Turkish Journal of Sport and Exercise
http://dergipark.gov.tr/tsed
Year: 2017 - Volume: 19 - Issue: 1 - Pages: 31-38

ISSN: 2147-5652

The effect of different type of exercises on the isokinetic strength of quadriceps and hamstring muscles

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Abstract

This study was conducted with the aim of investigating the effect of three different types of exercise on the isokinetic strength of quadriceps and hamstring muscles. Thirty recreational athletes aged of 23.19 years on average participated in the study. In the study, the subjects were divided into 3 groups consisting of 10 individuals (bicycle group, plyometric group, and weight group). The athletes were given 3 different exercises for 3 days and 30 minutes per week for 6 weeks. Muscular strength and endurance as was measured at a constant angular velocity of 60º/s and 180º/s and concentric quadriceps and concentric hamstring strength test were measured before and after exercises by an isokinetic dynamometer (Cybex Humac Norm-2009). The Kruskal-Wallis H test was used to determine the differences among the groups in the study, and the Mann-Whitney U test was used to determine the group that is the source of these the differences. Wilcoxon test was conducted to determine pre - test post - test differences within the groups. As a result; Weight exercises during 6 weeks provided a significant increase in parameters at NDQPT60º/s, NDQAP60º/s and NDHPT60º/s in constant angular velocity values compared to cycling exercise in the same period. In terms of other parameters, exercises done in the same time period in all three groups did not show the same significant effect on strength development.

Keywords: Bicycle, hamstring, isokinetic strength, quadriceps, plyometric.

INTRODUCTION

The concentric maximum power that a group of muscles or muscles responding toward a special tool that is previously bounded and fixed by a specific velocity is defined as the "isokinetic strength" (4). The isokinetic strength is the highest torque value that can be developed during contraction at a given speed. Isokinetically contracting muscles are faced with a resistance that is adaptable to the strengths throughout the entire range of motion, in accordance with the rule that for every action, there is an equal and opposite reaction (26).

Isokinetic evaluation can be done at different speeds to assess muscle performance at those speeds, and performance of an individual can be monitored by various objective data. The equilibrium between agonist and antagonist muscle groups can also be measured by isokinetic testing (13). It also allows the measurement of the net effect of strength produced by the lower extremity or upper extremity muscles (32).

The evaluation for isokinetic strength test gives valuable information in the process of the performance of the athletes. Isokinetic testing can be used in strength and fitness programs by documenting strength, strength, endurance and identifying specific weaknesses and imbalances. Isokinetic exercise is a valuable tool in terms of reproducibility and objectivity and development effectiveness of performance and strength (12).

Speeds between 5°-500°/s (26) or from 1°/s to about 1000°/s (10) can be achieved by various isokinetic dynamometers. The speed of the moving segment does not exceed the predetermined speed whatever the strength is applied to the isokinetic dynamometer is (26). Joint mobility range of motion is the only exercise that can be loaded at maximum capacity at each point along of the muscles (10).

The strength of quadriceps and hamstrings in the athletes can be measured isokinetic dynamometer. Isokinetic strength tests provide evaluation for the strength by allowing to test the concentric and eccentric muscle strength at a constant angular velocity. Torque peak value at low speeds (0-180º/s) can reach to the level of pure muscle strength the highest speed (>180º/s) by an intermuscular control mechanism (32).

The low torque peak/body weight ratio implies the need for more strength exercises, low total work value implies the need for repetitive exercises. Low average strength value indicates the exercises based on explosive strength (12).

The strength ratios of these muscle groups are measured to assess the strength balance among the mutual muscle groups. Studies on the Hamstring quadriceps (H / Q) force ratio provides the right decision about muscle stabilization and dynamic stabilization in the knee joint. Determination of the isokinetic strength profiles of the athletes in different branches is of great importance in terms of meeting the requirements of the branch of the athletes and maintaining the high performance of them (20).

In this study, it was aimed to determine the effect of 3 different types of exercise on the isokinetic strength of quadriceps and hamstring muscles.

