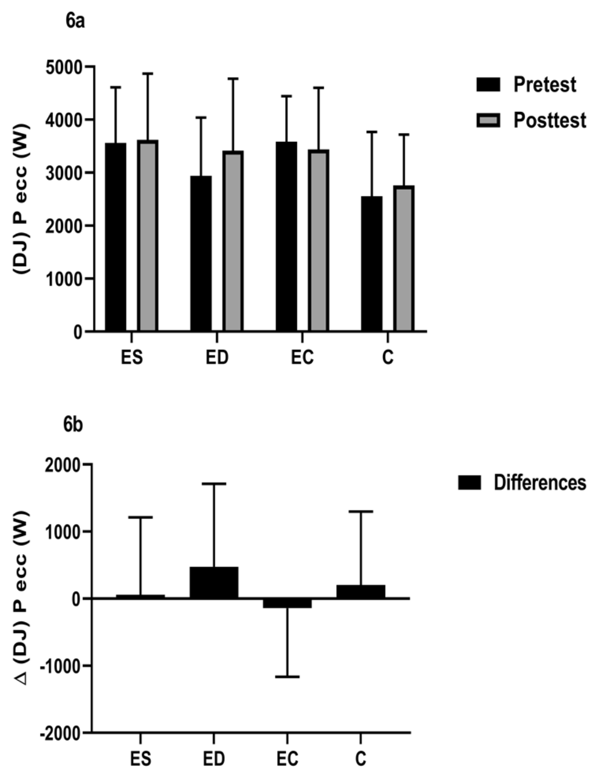
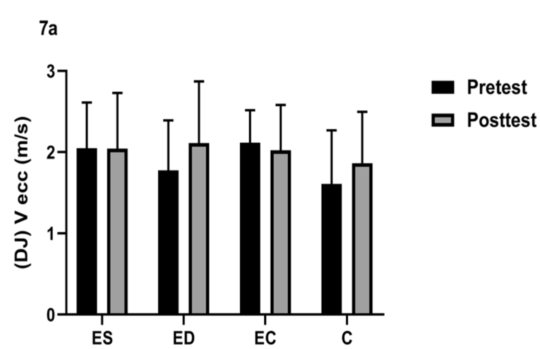


Fig. 6a and 6b. Depth jump results of average values muscle power (W; mean ± SD and mean 2 – mean 1 ± SD pooled) in eccentric phase for experimental groups and control participants in pretest and posttest.



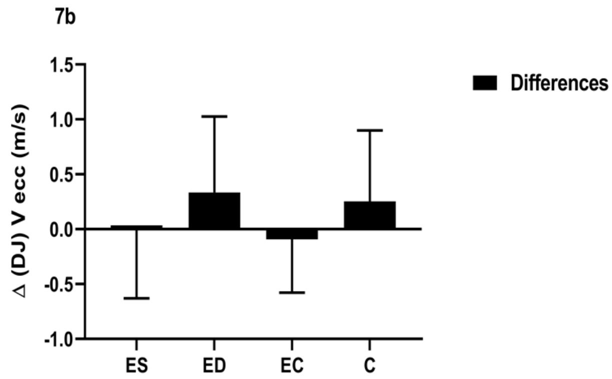


Fig. 7a and 7b. Depth jump results of average values muscle velocity (m/s; mean ± SD and mean 2 – mean 1 ± SD pooled) in eccentric phase for experimental groups and control participants in pretest and posttest.

The first figures present statistically significant differences in the static and dynamic groups in the variable (CMJ) Hdd (cm) (Fig. 1a and 1b: 34.48 vs. 39.07 cm; i.e., (ES): 13.3% [Cohen's d = 1.00]; then 35.90 vs. 39.24 cm; i.e., (ED): 9.3% [d = 0.59]; 31.89 vs. 33.30 cm; i.e., (EC): 4.4% [d = 0.32]; and 33.72 vs. 35.58 cm; i.e., (C): 5.5% [d = 0.34]). Tukey's HSD post hoc test (ES↔EC; and ED↔EC).

In the variable (CMJ) F ecc (N), it is noticeable that there are no statistically significant differences in the observed groups (Fig. 2a and 2b: (ES): 2.9% [Cohen's d = 0.24]; (ED): 1.1% [d = 0.07]; (EC): 1.1% [d = 0.06]; and (C): -1.2% (d = -0.11), respectively). Tukey's HSD post hoc test (ES↔EC; and ES↔C).

