Original Article

JER

https://doi.org/10.12965/jer.2346236.118

Journal of Exercise Rehabilitation 2023;19(4):228-236

Effect of contraction type at varying angular velocities on isokinetic muscle strength training

Bihter Akınoğlu[1,*], Büşra Paköz[2], Ayfer Ezgi Yilmaz[3], Salman Usman Shehu[1], Tuğba Kocahan[4]

[1]Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Ankara Yıldırım Beyazıt University, Ankara, Turkey
[2]Center of Athlete Training and Health Research, Department of Health Services, Sports General Directorship, The Ministry of Youth and Sports, Ankara, Turkey
[3]Department of Statistics, Faculty of Science, Hacettepe University, Beytepe, Ankara, Turkey
[4]Department of Sports Medicine, Gülhane Faculty of Medicine, Health Sciences University, Ankara, Turkey

The aim of this study is to determine whether concentric and eccentric isokinetic training performed at certain angular velocities in sedentary individuals is effective only in the angular velocities and contraction type where the training is performed, or at other angular velocities and contraction types that are not being trained. Twenty-eight sedentary individuals (matched according to weight, age and gender) volunteered to participate in this case study. The study was conducted on a total of 56 extremities belonging to 28 individuals (14 women, 14 men) aged between 24 and 60 years. Concentric and eccentric strength tests were performed at 30-60-90-120-150-180°/sec. The participants were randomly divided into two groups as concentric training group and eccentric training group, through stratified randomization matching. The training was done 3 days a week for a total of 6 weeks. At the end of the study, no difference was found between the pre- and posttraining measurements in the concentric training group ($P>0.05$). In the eccentric training group, the eccentric muscle strength of the knee flexors and extensors at angular velocity of 90°/sec, the eccentric strength of the knee extensors at angular velocity of 120°/sec, and the eccentric muscle strength of the knee flexors at angular velocity of 180°/sec were found to be different and an increase was seen after the training ($P=0.032$, $P=0.049$, $P=0.041$, $P=0.032$). These results demonstrate that eccentric training may be preferred in cases where muscle strength increase is needed in short time.

Keywords: Isokinetic, Training, Eccentric, Concentric, Angular velocity

INTRODUCTION

Strength can be defined as the neuromuscular ability to overcome internal and external resistances (Suchomel et al., 2018). Isometric, isotonic and isokinetic exercises are used to improve muscle strength (Park et al., 2020; Tseng et al., 2020). In isokinetic exercises, contraction occurs at a constant rate throughout the range of motion, and since the contraction can be at maximal strength at every angle of motion, it allows the growth of maximum tension (Douglas et al., 2017; Ivy et al., 1981; Park et al., 2020). The most important feature that distinguishes isokinetic exercises from other exercises is that they provide a dynamic load to the muscle at every point of the range of motion (Douglas et al., 2017; Ivy et al., 1981; Schoenfeld et al., 2017). It has been shown that with isokinetic exercises, using different angular velocities and different contraction types, significant increases in functional performance and muscle strength are achieved, and increase in power and/or hypertrophy is induced (Roig et al., 2009; Schoenfeld et al., 2017).

Based on the theory of velocity specificity, isokinetic resistance training enables power gains from slow angular velocities to high angular velocities (Akima et al., 1999). These power gains are velocity-specific, and isokinetic training has been reported to increase maximum torque at and near the velocity being trained (Bell and Wenger, 1992; Lesmes et al., 1978; Vieira et al., 2018). It has been suggested that the mechanisms underlying velocity-specific training may be due to neural adaptation and/or muscle components (Isner-Horobeti et al., 2013; Lee et al., 2018).