MATERIALS & METHODS

Participants

Thirty male recreational athletes in total voluntarily participated in this study aged as 23.19 years on average who did not perform professional sports and actively exercised for 3 days a week for at least 2 hours. The subjects were selected from the athletes who had not experienced any neurological, audio-visual discomfort in last year and didn't have any serious injuries in the upper and lower extremities during the last six months.

Measurement

Length measurement

Length Measurements (Welch Allyn) were made while the athlete was standing in an upright position. The scale was adjusted so that the caliper sliding on the scaffold was touched on the head of the athlete and the length was read with a sensitivity within 1 mm.

Body weight

Body weight measurements were made in bascule which is a sensitive within 20-gram (Welch Allyn), with bare feet by wearing shorts only.

Isokinetic strength test

Isokinetic strength pre-tests and post-tests were performed in a sports medicine treatment room in Meram Medical Faculty Hospital Sports Medicine Hospital with an isokinetic dynamometer (Cybex, Humac Norm-2009) in the control of an expert. The first measurement for isokinetic strength tests of quadriceps and hamstring muscles was performed before the exercises and the second measurement was performed after the 6-week exercise program was finished. Before starting the isokinetic test, each athlete was warmed up by using a horizontal bike at a speed of 5 minutes and 60 rpm and through stretching exercises on quadriceps femoris hamstring muscles. First, the dominant leg was tested, then the non-dominant leg was tested. The arms of the athletes were fastened by the grips of the seat next to the arm to lower the involvement of upper extremity. Quadriceps and hamstring muscles of athletes were tested. Concentric muscle strength was measured at constant angular velocities of 60º/s and 180º/s by an isokinetic dynamometer. Torque peak, mean work, mean strength values of concentric contraction type at each angular velocity (60º/s and 180º/sec) were measured for the evaluation parameters.

Training Procedure

Cycling

Athletes in the bicycle exercise group (n=10), were doing exercises for 30 minutes in 3 times a week for 6 weeks constituting 75 % of their maximal heart rate by with the BL909D Starline brand stationary bicycle. The pulse rate of the athletes was calculated by 220 heart rate formula and the pulse interval was found and followed by the polar watch.

Plyometric exercise

Plyometric exercises were applied to the plyometric exercise group by 3 sets of 10 repetitions for the first 3 weeks, by 3 sets of 15 repetitions for the last 3 weeks. The duration of the exercise is limited to 30 minutes in total, which will be 15 seconds for each set.

Weight exercise

In the weight training group, the athletes performed the exercises as 3 sets with 10 repetitions. 80% of the maximal 1 repetitions that the athletes can lift are calculated in every week. One minute break between sets, 5 minutes break between movements was given to the participants. The duration of the exercise is limited to 30 minutes in total, which will be 30 seconds for each set.

Statistical Analysis

The statistical evaluation of the findings was performed with the SPSS 21.0 computer package program, and the arithmetic mean and standard deviation of all parameters was calculated. The

Kruskal-Wallis H test was used to determine the differences between the groups and the Mann-Whitney U test was used to determine the source group for the differences because of the insufficiency of the data (n=30). Wilcoxon test was used to determine pre-test and post-test differences within the groups. P<0.05 was considered as a significant level for the differences.

RESULTS

When the isokinetic strength values of the bicycle group were examined, the values were found to be as at 60º/s and 180º/s as constant angular velocity, when the isokinetic strength was examined, it was found that there were a significant difference as DHPT60º/s and DHAW60º/s between the pretest and post-test values (p<0.05). It was determined there was a significant difference between isokinetic strength values as NDQPT60º/s, NDQAP60º/s and NDHAW60º/s between in pre-test and post-test values of cycling group at constant angular velocity values as 60º/s and 180º/s (p<0.05). Although, when the isokinetic strength values as DHPT60º/s and DHAP60º/s were examined it was found that there were significant difference at a constant angular velocity of 60º/s for the plyometric exercise group (p<0,05), there was no statistically significant difference between pre- and post-test values in other measurements (p>0.05). There was a significant difference (p<0.05) among isokinetic strengths as DQAP60º/s, DHPT60º/s, DHAW60º/s and DHAP60º/s at a constant angular velocity of 60º/s and 180º/sec in the pre-test and post-test values of weight training group. There was a significant difference (p<0.05) among isokinetic strengths of the weight training group as NDHAW60º/s, NDHAP60º/s and NDHPT180º/s at a constant angular velocity 60º/s and 180º/s.When the isokinetic strength values were examined at fixed angular velocity as 60º/s between the groups in our study, no statistically significant difference among groups was found between the groups (p>0.05).

