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Assessment of Eccentric-Concentric Exercises Applied in Different Resistances in Terms of Strength

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Abstract

The purpose of this study was to examine the effects of eccentric-concentric exercises applied at different resistances on strength parameters. Thirty-five sedentary volunteers participating in the study were divided into 4 groups by the stratified randomization method according to their mean strength parameters. These groups were named as control group (CG) (age 21.00 ± 2.44 years, height 178.13 ± 6.83 cm, body weight 80.13 ± 12.14 kg), eccentric group (EG) (age 22.22 ± 2.99 year, height 178.22 ± 5.95 cm, body weight 71.22 ± 9.36 kg), con-eccentric group (CEG) (age 21.22 ± 2.86 year, height 177.22 ± 4.68 cm, body weight 71.89 ± 13.93 kg) and modified con-eccentric group (MCEG) (age 21.67 ± 2.59 year, height 177.00 ± 4.30 cm, body weight 75.22 ± 8.16 kg). During the 8-week training period, 4 sets of leg extension exercises with different loads were applied to the training groups 3 days a week. Isokinetic strength outputs were measured both concentrically and eccentrically at 60°s^{-1} ve 180°s^{-1} angular velocities with the Cybex device. SPSS 24 package program was used in the statistical analysis of the data. For normally distributed data, paired sample t-test was used in paired comparisons, and a one-way ANOVA test was used for comparison between three or more groups. Tukey and Dunnett's T3 (non-homogeneous) test was used among the post hoc tests. Wilcoxon test (paired comparisons) and Kruskal-Wallis test were used for nonparametric data. When the intragroup comparisons were examined before and after the training period, it was found that the isokinetic strength outputs of EG, CEG, and MCEG showed a significant increase in all contractions and angular velocities ($p<0.05$), but no parameters increased in CG ($p>0.05$). When the isokinetic pre-test strength parameters between the groups were compared, no significant difference was found ($p>0.05$). While only MCEG increased significantly in 180°s^{-1} concentric strength outputs, 60°s^{-1} and 180°s^{-1} eccentric strength output increased significantly in both MCEG and EG compared to CG ($p<0.05$). As a result, when the strength tests are considered, although the general strength development is seen mostly in MKEG, no statistically significant difference was found between training groups. It is recommended to determine the load in the eccentric phases of the exercises by the eccentric 1RM (repetition maximum), at least as a result of this research, to generate more strength development rates while applying strength training.

Keywords; Eccentric, Contraction, Concentric, Strength.

INTRODUCTION

Muscle strength is one of the key factors of sportive performance, injury prevention, and physical fitness. In light of this knowledge, researchers have focused on the further development of strength (35). Muscle tissues exist in a dynamic state where proteins are synthesized and broken down alternately. Genetics, nervous system activation, environmental factors, hormonal effects, nutritional level and physical activity are listed as six factors that develop and maintain muscle mass (24). There is no doubt, that genetic factors provide the basic frame of reference that modulates each of the other factors that increase muscle strength and endurance. Muscle activity contributes little to tissue growth without the availability of proper nutrition, especially amino acids, to provide the necessary building blocks. Similarly, specific hormones (eg, testosterone, growth hormone) and nervous system innervation help model and amplify the appropriate training response (24). Without loading, each of the other factors cannot effectively produce the desired training response (29).

Loading in strength training can occur with different contractions of the muscles. These contractions can be commonly performed as concentric (CON), eccentric (ECC) or a combination of both CON/ECC (4). Recently, the physiological effects of eccentric contractions have been investigated, and as the results of these studies emerge, the application of the principles of intensity and frequency, which are among the basic scientific principles of training, gains importance. In the planning of training programs, the number of sets to be loaded is one of the most effective ways of training (10). In traditional strength training, the movements are performed first with a concentric contraction and then an eccentric contraction or vice versa. When the load applied to the muscle is higher than the force produced by the muscle, the muscle lengthens; this is called an eccentric contraction (23). Therefore, muscle forces tend to be highest during lengthening actions (4). Some studies have shown that the eccentric strength capacity can be 120–200% higher than the concentric strength capacity (1,5,8,16,17). The reason for this can be explained by the “winding filaments theory” (28). Nishikawa et al (28) suggested in their study that titin, a large protein, may be involved in the mechanics of muscle contraction, acting as an internal spring that can store and release elastic potential energy. It has been shown that actin rotates as myosin is translated during the cross-bridges cycle (27). The theory states that titin acts as a "winding filament" that is activated by the release of Ca++ and is wound onto the actin filament when rotated by myosin translation in the cross-bridges (26); therefore, it is emphasized that titin can "actively" participate in the force generation of a muscle by stiffening when the eccentric is wrapped on actin during eccentric contractions.

