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Original article

Comparison of strength training programs with different contraction types

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Abstract. *Study Objectives:* As one of the basic motoric characteristics, strength is the capacity required for the performance and perfection of techniques in several sports branches. Optimum gain can be achieved by following proper training methods according to the characteristic of the strength that is desired to be improved particularly in the youth. In this study, the effects of strength training programs with different contraction types on the muscular force were compared. *Methods:* Thirty-six sedentary individuals between the ages of 18-26 living in the province of Konya participated in the study. The participants with similar strength averages were divided into 3 groups as Concentric (CG), Eccentric (EG), and Static (SG) based on their one-repetition maximum (1RM) strength values (the weight they lifted for once but could not lift in the second repetition) measured. Strength values of the individuals in each group were measured by performing exercises appropriate to the type of contraction. *Results:* According to the results of these measurements, a difference was found between the total contraction scores of the groups of CG, EG, and SG ($F=20.99$; $p < .01$). Accordingly, the contraction scores of CG and EG were found to be significantly higher than the contraction scores of the SG. Moreover, a positive difference was found between the pre-test and post-test scores of the participants ($F=290.23$; $p<.01$) Also, the group-by-time interaction was found to be insignificant ($F = 193.82$; $p>.0.5$). *Conclusion:* As a result, it has been concluded that KG produces more power than EG and EG produces more force than SG.

Key words: Maximal Force, Types of Contraction, Musculer Force

Introduction

Strength, which is one of the basic motor characteristics, is defined as the capacity of muscles that face a resistance to contract or withstand this resistance to a certain extent (1). The power and strength training programs are supported by weight training in many sports branches. In these programs, muscle groups are exercised using the energy system and exercise models suitable for the sports branch, and thus it is aimed to improve the performance. Strength training becomes more important particularly in sports branches that require skill (2). Strength training, which is used to improve sportive performance and muscular strength, has become crucial for endurance, hypertrophy, and building muscular strength. Moreover, it is highlighted that factors such as the speed of muscle activation, characteristics of exercise, rest periods between sets, number of sets, and their intensity should be considered for effective, safe, and beneficial training (3). In the organism that has completed its development in many aspects, particularly in males, the rate of building strength reaches the highest value; also, the load/strength ratio is observed to be better in young males. When there is an appropriate impulse, the endurance strength is also improved following the maximal strength. The period of youth is a phase in which versatile exercises involving all muscle groups can be performed by switching to specific strength training programs for the branch (4). In this period, the optimum gain can be achieved by following training methods according to the characteristic of the strength that is desired to be improved. As one of the basic motoric characteristics, strength is the capacity required for the performance and perfection of techniques in several sports branches. In this context, the present study aims to examine the effects of different contraction types on the strengths of the Concentric (CG), Eccentric (EG), and Static (SG) muscles in maximal strength training programs.

Muscle Contraction

Skeletal muscles, as can be understood from their name, bind to our skeletal system; when these muscles are subjected to any impulse, they activate our body during contraction or they can be controlled voluntarily, besides helping the skeletal system (5). Each action of the muscles is the result of various metabolic events in the neuromuscular system. The actions performed by the muscles for a specific purpose in a sport exercise are also the result of the coordination of the neuromuscular systems. A muscle contains fibrils, and a fibril contains parallel packages of many myofibrils. On the other hand, each myofibril, which is the basic contractile unit of the muscle, is formed by the linear arrangement of the sarcomere. The fibrils are connected in various ways depending on the muscles, either one after the other or side by side. Fibrils in the human body are usually activated by neural impulses in a fusillade form. When the stretched fibril is activated by quick and sufficient impulses, a summation is observed, and the tension gradually increases up to the maximum value that the fibril can reach. Muscle fibrils are structured as functional groups of different sizes. A single motor neuron and all muscle fibrils stimulated by this motor neuron are called "motor units". Motor units, which have a small number of fibrils, provide actions that require fine skills, such as those in the eyes or fingers (4).

Skeletal muscle fibrils have various structural histological, chemical, and behavioral characteristics. After stimulation, fibrils of some motor units reach maximum tension earlier than others. Based on this characteristic, the fibrils are classified into the following two groups: "fast-twitch" (FT) and "slow-twitch" (ST) fibrils. The time required for the FT fibrils to reach the peak tension and relax is approximately half of the time required for the ST fibrils. This difference is thought to be due to the higher density of myosin ATPase in FT fibers. The diameter of FT fibrils is larger than that of ST fibrils (4).