The following figures present a significant difference only in the first group (ES), comparing the pre- and posttest (CMJ) P ecc (W) (Fig. 3a and 3b: (ES): 13.3% [d = 0.52]; (ED): 7.3% [ESs = 0.27]; (EC): -2.2% (d = -0.07); and (C): -2.0% (d = -0.08)). Tukey's HSD post hoc test (ES↔EC; ES↔C; ED↔EC; and ED↔C).

Variable (CMJ) V ecc (m/s) exhibits statistically significant differences in the first and second experimental groups (Fig. 4a and 4b: (ES): 12.9% [d = 1.01]; (ED): 5.9% [d = 0.41]; (EC): 1.1% [d = 0.09]; and (C): 0.9% [d = 0.06]). Tukey's HSD post hoc test (ES↔EC; ES↔C; ED↔EC; and ED↔C).

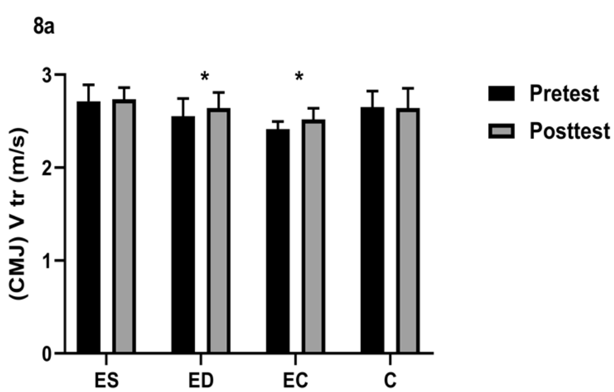
In variable (DJ) F ecc (N), no statistically significant difference was found in the groups (Fig. 5a and 5b: (ES): 1.5% [d = 0.10]; (ED): -2.1% (d = -0.18); (EC): -0.3% (d = -0.02); and (C): -5.5% (d = -0.33)). Tukey's HSD post hoc test (ES↔C).

Variable (DJ) P ecc (W) did not exhibit statistically significant differences (Fig. 6a and 6b: (ES): 1.6% [d = 0.05]; (ED): 16.2% [ESs = 0.39]; (EC): -4.0% (d = -0.14); and (C): 8.0% [d = 0.19]). Tukey's HSD test (/).

For variable (DJ) V ecc (m/s), no statistically significant changes were found in all observed groups (Fig. 7a and 7b: (ES): -0.2% (Cohen's d = -0.01); (ED): 18.9% [d = 0.48]; (EC): -4.4% (d = -0.19); and (C): 15.8 [d = 0.39]). Tukey's HSD test (/).

From the data sets countermovement and depth of jumps, statistically significant segments of the average values velocities time of rebound for each group in the pretest and posttest were presented (Fig. 8a, 8b and 9a, 9b).

Differences between groups in the pretest:
(CMJ) V tr (ES↔ED; ES↔EC; and EC↔C),
(DJ) V tr (ES↔ED; ES↔EC; and ES↔C).



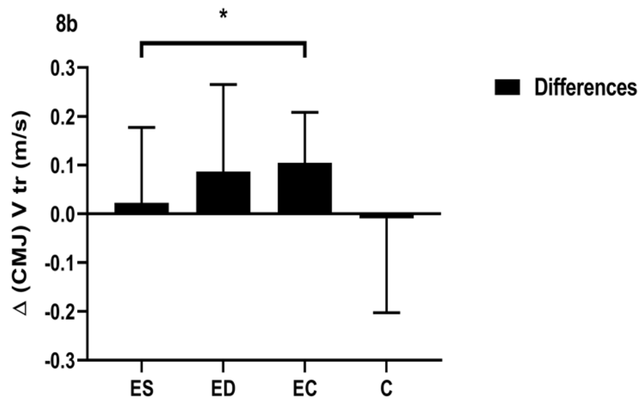


Fig. 8a and 8b. Countermovement jump results of average values velocity at the time of rebound (m/s; mean ± SD and mean 2 – mean 1 ± SD pooled) in concentric phase for experimental groups and control participants in pretest and posttest.