In traditional strength training, concentric 1RM is taken into account when determining strength intensity. Eccentric 1RM is used only in eccentric studies, and in this condition, the concentric contraction pattern is not used (20). The development expected from strength training is directly related to the load on the skeletal muscles in the exercise plan. In general, the load is determined according to the maximum concentric contraction. However, since the eccentric contraction force is higher than the concentric contraction, the exercise is limited to the concentric load. Due to differences in maximal strength capacities (1RM), fatigue levels, and potential muscle damage, it is emphasized by studies that more research needs to be done to establish appropriate training protocols for the frequency, load, and rest required for eccentric actions (20,32). Therefore, this study was to examine the effects of eccentric-concentric exercises applied at different resistances on strength parameters.

MATERIAL and METHOD

Participants

35 sedentary individuals voluntarily participated in this study. For the study, necessary permission was obtained from Selcuk University Faculty of Sport Sciences, non-interventional clinical research ethics committee (21.09.2020/63). Before the study, each of the participants was given detailed information about the risks and inconveniences that may be encountered, and the voluntary consent form was read and signed by the participants.

Inclusion criteria were in the study; being healthy, not doing exercises for 1.5 hours a day and 4 days a week or more for 12 months before the study, and not taking any medical treatment or medication or supplements that could affect the results until 3 months from the start of the study. After determining the quadriceps strength of the participants to participate in the research, groups were formed from people with similar strength averages, taking these data into account. The groups consisted of 3 different experimental groups and 1 control group.

Training Protocol

The training protocol applied to the participants participating in the study was designed using the ECC and combined contraction principles. Literature review and pre-tests were conducted to determine the severity of loading. The 1RM values of the subjects were determined and the number of repetitions of the exercises, their tempo, and the percentage of weight to be lifted was determined in the light of the pre-tests. These tests, which were made one week before the practices, provided the participants with the opportunity to recognize the leg extension device.

Table 1. Training Protocol

Group	Exercise Method	1RM%	Tempo	Number of Repetitions (up to fatigue)
EG	Eccentric	80-85	60^0 s^{-1}	8-10
CEG	Combined	80-85 (CON 1RM)	60^0 s^{-1}	4-5
MCEG	Combined	80-85(CON/ECC 1RM)	60^0 s^{-1}	4-5

EG: Eccentric contraction group, CEG: concentric and eccentric contraction group, MCEG: Modified concentric-eccentric contraction group.

1RM Measurement (Concentric and Eccentric)

Before beginning the study program, the 1RM (maximum repetition) values of the participants were determined for determining the loads. In order for the movement to be regular, the angle and technique were explained to the participants (35). The following steps were followed while determining the 1RM values. After warming up on the cycle ergometer at a rate of 60–70 rpm, standard stretching was done. Before the 1RM measurement, the weights suggested by the literature were taken into account according to the weight of the individuals. The load is increased by 5 to 10 kg after each regular weight that the participants can lift. Participants were not allowed to do more than 5 lifts as fatigue would occur. For the concentric contraction type, 1RM visual animation was followed and the concentric contraction, which they could lift once with knee extension, was recorded as 1RM, taking into account 60º s^{-1} speed tempo. eccentric 1 RM that the participant was able to do once in a controlled manner with knee extension at 60º s^{-1} speed tempo by following the visual metronome was recorded as 1 RM. During the eccentric contraction, the participant's inability to control the descent rate at any time or the completion of the movement before the expiration of 1 second was considered as an error (17).

Eccentric Strength Exercise

In order to prevent the participants from making concentric contractions in eccentric exercises, the load arm was brought to the starting point of the eccentric contraction by the assistants. The assistants followed the tempo animation while lifting the load.

Combined (Concentric + Eccentric) Strength Exercise

In the combined exercise, participants performed traditional concentric and eccentric contractions, respectively.

Modified Combined (Concentric + Eccentric) Strength Exercise

In the modified combined exercise, participants were asked to perform both concentric and eccentric contractions. Different from the traditional combined exercise, loads were applied differently according to the eccentric and concentric 1RM contraction types. With an apparatus attached to the leg extension device, the extra load to be applied during the eccentric contraction phase was placed on this apparatus by the assistants, thereby increasing the resistance and in the concentric contraction phase, this extra load was taken from the apparatus and the resistance was reduced.

Figure 1. A concentric contraction phase, B eccentric contraction phase.