Concentric Contraction

It is a form of dynamic contraction. While the tonus, i.e. the tension, of the muscle remains constant, its length shortens. At the moment of exercise, the muscle length decreases, and a workout breaks out. Lifting a weight from the ground is a simple example of this type of contraction (6).

Static Contraction

Although it is completely a form of dynamic contraction, the muscle's tonus (tension) remains constant while its length shortens. Also, the work performed is positive since it is against gravity. Lifting a constant weight from the ground at a constant speed depends on the initial length of the muscle fibrils, the angle between the muscles and the bones (the angle of pull), and the rate of shortening. In this type of contraction, tension occurs in the elastic structure of the muscle (1,5,7). Positive mechanical work is performed in the contraction of the CG. The contraction of the arm muscles while lifting a dumbbell can be given as an example of this (6,7).

Eccentric Contraction

It is a form of dynamic contraction. The length of the muscle also increases while its tonus (tension) increases (5,8). EG contractions are performed either as elastic EG contractions (contractions performed by the athlete using less resistance than his/her resistance; for example, landing in a triple jump) and plastic EG contractions (the contraction of the athlete with more loading than his/her maximum isometric action limit) (1,7).

Strength Training Methods

Force is one of the most important biomotor abilities, and this feature can be improved by overcoming internal and external resistance, which has a key role in the athlete's training program (9). Strength training is performed by conducting a weight training program to strengthen the muscles. This program should be suitable for the requirements of the sports branch. Special muscle groups are exercised by the energy system and action patterns involved. The purpose of these exercises is to ensure that muscle groups always apply more of the force and resistance they normally apply (2). The maximal force, rapid force, and strength endurance are improved by changing the loading height, the number of repetitions, or the number of series and the application method (10)

Pyramidal Method: The maximal force, rapid force, and strength endurance of the athlete are improved by this method. The maximal strength of the athlete is determined before the training, and the intensity of the loading is adjusted accordingly. The loading pattern varies according to the number of repetitions at the end of the pyramid (For example, the loading intensity of 100-70% for 1-5 repetitions). In SG strength training, pyramidal training is applied by changing the duration of the tension (10).

Duration Method: The duration of the exercise and rest intervals are determined in advance. The athlete repeats the exercise as quickly as possible within the specified time at each station.

Repetition Method: The number of repetitions of the exercise is determined for each station. There is no rest period before passing to the next station. The time is measured for each athlete at the end of all stations. When there is a 10-20% improvement in time throughout the training program, the number of repetitions of each exercise is increased, therefore, the load also increases.

Wavy Loading Method: In this training method, the load stays constant during the exercises the number of which changes by rising and declining in a waveform. For example, the exercise repeated for 1 + 2 + 3 + 4 + 5 times with a load of 70 kg, then it is repeated for 5 + 4 + 3 + 2 + 1 times (2).

Series Method: It can be used particularly in rapid force and strength endurance training programs. As a basic principle, the loads and the number of exercises are kept constant.

Material and Methods

Participants

The study was started with the participation of 45 volunteer males between the ages of 18-26. However, 36 of these participants were included in the study after making the required evaluations about their health and physical conditions. Participants were informed in writing about the study protocol, and their informed consent forms were received.

Experimental Design

Before the study, the 1RM (the weight they lifted for once but could not lift in the second repetition) values of the participants were determined. The correct technique was explained to the participants to perform the exercise with the desired angle and technique (11). While determining 1RM values, the participants were informed before performing measurements (11), information about warming up and using the equipment was provided (12), and the participants were encouraged verbally and visually for motivation following the literature. After each successful lift, the weight was increased by 5 to 10 kg, taking into account the determined maximal force percentages. In all contraction groups, the weights that individuals could lift for once on all equipment but could not lift for the second time after 5 attempts at most (1RM values) were determined every 2 weeks during the 6-week training program. Thus, the weights used in the study were adjusted and determined again.