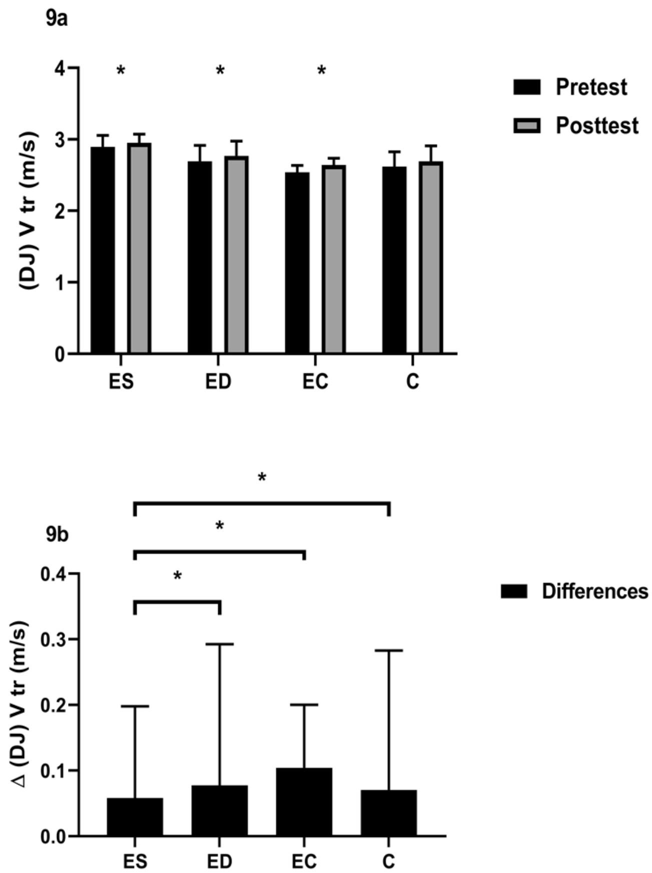


Fig. 9a and 9b. Depth jump results of average values velocity at the time of rebound (m/s; mean ± SD and mean 2 – mean 1 ± SD pooled) in concentric phase for experimental groups and control participants at pretest and posttest.

Variable (CMJ) V tr (m/s) exhibits statistically significant changes in the groups of dynamic and combined conditioning contractions (Fig. 8a and 8b: (ES): 0.8% [Cohen᾽s d = 0.15]; (ED): 3.4% [d = 0.49]; (EC): 4.3% [d = 1.01]; and (C): -0.4% (d = -0.05)). Tukey᾽s HSD post hoc test (ES↔EC).

Variable (DJ) Vtr (m/s) showed statistically significant differences in all experimental groups (Fig. 9a and 9b: (ES): 2.0% [Cohen᾽s d = 0.42]; (ED): 2.9% [d = 0.36]; (EC): 4.1% [d = 1.08]; and (C): 2.7% [d = 0.33], respectively). Tukey᾽s HSD test (ES↔ED; ES↔EC; and ES↔C).

Discussion

The obtained overall results (primarily CMJ performance) in relation to statistical significance confirm the assumptions about changes in the studied variables and mainly increments of performance of experimental groups depending on applied training sessions. The obtained parameters suggest that the conditioning contractions were quite an efficient physiological phenomenon. Special attention should be paid to the combined conditioning contractions in strength training (no studies were found that dealt with this type of activation with external load, but only those that conducted static-dynamic stretching after different running sessions as a form of warm-up, in terms evaluated various motoric tests), because these stimuli showed their full efficiency in concentric phases of (CMJ and DJ V tr) jumps, unlike eccentric phases.

The fact is that better performance after the application of combined conditioning contractions in concentric variables (the participant who lifted the imposed load in the concentric phase will be able to lower the external resistance in the eccentric phase, in terms of subtraction or addition of active, passive and viscous muscle components) should be associated with the stretching reflex mechanism, i.e., that explosive eccentric muscle actions subsequently activated the stretching reflex, as well as better storage of elastic energy in tendons and muscles (Potash & Chu, 2008).