When the isokinetic strength values were examined at fixed angular velocity as 60º/s between the groups in our study, no statistically significant difference among groups was found between the groups (p>0.05).

It was found that there was no statistically significant difference among groups (p>0.05) when the isokinetic strength values were examined at fixed angular velocity of 180º/s between groups in our study.

Table 1. Intergroup comparisons of quadriceps-hamstring strength values of the dominant leg at a constant angular velocity of 60º/s (n=10).

Groups	Pre-test (Nm)	P	Post-test (Nm)	P
	QPT		QPT	
BG-PG	244.20±28.25 - 223.90±43.03	0.241	233.10±21.53 - 235.20±26.66	0.889
BG-WG	244.20±28.25 - 241.90±40.53	0.893	233.10±21.53 - 254.20±46.76	0.170
PG-WG	223.90±43.03 - 241.90±40.53	0.297	235.20±26.66 - 254.20±46.76	0.215
	QAW		QAW	
BG-PG	1225.60±202.19 - 1150.30±222.12	0.398	1217.30±117.95 - 1191.50±162.63	0.764
BG-WG	1225.60±202.19 - 1181.80±159.00	0.622	1217.30±117.95 - 1261.10±261.89	0.611
PG-WG	1150.30±222.12 - 1181.80±159.00	0.722	1191.50±162.63 - 1261.10±261.89	0.421
	QAP		QAP	
BG-PG	171.20±22.59 - 159.50±30.58	0.363	167.00±16.05 - 170.60±21.93	0.760
BG-WG	171.20±22.59 - 170.50±30.81	0.956	167.00±16.05 - 189.60±35.98	0.063
PG-WG	159.50±30.58 - 170.50±30.81	0.392	170.60±21.93 - 189.60±35.98	0.114
	HPT		HPT	
BG-PG	114.00±19.61 - 119.30±17.34	0.648	122.60±18.01 - 130.30±17.82	0.406
BG-WG	114.00±19.61 - 116.20±35.91	0.849	122.60±18.01 - 136.30±24.59	0.145
PG-WG	119.30±17.34 - 116.20±35.91	0.789	130.30±17.82 - 136.30±24.59	0.516
	HAW		HAW	
BG-PG	609.00±150.86 - 650.60±120.51	0.540	686.00±107.27 - 691.40±80.34	0.908
BG-WG	609.00±150.86 - 609.90±173.32	0.989	686.00±107.27 - 705.30±119.46	0.680
PG-WG	650.60±120.51 - 609.90±173.32	0.549	691.40±80.34 - 705.30±119.46	0.767
	HAP		HAP	
BG-PG	89.40±16.49 - 91.60±13.40	0.809	96.40±14.79 - 100.90±11.17	0.505
BG-WG	89.40±16.49 - 89.60±27.80	0.983	96.40±14.79 - 108.40±17.95	0.083
PG-WG	91.60±13.40 - 89.60±27.80	0.826	100.90±11.17 - 108.40±17.95	0.270

BG: Bicycle Group, PG: Plyometric Group, WG: Weight Group, QPT: Quadriceps Peak Tork, QAW: Quadriceps Average Work, QAP: Quadriceps Average Power, HPT: Hamstring Peak Tork, HAW: Hamstring Average Work, HAP: Hamstring Average Power

Table 2. Intergroup comparisons of quadriceps-hamstring strength values of the dominant leg at a constant angular velocity of 180º/s (n=10).