Following these procedures, combinations with different loading tempo and weight percentages were tried. The 1RM values of the participants were determined. Accordingly, the number of repetitions of the exercises, the tempo, and the weight percentage to be lifted were determined based on the results of the pretests. The measurements were performed following the exercise principles of CG, EG, and SG in strength training. Participants were divided into the following 3

Table 1. 1RM Measurement Protocol

	Gruplar		
Criteria	**Concentric Contraction CG (n=12)**	**Eccentric Contraction EG (n=12)**	**Static Contraction SG (n=12)**
Exercises used in the measurement	lat pull down, cable seated row, leg hamstring curl, leg calf, cable barbel biceps	leg extension curl, leg press, butterfly, push down triceps extension	leg extension curl, leg press, butterfly, push down triceps extension
Measurement interval (Once in two weeks)	1RM-1 (Before training program) 1RM-2 (At the end of the 2nd week) 1RM-3 (At the end of the 4th week) 1RM-4 (At the end of the 6th week)		

groups with similar force averages based on their 1RM force values measured: CG, EG, and SG.

In the concentric workout, the assistants held the force lever of the equipment and brought it back to its initial position after the participant lifted the weight. Care was taken for the participant not to apply force while bringing the equipment to the initial position. In the eccentric study, the force lever of the equipment was lifted by the assistants to prevent the participant from performing concentric training, and the participant was asked to return this weight to the initial position by eccentric contraction. In the static workout, the time passed until the end of the exercise was taken into account. The time was recorded when the energy of the participant, who adapted to the gradual increase in training load, ended.

Statistical analysis

In the study, the arithmetic means, standard deviations of the data obtained, and the differences between the measurements were calculated using the Repeated Measures Analysis of Variance (ANOVA) test at a significance level of p<.05. Moreover, the differences between the data, if any, were analyzed to find the parameter that caused this difference using the Tukey Test.

Results

Information on the research results is given below.

Considering Table 1, the total contraction scores of CG, EG, and SG were found to show a difference (F = 20.99; p <.01). According to these figures, contraction scores of CG and EG were found to be significantly higher than those of the contraction scores of SG. Moreover, it was determined that there was a difference between the pre-test and post-test scores of the participants (F = 290.23; p <.01). Additionally, group time interaction was found to be insignificant (F = 193.82; p> .05).

Discussion and Conclusion

In the present study, measurements were made following the strength training protocol for 6 weeks to

Tablo 2. Training protocol

Leg exercises	smith machine squat, leg press, leg extension, and leg hamstring curl
Upper extremity exercises	lat pull down, pull row, biceps brachii, triceps extension
Duration of the training program	6 weeks
Frequency of training	2 days a week
Number of exercise sets	5 sets
Method	Inverted pyramidal method

Table 1. Comparison of the pre-test and post-test scores of mean contractions of the participants in the Concentric CG, Eccentric EG, and Static SG groups

Variables	n	Pre-test	Post-test	Total		F	p
		$\bar{X}$ ± SD	$\bar{X}$ ± SD	$\bar{X}$ ± SE			
CG	12	240.83±40.39	295.00±42.48	267.92±11.60[a]		20.99	00 .01
EG	12	229.17±35.47	280.83±36.92	255.00±11.60[a]			
SG	12	141.83±34.11	198.33±54.90	170.08±11.60[b]			
Total	36	203.94±57,28	258,06±61.74				
		F=290.23; p<.01				Group-by-time interaction F=193.82; p>.05	

a, b: Different letters shows statistical difference between groups

examine the physiological results of the effects of maximal strength training on the muscular force by different contraction types. Campos et al. (2002) stated that strength training with a low number of repetitions improved maximal strength more than multi-repetitive strength training. Therefore, the tempo factor was changed to achieve exhaustion with less repetition while preparing training models in the present study. According to the literature review and the results of the pre-tests performed to determine the training models, the tempo that leads to exhaustion while performing the exercises was used in the training models. On the other hand, the studies on strength training emphasize that one of the most important variables used in planning training methods is the contraction principles. While some studies report that EG contractions improve EG muscle strength, CG contractions improve CG muscle strength, and SG muscle contractions improve SG force (13,14,15), other studies report that EG contractions improve the strength more (16). Moreover, several studies argue that CG contraction strength exercises have a much more effect on strength improvement (17). The appropriate duration for the exercise tempo of the contraction types was determined in the present study to determine which of these contraction principles causes more intense muscle strength and to compare the contraction types in terms of strength. Thus, CG, EG, and SG contraction principles were used. In the present study, 1RM values obtained by the CG, EG, and SG contractions were taken into account to determine the weights to be lifted. Also, it was reported that muscle could produce 30% more power by EG contraction compared to CG contraction (18-19). Some researchers reported that the 1RM value in EG contractions could be 150% of that of CG contractions (20). Considering the results of the first and last tests, the present study revealed that significant increases were observed in CG, EG, and SG contraction types in maximal strength training that lasted 6 weeks. Also, a significant difference was found between the total scores (F = 20.99; p <.01).