Anthropometric Measurements

Height Measurement

The height of the athletes; In anatomical posture, bare feet, feet together, holding breath, head in the frontal plane, after positioning with the overhead plate touching the vertex point, the measurement was taken in 'cm' with a stadiometer (Holtain Ltd., UK) measuring ±1 mm. (33).

Body Weight Measurement

Bodyweight; It was measured in 'kg' with a scale (Tanita 401 A, Japan) that measures with ±100 g precision when the subjects were only in shorts, bare feet, and in the anatomy posture position (33).

Isokinetic Strength Measurements

Before the isokinetic strength tests, a 10-minute warm-up was done to warm up the leg muscles of the participants. Isokinetic concentric and eccentric measurements were made with Cybex NORM (Lumex Inc, Ronkonkoma, New York, USA) isokinetic dynamometer in Selcuk University Faculty of Sport Sciences kinanthropometry Laboratory.

According to the prepared exercise protocol, the highest isokinetic CON and ECC knee extension were applied in the dominant leg with 2 different motion angle speeds. According to the prepared protocol, the knee extension was performed at $60^{\circ}s^{-1}$ speed and at $180^{\circ}s^{-1}$ speed. As a result of studies carried out in similar protocols, 90 seconds of rest was given between sets (11). The best values were recorded in N/m.

Statistical Analysis

SPSS 24 package program was used for statistical analysis of the data. The mean values and standard deviations of the parameters of all subjects are given. The normal distribution of the data belonging to the research was tested with the Shapiro-Wilk test. Skewness and kurtosis values were checked for non-normally distributed data sets, and ± 2 contents were considered to be normally distributed. Paired sample t-test was used in binary variables for normally distributed data, and the one-way analysis of variance (ANOVA) was used for comparing more than 2 variables. Tukey and Dunnett's T3 (non-homogeneous) test, which is one of the post hoc tests, was used to determine which groups caused the differences. Wilcoxon Test (pairwise comparisons) and Kruskal-Wallis test were used for data that did not show normal distribution.

RESULTS

Table 2. Descriptive Statistics of Participants

Variables	Time	CG	EG	CEG	MCEG	P
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Age (year)	**Pre and post Tests**	21.00±2.44	22.22±2.99	21.22±2.86	21.67±2.59	0.800
Height (cm)	**Pre and post Tests**	178.13±6.83	178.22±5.95	177.22±4.68	177.00±4.30	0.952
Body Weight (kg)	**Pre-Test**	80.13±12.14	71.22±9.36	71.89±13.93	75.22±8.16	0.245
	Post-Test	82.13±13.83	73.22±8.54	72.56±12.23	76.56±7.76	0.230

EG: Eccentric contraction group, CEG: concentric and eccentric contraction group, MCEG: Modified concentric-eccentric contraction group, CG: Control group. Significant difference p<0.05.

When the physical values of the participants before and after the training period were compared, no statistically significant difference was found (p>0.05) (in table 2). In addition, there was no significant difference according to the comparison of the parameters between the groups (age P=0.800, height P=0.952, first test weight P=0.245, and post-test weight P=0.230).

In table 3, the strength values within the group were compared. In the table, it is stated that all strength values of EG, CEG and MCEG showed a statistically significant increase after the training periods (p<0.05). However, no significant change was found in CG strength values (p>0.05).

Table 3. Comparison of Pre-test and Post-test Isokinetic (60° s^{-1} and 180° s^{-1}) Strength Values within the Groups.

Variables Newton/m	Time	CG Mean ± SD	EG Mean ± SD	CEG Mean ± SD	MCEG Mean ± SD
	P				
60° s^{-1} Concentric	Pre Test	218.50±27.53	221.00±41.55	203.11±50.59	204.67±45.19
	Post Test	218.88±37.39	273.33±68.69	245.00±35.11	269.22±29.92
	P	0.964	**0.008**	**0.001**	**0.002**
180° s^{-1} Concentric	Pre Test	158.63±31.62	146.22±27.72	147.78±38.92	153.11±12.89
	Post Test	156.38±24.04	183.78±44.66	196.44±34.92	214.67±48.33
	P	0.759	**0.005**	**0.000**	**0.008**
60° s^{-1} Eccentric	Pre Test	252.38±39.93	259.89±67.44	257.00±27.19	236.67±35.60
	Post Test	243.13±36.84	333.56±88.24	308.11±50.93	354.11±35.60
	P	0.517	**0.002**	**0.004**	**0.000**
180° s^{-1} Eccentric	Pre Test	236.88±31.29	239.89±55.80	252.00±30.99	243.67±39.84
	Post Test	236.88±46.30	310.89±73.71	299.44±40.55	321.78±38.78
	P	1.000	**0.021**	**0.003**	**0.008**

EG: Eccentric contraction group, CEG: concentric and eccentric contraction group, MCEG: Modified concentric-eccentric contraction group, CG: Control group. Significant difference p<0.05.