Groups	Pre-test (Nm)	P	Post-test (Nm)	P
	QPT		QPT	
BG-PG	158.20±22.82 - 143.10±27.46	0.170	157.60±17.91 - 150.50±24.53	0.536
BG-WG	158.20±22.82 - 152.80±21.13	0.618	157.60±17.91 - 167.80±31.67	0.376
PG-WG	143.10±27.46- 152.80±21.13	0.373	150.50±24.53- 167.80±31.67	0.138
	QAW		QAW	
BG-PG	2060.20±306.25-1876.20±343.11	0.185	2038.00±231.77 - 1943.90±327.94	0.520
BG-WG	2060.20±306.25- 1953.00±250.29	0.435	2038.00±231.77 -2114.10±389.34	0.603
PG-WG	1876.20±343.11- 1953.00±250.29	0.575	1943.90±327.94- 2114.10±389.34	0.249
	QAP		QAP	
BG-PG	273.90±40.34 - 227.40±86.75	0.092	276.50±37.46 - 261.60±42.27	0.465
BG-WG	273.90±40.34 - 263.20±38.29	0.691	276.50±37.46 - 287.90±53.50	0.575
PG-WG	227.40±86.75- 263.20±38.29	0.190	261.60±42.27- 287.90±53.50	0.202
	HAW		HAW	
BG-PG	911.30±230.56 - 977.80±195.43	0.564	914.60±154.02 - 1038.50±104.97	0.180
BG-WG	911.30±230.56 - 937.70±320.33	0.818	914.60±154.02 - 1041.30±294.30	0.170
PG-WG	977.80±195.43- 937.70±320.33	0.727	1038.50±104.97- 1041.30±294.30	0.975
	HAP		HAP	
BG-PG	131.40±30.51 - 138.90±29.43	0.651	136.40±25.50 - 144.40±15.67	0.520
BG-WG	131.40±30.51 - 134.80±47.26	0.837	136.40±25.50 - 153.00±36.94	0.188
PG-WG	138.90±29.43 - 134.80±47.26	0.804	144.40±15.67- 153.00±36.94	0.490

BG: Bicycle Group, PG: Plyometric Group, WG: Weight Group, QPT: Quadriceps Peak Tork, QAW: Quadriceps Average Work, QAP: Quadriceps Average Power, HPT: Hamstring Peak Tork, HAW: Hamstring Average Work, HAP: Hamstring Average Power

Table 3. Intergroup comparisons of quadriceps-hamstring strength values of the non-dominant leg at a constant angular velocity of 60º/s (n=10).

Groups	Pre-test (Nm)	P	Post-test (Nm)	P
	QPT		QPT	
BG-PG	232.90±32.55-231.20±41.38	0.926	213.90±25.57-233.80±28.51	0.152
BG-WG	232.90±32.55-247.30±46.26	0.433	213.90±25.57-242.00±35.51	0.047*
PG-WG	231.20±41.38-247.30±46.26	0.382	233.80±28.51-242.00±35.51	0.548
	QAW		QAW	
BG-PG	1007.50±359.28-1130.40±224.94	0.344	1107.70±133.57-1170.90±163.57	0.458
BG-WG	1007.50±359.28-1160.20±253.47	0.242	1107.70±133.57-1149.20±247.51	0.625
PG-WG	1130.40±224.94-1160.20±253.47	0.817	1170.90±163.57-1149.20±247.51	0.798
	QAP		QAP	
BG-PG	157.20±25.23-158.90±28.26	0.901	149.30±19.35-164.90±21.80	0.156
BG-WG	157.20±25.23-175.10±36.26	0.197	149.30±19.35-175.20±29.43	0.022*
PG-WG	158.90±28.26-175.10±36.26	0.242	164.90±21.80-175.20±29.43	0.344
	HPT		HPT	
BG-PG	112.20±24.14-112.50±16.38	0.978	119.70±21.16-120.80±17.20	0.899
BG-WG	112.20±24.14-118.40±28.99	0.564	119.70±21.16-137.70±19.07	0.046*
PG-WG	112.50±16.38-118.40±28.99	0.583	120.80±17.20-137.70±19.07	0.060
	HAW		HAW	
BG-PG	595.60±149.50-571.90±119.42	0.694	661.60±114.86-625.60±109.70	0.473
BG-WG	595.60±149.50-566.70±129.33	0.632	661.60±114.86-648.80±107.32	0.798
PG-WG	571.90±119.42-566.70±129.33	0.931	625.60±109.70-648.80±107.32	0.643
	HAP		HAP	
BG-PG	86.10±22.09-86.30±14.51	0.982	92.80±16.27-93.50±13.06	0.918
BG-WG	86.10±22.09-89.70±22.11	0.689	92.80±16.27-101.60±15.75	0.203
PG-WG	86.30±14.51-89.70±22.11	0.705	93.50±13.06-101.60±15.75	0.241