According to the measurements performed in the 1st week at the end of the 6-week program, the CG contraction exercises were found to contribute more than EG contraction exercises in the very early stages in terms of strength improvement. Also, it was revealed that there was a significant difference between the two study groups (F = 290.23; p <.01). Moreover, the CG group was observed to show a statistically significant improvement in strength in the following weeks of the training program (p <.001). Supporting the findings of the present study, several studies revealed that the strength improved significantly even in a 3-week strength training program. For example, Ingebrigtsen et al. (2009) stated that a 3-week strength training program with high weight and high tempo resulted in a 9.7% increase, while an 8.5% increase was obtained by exercises performed with high weight and low tempo. Although the researchers stated that an increase in strength could be observed within 3 weeks, they also stated that more strength improvement could be achieved by extending the strength training, particularly in the period of the preparation camps before the season. In a different study similar to our findings, Raue et al. (2005) found a 1RM increase of 19.00% at the end of a 4-week training program with CG contractions performed with 8 repetitions at 80% of the 1RM value. However, no strength improvement could be achieved after a 3-week strength training with lower weights and high speed. Although several studies report that CG training improves motor unit and strength more (13), other studies report that EG training improves muscular force and hypertrophy much more (11). According to the maximum isokinetic strength measurements at 60° sec^{-1} after a 10-week strength training, Higbie et al. (1996) stated that EG training improved EG strength more (EG strength: 34%; CG strength: 12.5%), and CG training improved KG strength more (EG strength: 5.4%; CG strength: 14.4%). On the other hand, Seger et al. (1998) performed maximum isokinetic force measurements at 60° sec^{-1} and found that the increase in EG strength was 18% in the EG group, while the increase in CG strength was 2%. Considering the results of the same study, the CG strength was found to increase by 14% in the CG group, while there was a 10% increase in the EG group. In a similar study on women, Ramirez et al. (2014) revealed that the strength training applied with a higher tempo was more effective in the improvement of both muscle strength and functional capacity compared to the strength training with a slow tempo. Munn et al. (2005) performed a 6-week strength training by applying leg extension training. According to the results of their study, they stated that strength training with a fast tempo (140° sec^{-1}) improved the strength much more compared to strength training with a slow tempo (50° sec^{-1}).

In their meta-analysis, Roig et al. (2009) stated that EG workouts would produce more total force and ensure EG strength improvement compared to the CG workouts in case the exercises were applied at high intensity. However, the results in the present study revealed that the strength improvement was higher in the CG contraction group compared to the other groups when the strength training in which CG, EG, and SG contractions were used together.

As a result, a certain improvement was found in all muscle contraction parameters after a 6-week training program. Particularly, the force generated in the CG contraction type was found to be higher than the force generated in other contraction types. This is thought to be associated with the concentric contraction when the exercise is finished at the right angle while increasing the intensity during exercise.

In the present study, strength training models with various contraction types were applied in maximal strength training programs examined to determine which contraction type produced more force for strength improvement. Accordingly, training models involving CG, EG, and SG contractions were found to be the most effective methods for strength improvement in sedentary individuals in terms of physical aspects. Statistically significant differences were found between the groups included in this study in terms of strength improvement. However, the highest strength improvement in all strength parameters was detected in the CG contraction group. According to the results of the research, no contraction type alone is recommended for a 6-week strength training program. Considering similar studies that support the present study, combined training programs are recommended to improve the muscular force. According to the results of the present study on the muscular force, a certain difference was found between the CG contraction and EG contraction groups. However, this difference was not significant. Moreover, the CG contraction group was observed to have the training model that created the most intense muscle strength. It is concluded that increasing or decreasing the frequency of training, applying these training programs for women or active athletes, or planning different muscle groups to activate the same contraction types may lead to different results.

Conflict of Interests: The authors declare that there is no conflict of interest.

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