Variable (CMJ Hdd) (Table 2 and 3; Fig. 1a and 1b), was treated in the study in terms of the influence of the transfer of spontaneous descent depth of the body center of mass on the maximum output of eccentric and concentric performance, i.e. velocity at time of rebound (CMJ Vtr). The largest and statistically significant improvements between the two measurements in variable (CMJ Hdd) are visible only in the group of applied static, and dynamic conditioning contractions. The obtained finding of variable (CMJ Hdd) shows moderate test-retest reliability of statistically significant groups. There were no instructions on the velocity or duration of the eccentric jump phase, i.e. the respondents had different performance strategies. The authors (Moir et al., 2004; Moir et al., 2005) indicated high levels of reliability when testing similar variables. In the group of static conditioning contractions, in addition to significance and moderate reliability, a large effect size (Cohen, 1988) was found, which indicates that the research outcome has full practical application, unlike dynamic conditioning contractions i.e., combined conditioning contractions and control participants, in whom limited practical application were found. Tukey᾿s HSD post hoc test and the difference between the static and dynamic conditioning contractions in relation to the combined stimuli favors of practice. What is noticeable in the obtained indicators of muscle force of eccentric phases both types of vertical jumps (CMJ and DJ F ecc) is that no statistically significant differences were found between pre- and posttest in experimental groups. Moreover, in the dynamic and combined groups of depth jump, negative signs of the obtained forces were found. Subsequent procedures calculated the effect size (Fig. 2a, 2b and 5a, 5b) i.e., its triviality in most cases at the both jumps. Only in the group of static conditioning contractions (CMJ) jump, a small effect size was found. In the depth jump, trivial values of the effect size were only found in the group of static conditioning contractions values, which indicates almost insignificant practical application of these stimuli during the increase of muscle force in eccentric phase of depth jump. In the remaining two experimental groups (ED and EC) and control (C) no need to be discussed, as they have no practical application. Using Tukey's HSD post hoc test, differences were found between static conditioning contractions and the combined group, i.e., control participants at countermovement jump, or between static and control group of depth jumps.

Possible factors that influenced the muscle force potential of the sample of student (unaccustomed to the type of muscle strength training), are peripheral factors such as muscle dimensions, or insufficient muscle capacity to produce force, which depends on the size of its physiological cross-section, or number of muscle fibers in the muscle, and on the cross-section of the fibers. Another possible factor is the hormonal status, since anabolic hormones accelerate the synthesis of muscle proteins from amino acids. And the intramuscular coordination as a central (nervous) factor (Zatsiorsky, 1995) probably had an impact on the mentioned results, referring to insufficient synchronization of activation and deactivation of activated motor units.

Since muscle power is most often related to muscle velocity, these abilities will be observed as sublimated. A review of the obtained results of muscle power in the eccentric phases (CMJ and DJ P ecc) shows that the only statistically significant difference was found in the group of static conditioning contractions at the countermovement jumps. It is evident that there are large discrepancies between the increase and decrease in the repercussions of the power of the participants by groups. At the countermovement jump, a considerable increase in muscle power performance in the group of dynamic conditioning contractions must be noted, but without significance, while the remaining groups recorded a decrease in performance.

Unlike the mentioned type of jump, depth jump has no significance, i.e., it is necessary to mention the large increase in muscle power performance in the group of dynamic conditioning contractions. Subsequent procedures calculated the effect size (Fig. 3a, 3b and 6a, 6b), based on which it can be ascertained that after significance, the application of static stimuli also brought relative practical application, unlike limited practical application of the group of dynamic stimuli at the countermovement jump. Indicators of the effect size of muscle power parameters in the eccentric phase of depth jump say that the group of dynamic conditioning contractions had relative practical application to the study outcome, unlike the trivial practical application static group. Using the Tukey's post hoc test, the difference between static and dynamic conditioning contractions was determined in relation to combined and control participants (CMJ), while at (DJ) there were no differences in the observed variable.

The results of the muscle velocity (Fig. 4a, 4b and 7a, 7b) of the eccentric phases of vertical jumps present statistically significant differences only in the groups of static and dynamic conditioning contractions at the countermovement jump. It is evident that all observed groups countermovement jump have a certain proportional increase, while in depth jump, there are large deviations between the increase and decrease of repercussions of the velocity i.e., a significant increase in muscle velocity performance in the group of dynamic conditioning contractions but without significance. The group of static conditioning contractions brought complete pragmatic application in terms of muscle velocity increase (CMJ V ecc), unlike the significant borderline small practical application of the group dynamic stimuli and trivial practical application of the combined stimuli.