Table 4. Comparison of Isokinetic (60° s^{-1} and 180° s^{-1}) Strength Values Between Groups

Variables Newton/m	Time	CG Mean ± SD	EG Mean ± SD	CEG Mean ± SD	MCEG Mean ± SD	P
60° s^{-1} Concentric	Pre Test	218.50±27.53	221.00±41.55	203.11±50.59	204.67±45.19	0.742
	Post Test	218.88±37.39	273.33±68.69	245.00±35.11	269.22±29.92	0.073
180° s^{-1} Concentric	Pre Test	158.63±31.62	146.22±27.72	147.78±38.92	153.11±12.89	0.937
	Post Test	156.38±24.04**b**	183.78±44.66**b**a	196.44±34.92**ba**	214.67±48.33**a**	**0.035**
60° s^{-1} Eccentric	Pre Test	252.38±39.93	259.89±67.44	257.00±27.19	236.67±35.60	0.706
	Post Test	243.13±36.84**b**	333.56±88.24**a**	308.11±50.93**ab**	354.11±35.60**a**	**0.003**
180° s^{-1} Eccentric	Pre Test	236.88±31.29	239.89±55.80	252.00±30.99	243.67±39.84	0.472
	Post Test	236.88±46.30**b**	310.89±73.71**a**	299.44±40.55**ab**	321.78±38.78**a**	**0.011**

EG: Eccentric contraction group, CEG: concentric and eccentric contraction group, MCEG: Modified concentric-eccentric contraction group, CG: Control group. The difference between values with different letters in the same line is significant p<0.05.

As a result of the comparison of isokinetic strength values between the groups, no statistically significant difference was found between the pre-test values (in table 4). There was a difference between the post-test values of the groups. Between the 180° s^{-1} concentric post-test values, MCEG (P=0.024) showed a significant increase compared to the control group. Between 60°s^{-1} eccentric post-test values, MCEG (P=0.002) and EG (P=0.015) showed a significant increase compared to the control group. Between the 180° s^{-1} eccentric post-test values, EG (P=0.030) and MCEG (P=0.011) showed a significant increase compared to the control group. However, no significant difference was found between the experimental groups.

DISCUSSION

In the research, the 8-week training program significantly increased the pre-test and post-test strength values of the training groups. However, the strength values of the training groups did not make a significant difference from each other after the training period. Although there was no significant difference between groups, considering the MCEG development rates, it provided more strength than the other groups.

The post-test comparison of concentric 60°s^{-1} strength values between the groups in table 4 shows that the training did not significantly increase the 60° s^{-1} concentric strength increase. However, when the change rates are considered, it is seen that CG increased 0.03%, EG increased 23.23%, CEG 24.73%, and MCEG increased 36.06%. In the study of (35), 41 recreationally active individuals (age 21.1± 1.8 years) had strength training for 12 weeks. In their study, no statistically significant difference was found between the isokinetic strength outputs of the fast (180°s-1) eccentric study groups and the combined groups training with CON-ECC. Friedmann-Bette et al. (9) performed leg strength training on 25 trained male participants (age 24.4 years) 3 days a week for 6 weeks. They divided the participants into 2 groups, ECC and ECC-CON. According to the strength measurements made at the end of the training, the concentric contraction strength did not differ significantly between the two groups. In their study, Godard et al. (12) divided the recreationally active participants into 3 different groups as the ECC group (9) ECC-CON group (9), and the control group (10) (age 22.4 years) and had them undergo strength training for 10 weeks. While there was no significant difference in terms of strength output, comparisons with the control group show a significant difference. Similar to our study, Gross et al. (13) investigated the effect of eccentric and traditional (CON-ECC) training methods on strength. Similar to our study, concentric strength outputs were found to be numerically superior in the CON-ECC (12%) group compared to EG (10%). In the study of Hortobágyi et al. (18), 48 male and female untrained individuals (age 20.0 years) had strength training done 3 days a week for 12 weeks. The groups were formed as ECC, CON-ECC, CON, and Control. In the study, 10 repetitions and 60° s-1 tempo were used. There was no statistically significant difference in concentric strength test results between strength groups. The results of these studies mentioned in the literature in the field of contractions have similarities to the 60°s1 maximum concentric strength outputs of our study. Although our study and other studies did not emphasize a significant difference between the groups, it was determined that the maximum concentric strength development rates were higher in studies with concentric and combined contractions, while it was lower in groups with only eccentric contractions.