Isokinetic training can be applied with both concentric and ec-

*Corresponding author: Bihter Akınoğlu https://orcid.org/0000-0002-8214-7895
Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Ankara Yıldırım Beyazıt University, Ankara 06760, Turkey
Email: rgkardelen@yahoo.com
Received: May 22, 2023 / Accepted: June 12, 2023

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (https://creativecommons.org/licenses/by-nc/4.0/) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

centric components. When the muscle produces force during concentric contraction; the length of the muscle becomes shorter and the joint angle decreases, while when the muscle produces force during eccentric contraction; the length of the muscle increases and the joint angle increases (Handford et al., 2022; Isner-Horobeti et al., 2013). The tension force in the muscle in eccentric contraction is higher than the tension force in the concentric contraction (Isner-Horobeti et al., 2013). It has been proved that concentric training increases concentric muscle strength and eccentric training increases eccentric muscle strength (Duncan et al., 1989; Ryan et al., 1991).

Also, there are studies in the current literature showing that angular velocity and contraction type are important in isokinetic strength training (Bishop et al., 1991; Harris-Love et al., 2021; Roig et al., 2009; Tomberlin et al., 1991). However, we could not find any study that revealed this information in a single study, and also none of these studies explored or expanded on the effect of contraction type at varying speeds on isokinetic strength training. Therefore, our study aims to determine whether concentric and eccentric isokinetic training performed at certain angular velocities in sedentary individuals is effective only in the angular velocities and contraction type in which the training is performed, or at other angular velocities and contraction types are not being trained.

MATERIALS AND METHODS

Participants

Twenty-eight sedentary individuals (matched according to weight, age and gender) volunteered to participate in this case study. Sample size was estimated using the Cochran formula for a cross-sectional study using the following parameters; (N = 1,000,000, *P* = sample rate 12.5%, Z = 1.64% at 90% confidence level, e = margin of error ± 10%). The study was conducted on a total of 56 extremities belonging to 28 individuals aged between 24 and 60 years. 50% of the individuals participating in the study were females and the other 50% were males. The participants were divided into two groups, concentric and eccentric group (concentric group = 31.93 ± 8.83 years, 67.29 ± 17.42 kg, 166.71 ± 9.35 cm; and eccentric group = 33.00 ± 10.26 years, 70.92 ± 15.22 kg, 172.62 ± 12.93 cm). Inclusion criteria for the participants; not having any known systemic problems, not having any lower extremity injury in the past 6 months, not having undergone any surgical operation on the lower extremity, and volunteering to participate in the study. Exclusion criteria; not meeting the inclusion criteria, doing sports regularly and using supplements. All participants were apparently healthy and declared that they were free from any chronic disease or orthopedic injury. Participants were not allowed to perform any vigorous physical activities, participate in unaccustomed exercise, take medications, or consume any type of supplement 48 hr prior to testing and during the treatment. Ankara Yıldırım Beyazıt University Social and Humanities Ethics Committee provided ethical approval for this study (2019/240/29).

Firstly, the individuals were educated about the tests and consent forms were signed. Concentric isokinetic muscle strength tests of the knee joint were performed on the same day, and the birth dates, heights, and body weights of the individuals were recorded. The next day, knee joint eccentric isokinetic muscle strength test was performed. After concentric and eccentric strength tests were performed, individuals were randomly divided into two groups as concentric training group and eccentric training group through stratified randomization matching.

Isokinetic muscle strength evaluation

Isokinetic muscle strength was evaluated using the IsoMed 2000 (D.&R. Ferstl GmbH, Hemau, Germany) device. Before each test, the device was calibrated according to the procedures set by the company. Also before starting the test, the athletes were given a warm-up exercise on a reciprocal bicycle ergometer at 60 rpm for 10 min. The tests were performed in sitting position. While evaluating the isokinetic muscle strength of the participants, the device's shoulder apparatus was used on the shoulders, and stability bands over the waist and distal femur for stability as recommended by the company. The lateral condyle of the femur was adjusted to be the pivot point. During the tests, the participants were motivated and encouraged verbally. The strength of the knee flexor and extensor muscles at 30-60-90-120-150-180°/sec was evaluated in concentric and eccentric contraction types. Three repetitions of warm-up and movement education were performed before each movement and velocity. One-min rest was given between each set repetition and angular velocity, and 3 min when switching from one leg to the other. Evaluations were made on 2 different days with concentric contraction on the first day and eccentric contraction on the second day. The same evaluation protocol was applied for both contraction types. In the evaluation result; separate peak torque values were recorded for knee flexor and extensor muscles' concentric and eccentric contraction types and each angular velocity.