Indicators of the effect size of the muscle velocity parameter in the eccentric phase of depth jump say that the group of dynamic stimuli had mediocre practical application to the research outcome, unlike the other two training groups (ES and EC) which had no practical application. The applicable Tukey's post hoc test, found differences between static and dynamic conditioning contractions in relation to the combined and in relation to the control participants. In depth jump, no significant differences were found.

A possible explanation contradictory parameters of muscle power and velocity of eccentric phases both of jumps in three experimental groups is that physiological mechanisms (phosphorylation regulatory light chains of myosin – RLCM and increased neural activity), and biomechanical factors (change in the angle of muscle contraction) were caused the obtained results. A different relationship between muscles with shorter or longer time of twitch contraction was considered in terms of achieved velocities, unlike in control participants in which it is possible to associate the found results with influencing factors i.e. with certain intervals of rest and recovery at regular physical activities at the Faculty. The positive results of the conditioning contraction groups came due to the activation of the enzyme light chain kinase of myosin – LCKM, when increasing the concentration of Ca^{2+} (sarcoplasmic reticulum) and its binding to the Ca^{2+} - calmodulin complex. Increased Ca^{2+} concentration resulted in LCKM activation and increased RLCM phosphorylation (Rassier & MacIntosh, 2000), which causes increased sensitivity of contractile proteins to Ca^{2+}, thereby strengthening the manifestation of submaximal (voluntary) and slightly maximal (involuntary) contractions.

Intensified submaximal contractions under conditions of high levels of RLCM phosphorylation have led to an increased frequency of connecting cross bridges or a greater degree of transition from weak to strong ties. Muscle stiffness (hardness) also increased proportionally, so that the activity of myosin ATPase was proportional to the mentioned increase, while the rate of relaxation did not decrease. Also, the process of increasing post - synaptic potentials with the same level of pre - synaptic potentials during the subsequent muscle activities followed the mechanism of increased transmission of action potentials via synaptic junctions in the spinal cord.

The angle of action of the muscles as the angle formed by the fascia of the internal aponeurosis simultaneously reflected the orientation of muscle fibers in relation to connective tissue, i.e. the ratio of fibers and relevant tendons during muscle contraction was reduced in terms of advantage or increased by the factor of the magnitude of the angle of muscle action (penation angle). Positive results of muscle velocity of eccentric phases of vertical jumps can probably be explained by a higher share of fast muscle fibers (type II) compared to negative results of conditioning contraction groups, in which participants of slow muscle fibers (type I) predominated. Only a muscle biopsy in a future study could completely unravel all doubts.

Unlike the conditioning contraction groups that presented gains corresponded by rest intervals of 5 and 6 minutes between sets, the lower final values found can be explained by the fact that due to increased preload volume in students unaccustomed to this type of training, fatigue became the dominant factor with a negative impact (opportunity or window 2) (Tillin & Bishop, 2009). The mentioned findings in the current study quite agree with the study of the authors (Jones & Lees, 2003) which, on a sample of 8 trained and strength participants, assumed that heavy resistance exercises, containing 5 squats at 85% 1 RM, will lead to the increase in the height (CMJ and DJ), which were performed in conditions (4 sets x 3 CMJ / 3 DJ), as well as an increase in the electromyographic activities of the subsequent plyometric exercises. The results showed that the only statistical difference in the variables was found on electromyography in m. biceps femoris during the propulsive phase (DJ), which was significantly higher in the trained participants, compared to the control (I training group had a short rest interval and rest of 3, 10 and 20 minutes during the sessions, and the II control group had no rest in the first two sets). In the other variables no significant differences were found between the participants. The influence of the training treatment could not be completely ruled out, considering there were no negative effects of subsequent plyometric repercussions.

After eccentric (plyometric) muscle contraction (tension in cross bridges lower than resistance, and the muscle elongates despite contacts between the head of myosin bridges and actin filaments) came concentric (myometric) muscle contraction (achieved total tension in all cross bridges, and any resistance to shortening is overcome, i.e. muscle shortens), since muscle fibers are innervated by a motor neuron, the same excites the muscle fiber and innervates it by chemical transmission. The action potentials caused the release of acetylcholine, which diffused through the neuromuscular junction, causing the excitation of sarcolemma (release of Ca ions). By reducing the interval between the twitch, a greater sum of force was obtained, and thus other repercussions by variables, i.e. stimuli were emitted at a high frequency so the twitches fused into a state called tetanus (fast-twitch FT (white muscle fibers) - the ability of anaerobic potency and their susceptibility to fatigue) (Latash, 2008).