* $p < 0.05$; BG: Bicycle Group, PG: Plyometric Group, WG: Weight Group, QPT: Quadriceps Peak Tork, QAW: Quadriceps Average Work, QAP: Quadriceps Average Power, HPT: Hamstring Peak Tork, HAW: Hamstring Average Work, HAP: Hamstring Average Power

Table 4. Intergroup comparisons of quadriceps-hamstring strength values of the non-dominant leg at a constant angular velocity of 180º/s (n=10).

Groups	Pre-test (Nm)	P	Post-test (Nm)	P
	QPT		QPT	
BG-PG	156.00±24.88-151.10±21.36	0.699	154.20±24.80-156.50±15.66	0.831
BG-WG	156.00±24.88-160.50±35.78	0.722	154.20±24.80-162.30±29.06	0.454
PG-WG	151.10±21.36-160.50±35.78	0.460	156.50±15.66-162.30±29.06	0.591
	QAW		QAW	
BG-PG	1996.20±352.81-1961.80±322.14	0.836	1987.80±281.24-1994.30±197.44	0.958
BG-WG	1996.20±352.81-2062.00±424.05	0.693	1987.80±281.24-2020.20±319.24	0.791
PG-WG	1961.80±322.14-2062.00±424.05	0.549	1994.30±197.44-2020.20±319.24	0.832
	QAP		QAP	
BG-PG	273.20±47.26-264.70±39.90	0.725	264.40±48.05-266.80±24.75	0.903
BG-WG	273.20±47.26-275.60±68.86	0.921	264.40±48.05-277.30±52.77	0.514
PG-WG	264.70±39.90-275.60±68.86	0.652	266.80±24.75-277.30±52.77	0.595
	HPT		HPT	
BG-PG	74.10±23.41-71.40±12.26	0.769	76.90±18.74-79.90±7.27	0.703
BG-WG	74.10±23.41-71.40±23.31	0.769	76.90±18.74-83.50±22.40	0.403
PG-WG	71.40±12.26-71.40±23.31	1.000	79.90±7.27-83.50±22.40	0.647
	HAW		HAW	
BG-PG	910.90±330.99-928.30±172.53	0.888	910.40±239.42-1000.00±131.66	0.362
BG-WG	910.90±330.99-881.00±292.09	0.809	910.40±239.42-959.40±255.56	0.616
PG-WG	928.30±172.53-881.00±292.09	0.702	1000.00±131.66-959.40±255.56	0.678
	HAP		HAP	
BG-PG	131.60±43.87-128.60±21.94	0.859	132.50±32.19-142.10±15.60	0.518
BG-WG	131.60±43.87-128.70±42.58	0.864	132.50±32.19-150.00±43.98	0.242
PG-WG	128.60±21.94-128.70±42.58	0.995	142.10±15.60-150.00±43.98	0.594

BG: Bicycle Group, PG: Plyometric Group, WG: Weight Group, QPT: Quadriceps Peak Tork, QAW: Quadriceps Average Work, QAP: Quadriceps Average Power, HPT: Hamstring Peak Tork, HAW: Hamstring Average Work, HAP: Hamstring Average Power

There was a significant increase among groups ($p<0.05$) in isokinetic strength values as NDQPT60º/s, NDQAP60º/s and NDHPT60º/s at fixed angular speeds of 60º/s.