When the 60° s-1 eccentric strength values in table 4 are examined in terms of post-tests between the groups, it is seen that the 60° s-1 eccentric force values of the EG and MCEG groups differ statistically from the control group. Blazevich et al. (2) measured the eccentric strength values of the participants (age 22.8) after the participants had strength training (tempo 30° s-1) for 10 weeks and 3 days a week for 10 weeks. While there was no significant difference between the experimental groups, the strength change rates increased by 39% in the ECC group, while it increased by 36% in the CON group. Similarly, Duncan et al. (7) found the ratio of 60°s-1 eccentric isokinetic strength to be 27.5% in the ECC group and 7.2% in the CON group. In the study of Hawkins et al. (14), some of the 30 untrained individuals had only ECC, the other part only CON, and the rest did not train. According to comparisons, knee extension strength increased significantly in the ECC group (22%) compared to the CON group (17%). In the study of Hortobágyi et al. (18), ECC, CON and CON-ECC and control groups were formed. After 12 weeks of training, the eccentric knee extension strength was determined as 86% in the ECC, 20% in the CON, and 70% in the CON-ECC group. In the study of Kaminski et al. (19), 27 untrained male individuals (mean age 22.9 years) were grouped as CON only, only ECC and control group and they applied leg strength training for 6 weeks. Although there was no statistically significant difference between the experimental groups in terms of knee extension eccentric strength outputs.

When the 180°s-1 concentric strength values were examined in terms of post-tests between the groups, it was seen that only the 180°s-1 concentric strength values of the MCEG group differed statistically from the control group. When the results are evaluated, it is seen that the strength increase rates are similar at the angular speed of 60°s-1, as well as at the angular speed of 180° s-1. In the study of Ünlü et al. (35), they trained at an angular speed of 30°s-1 in the slow eccentric group. At the end of the training, while 24.9% improvement was found at 60° s-1 angular speed, this improvement decreased to 13.5% at 180°s-1 angular speed. Duncan et al. (7) found the 180°s-1 eccentric strength development of the eccentric contraction group to be 25.1%, while the concentric strength development was found to be 1.2%. While they found the 180° s-1 eccentric strength development of the concentric contraction group to be 7.8%, they also found the concentric strength development to be 7.8%.

Most of the studies mentioned above support our study. The majority of the studies on contractions, as we found in our results, show that exercises using contraction type improve that type of contraction more. In other words, it was found that concentric exercises improved more the concentric strength outputs (2, 7, 15, 31, 34) while exercises with eccentric contractions improved the eccentric strength outputs more (3, 14, 25, 34). In a study, it was emphasized that the control of eccentric force is much higher in alpine slalom skiers, where more eccentric force is used (36). In the light of the information of this study, the contractions in the exercise used in the exercise or the sports branch affect the strength of that contraction more. Although the reason for this is not fully explained, it is thought that the neural, motor unit, and neural pathways used and the differences in hormone release may have increased their contraction strength.

Roig et al. (30) emphasized that in traditional training the intensity of eccentric exercise is well below its maximum potential when the intensity between contractions in concentric and eccentric exercise is equalized. In addition, studies in which loads of eccentric contractions are applied at the same load as concentric contractions have emphasized that growth hormone is at the same level as concentric contractions (21,22). In addition, in studies where eccentric contraction is high, the excessive mechanical load may increase the magnitude of motor unit outputs. Although the mechanisms underlying the unique neural strategies during eccentric contractions are not well understood, it is thought to likely result from a combination of supraspinal and spinal factors (6). In summary, eccentric contractions exhibit unique neural strategies compared to concentric contractions under both maximal and submaximal conditions (4). In the light of this information, the application of the ECC load according to the eccentric 1RM shows that the potential strength outputs of the muscle can be maximized as in the MCEG strength outputs. Participants in the study were informed about their nutrition during the training, but it was not taken under control. This can be cited as a limitation of our study. In the study, the experimental group was selected from male and non-sports individuals. In future studies, the effects on different experimental groups can be investigated.

CONCLUSION

In this study, the effects of different contraction types and exercise loads on eccentric and concentric strength were investigated by adjusting them according to contractions. According to this study, the modified concentric and eccentric exercise method seems to be the most effective method in improving the strength parameters of the participants.

Conflicts of Interest

The authors declare no conflict of interest.

Note

This study was produced from the doctoral thesis titled "Assessment of Eccentric-Concentric Exercises Applied in Different Resistances in Terms of Strength and Hypertrophy" published in 2021.

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