The velocity at time of rebound parameters in the concentric phase of vertical jumps show that statistically significant differences were found in the groups of dynamic and combined conditioning contractions at the countermovement jump (3.4, and 4.3%), unlike significant changes in all three experimental groups at the depth jump (2.0, 2.9, and 4.1%). The application of static conditioning contractions (Fig. 8a, 8b and 9a, 9b) brought a trivial practical application in terms of increase in velocity at time of rebound (CMJ V tr), unlike mediocre practical application of the group of dynamic stimuli and complete practical application of the combined group. Indicators of the effect size velocity at time of rebound in the concentric phase of depth jump say that the group of static stimuli had mediocre practical application to the study outcome, unlike limited practical application of the group dynamic stimuli and complete practical applications of the combined group.

Using Tukey's HSD post hoc test, a statistical difference was observed only between static and combined conditioning contractions groups (CMJ V tr), and the application of the same test (DJ V tr) found a statistical difference between the static group and the other two experimental and control groups.

The possible explanation of these neurophysiological mechanisms is as follows: 1) due to greater elongation of intrafusal muscle fibers, increased neuronal stimulation occurs, resulting in greater "provocation" of γ thinner muscle fibers of motor neurons in the reflex arc and thus signaling (CNS), to increase the "trigger rates" of α thicker myelin fibers of anterior motor neurons, as physiological flexors, which lead to a possible increase in contractile muscle force (Walshe et al., 1998), 2) increase in elongation of parallel (epimysium, perimysium, endomysium and sarcolemma) and serial muscle- tendon structures lead to increased elasticity, 3) the mechanism of improvement of key concentric muscle indicators occurs due to increased muscle force product, i.e. reduced displacement of myofibrils (Cohnheim's fields) as a consequence of stored elastic energy in fibers and 4) as a possible mechanism of increased conditioning contraction, which probably has the greatest impact on improving concentric performance in consequent eccentric phases (Bobbert et al., 1996; Cronin et al., 2001).

Based on the previous findings, a study was found in which the authors (Bogdanis et al., 2014), in the performance study attributed a superior benefit to isometric half-squats (3 x 3 sec.), compared to eccentric (70% 1 RM) and concentric (3 x 90% 1 RM) when increasing the rapid movement performance of the legs of the countermovement jump, in the case when the impulse of the ground reaction force was equated between conditioning exercise. The gain during eccentric phases and concentric phase countermovement and depth of jumps can be related with the physiological mechanism of accentuated eccentric loading (AEL) in terms of imposed conditioning contractions, which led to current increases in the concentric performance of the velocity of the body centre of mass at time of rebound, referring to the mechanisms stretch-shortening cycle and post-activation performance enhancement.

Observed as sublimated, statistically significant progress, i.e., the largest increases in variables eccentric phases countermovement of jumps, were found after static and dynamic conditioning contractions (ES and ED), unlike in depth jumps in which the largest increases without significance were found first in dynamic stimuli and to some extent in static. In contrast, concentric variables generally showed significant improvements in the conditioning contraction groups, with the exception of the static stimulus at countermovement jump. These facts, both phases of the jumps, can be explained by a similar neuro-muscular coordination pattern of training sessions and jump testing process (originally referring to a group of dynamic stimuli).

Some of the future papers should include some other research techniques, such as electromyography, color Doppler,... considering the great importance of neural adaptations of the CNS and peripheral nervous system that could affect muscle force, power, velocity,... Namely, the effects of post-activation performance enhancement have been attributed to vascular mechanisms, and increases in muscle temperature (responses found in a range of 5-15 minute).

Conclusion

Presented training sessions in the form of "provocation" of different types conditioning contractions (static, dynamic and combined), which are followed by significant increases in (CMJ) jumps and general increases in (DJ) jumps of eccentric phases, clearly demonstrate improvements of coordination patterns. In essence, when researching and practicing the post-activation performance enhancement (PAPE), there should be no uniform model of training and testing that could equally benefit all participants, but programmed training interventions should be tested individually and in a team, considering their advantages and disadvantages. The fact is that experts mostly strive for the situation-training process, both in team and individual sports, so the question is whether a smaller or larger sample of participants would be more important for science in sports, which should be considered in the future.

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