In our study, there was no significant difference among groups ($p<0.05$) when the isokinetic strength values as NDQPT180º/s, NDQAW180º/s, NDQAP180º/s, NDHPT180º/s, NDHAW180º/s and NDHAP180º/s were examined at fixed angular speeds of 180º/s.

DISCUSSION

Various studies have reported that different exercises involving different strength training develop some strength-requiring features such as squat bouncing and multiple bouncing (3, 9, 16).

It is observed that there is a significant difference among the strength values of 30 minutes cycling exercises constituting 75% of their maximal heart rate performed by cycling groups as DHPT60º/s, DHAW60º/s, NDQPT60º/s, NDHAW60º/s and NDQAP60º/s at fixed angular speeds of 60º/s, no significant difference was found for the fixed angular speeds of 180º. Six male students performed bicycle ergometer test by 90 % of VO2 max for 7 weeks, in the study of Tabata et al. (28) which supports our findings investigating the effect of endurance exercises in the high-intensity interval on isokinetic muscle strength. They reported that they did not find any significant difference in isokinetic knee extension strength values at a constant angular velocity of 180º/s. In a study of Sangnier and Tourny-Chollet (25) conducted to semi-professional footballers, no statistically significant difference was found between dominant and nondominant legs in terms of flexor peak torque values at 180 rpm angular velocity. In the same study, similar results with what have been found in this study were found that the peak torque values at both spots at 180 rpm angular speed were found to be higher than the 240 rpm angular velocity peak torque of the work done. This difference may be related to the reduction of strength values due to the increase in angular velocity.

Martinmäki (21) in another study, reported that bicycle exercises high-intensity intervals for 6 weeks provided a significant increase in knee flexion strength. Sözen (27) also examined muscle activations during cycling exercises and found a significant improvement in rectus femoris muscles which can be regarded as muscles of the lower extremity in his study supporting our findings regarding NDQPT strength increase.

Similarly, it was determined that exercises for 25-45 minutes on 3 days a week for 9 weeks at 60-85% heart rate result in a significant increase in the ratio of 4-6% for the isokinetic strength of knee extension in the research of Van Zant & Bouillon (30) investigating the effect of cycling strength training on aerobic fitness and muscle strength. Differently, Bentley et al. (5) found a decrease in 60°/s isokinetic torque peak values after 30 minutes of bicycle exercise. The reduction in quadriceps strength values in our study supports the studies reported by Lepers et al. (19) finding a decrease in muscle strength after aerobic exercises with 30 min by 80% heart rate. Takashi et al. (29) reported that knee flexor strength developed more than knee extensor muscles, resulting in muscle activity for knee extender muscles and decreased pedal peak strength at high speed (>100 rpm). It was thought that this study suggested that the group of hamstring muscle provided isokinetic strength values with an increase.

We observed a significant increase in DHPT60º/s and DHAP60º/s strength values at a constant angular velocity of 60º/s after a 30-minute plyometric exercise program conducting for 3x10 for the first 3 weeks and 3x15 for the next 3 weeks. As a matter of fact, it has been reported to increase the strength in lower extremity flexion and extensional torque peak in plyometric studies conducted by Carvalho et al. (7) by 20 male handball players. Similarly, Sağıroğlu et al. (24) reported that plyometric training resulted in an increase in knee flexion concentric isokinetic torque peak values in both dominant and nondominant legs at 60°/s. In another study, Akdeniz (1) reported that plyometric exercises continuing for 3 days a week for 8 weeks resulted in a significant increase in right quadriceps torque peak strength values at a constant angular velocity of 60º/s. Matavulj et al. (22) also found that the strength development rate of knee extensors increased after plyometric training in basketballs aged 15-16 years. According to Willigenburg et al. (32), it has been reported that hamstring muscles are able to improve take-off performance by allowing hip flexor extensibility during liftoff, providing knee stabilization during a fall.

Characteristics of phenomena in the study, such as training level, gender, age, sports activities or similarities with plyometric exercise, may differentiate the effects of plyometric exercises. The intensity of training and the duration of the program are also among the factors that change the effectiveness of plyometric exercises. Besides, according to previous studies, there is a disagreement over the ideal height of the boards for the depth jumps in order for the best use of plyometric exercises. Trainers and athletes should work out to find the appropriate height to achieve the shortest amortization phase and to maximize the jump height (32). Chu and Myer (8) reported that the height of the boards should be between 45 and 121 cm. Some researchers said that it should be less than 60 cm or more (31). Chu and Myer (8) reported that the height should be increased for quadriceps activation. Although the height of the jump boards, jumpings and in the values of the torque peak, mean work and mean power values of the muscle groups in all other values of 6 weeks of exercise time were increased, it was revealed that there is no significant difference in the post-test values statistically.

It found that the leg press, hack squat machine, leg extensions and seated leg curl exercises done by the weight training group for 30 minutes resulted in significant increase in the values of strength as DQAP60º/s, DHPT60º/s, DHAW60º/s, DHAP60º/s, NDHAW60º/s at 60º/s at constant angular velocity of 180º/s.

As a matter of fact, Brito et al. (14) studied the effect of 20-minute training program on 57 male soccer players for 9 weeks and 2 times a week. At the end of the exercise program, the concentric peak torque value of the knee extensor dominant muscle of the group performing the resistance weight program was significantly higher than the other groups. No significant difference was determined in non-dominant leg values. Nevertheless, there was a significant increase in the non-dominant muscle eccentric peak power of the complex strength group. Furthermore, Goto et al. (14) reported a significant increase in lower extremity isokinetic strength values after 4th week in the leg exercise program, which was applied with 90% of maximal repetition for 10 weeks. In another study, Akkoyunlu et al. (2) investigated the effects of squat training on the knee flexion and extension strength development in 8 weeks of different positions. and the right leg quadriceps had a mean angular velocity of 180º/s. Akkoyunlu et al. (2) found improvements in the right leg quadriceps as a mean angular velocity of 60º/s and 180º/s in their study investigating the effects of squat training on the knee flexion and extension strength development in 8 weeks of different positions. Similarly, Krisnan et al. (18) found significant differences in the strength of the quadriceps muscle in post-test measurements between the control and experimental groups in their study investigating the effect of 4-week leg extension exercises on quadriceps muscle strength. Wyatt & Edwards (33) reported that the mean of the torque values of the dominant knees was significantly higher than the mean value of the torques produced by the nondominant knee at constant angular velocities of 60-180-300º/s in their research comparing the quadriceps and hamstring torque values of male subjects aged between 25 and 34 after isokinetic exercise. This finding is important in the sense that the dominant mean torque values in our study are higher than the nondominant torque values.

In exercises, the way of the contraction determines the ability of the intramuscularly produced tension. In weight training, 1-10 repetitive sets cause a significant increase in force values (15). Resistance exercises required for maximal strength recovery of max. 1 repeat of 70-85% with 8-12 repetitions are the best ones in which both concentric and eccentric muscle action are benefited from (17). The muscular efficiency is increased both by gravity and by the effect of the machine being worked during eccentric contraction (6). For this reason, eccentric phases of exercises are thought to cause a significant increase in hamstring muscles. There is thought to be a significant increase in both quadriceps mean power values applied at 80% density, dominant-nondominant hamstring strength values of 60º/s and nondominant hamstring torque peak values of 180º/s because of the reason for the 3x10 re-selection of the weight exercises in our study. Rahimi & Behpur (23) reported that if strength training programs are maintained at the appropriate intensity and severity, plyometric and weight training for 6 weeks and/or 2 days per week may be sufficient to improve muscle strength and vertical jumps.

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