Isokinetic stength training

IsoMed 2000 (D.&R. Ferstl GmbH) device was used for isokinetic muscle strength training of the individuals. Individuals re-

ceived isokinetic training 3 days a week for a total of 6 weeks. Treatment days were set at least a day apart from each other. Concentric strengthening training was given to one group (concentric training group), and eccentric strengthening training was given to the other group (eccentric strengthening group) according to age, body weight and gender parameters set through stratified randomization. Strength training was performed with a protocol of 3 sets of 10 repetitions at 60°/sec angular velocity, and 3 sets of 15 repetitions at 180°/sec angular velocity (Bernárdez-Vázquez et al., 2022).

Statistical analysis

The data obtained from the study was evaluated with the IBM SPSS Statistics ver. 23.0 (IBM Co., Armonk, NY, USA). Mean, standard deviation, and median were taken as measurement values. The Shapiro–Wilks test was used to determine whether the data showed normal distribution at variable levels, and the Levene test to investigate the equality of variances. In order to test the homogeneity of the individuals, it was examined whether there was a difference between the training types in terms of personal characteristics and baseline measurements. Pearson chi-square test was used to determine whether there was a difference between genders in terms of training type. For quantitative variables, the independent samples *t*-test was used in normally distributed groups, and the Mann–Whitney *U*-test for nonnormally distributed groups. To check whether there was a difference between the before and after measurements of individuals, the dependent samples *t*-test was used in normally distributed groups, and the Wilcoxon matched-pairs test in nonnormally distributed groups. The results were

Table 1. Comparison of pretraining measurements according to contraction types

Variable	Concentric (n=28)		Eccentric (n=28)		*P*-value
	Mean±SD	Median	Mean±SD	Median	
Age (yr)	31.93±8.83	28.50	33.00±10.26	28.00	0.781‡
Height (cm)	166.71±9.35	163.50	172.62±12.93	170.00	0.040†,‡
Weight (kg)	67.29±17.42	65.00	70.92±15.22	65.00	0.212‡
BMI (kg/m^2)	23.88±3.72	23.11	23.56±2.25	22.96	0.945‡
C_30FLPTW	1.13±0.35	1.06	1.10±0.25	1.08	0.721†
C_30EXPTW	2.10±0.74	1.90	1.93±0.82	2.05	0.417†
C_60FLPTW	1.03±0.35	0.93	1.02±0.30	1.03	0.905†
C_60EXPTW	2.01±0.66	1.92	2.03±0.59	2.08	0.929†
C_90FLPTW	0.91±0.30	0.86	0.89±0.27	0.91	0.746†
C_90EXPTW	1.85±0.60	1.73	1.68±0.67	1.78	0.340†
C_120FLPTW	0.85±0.27	0.80	0.82±0.30	0.81	0.744†
C_120EXPTW	117.17±53.81	93.20	121.67±61.87	109.25	0.674‡
C_150FLPTW	0.76±0.26	0.70	0.75±0.26	0.73	0.865†
C_150EXPTW	1.49±0.46	1.43	1.44±0.54	1.54	0.707†
C_180FLPTW	0.74±0.23	0.74	0.68±0.30	0.66	0.484†
C_180EXPTW	99.29±45.74	78.35	95.08±51.83	80.80	0.714‡
E_30FLPTW	2.37±0.78	2.21	2.18±0.76	2.24	0.545‡
E_30EXPTW	1.29±0.37	1.28	1.08±0.41	1.01	0.048†
E_60FLPTW	2.57±0.75	2.45	2.18±0.71	2.30	0.073‡
E_60EXPTW	1.32±0.38	1.28	1.08±0.37	1.02	0.021†,‡
E_90FLPTW	2.53±0.72	2.47	2.25±0.73	2.28	0.148†
E_90EXPTW	1.28±0.34	1.27	1.11±0.39	1.02	0.082†
E_120FLPTW	2.59±0.76	2.54	2.38±0.79	2.45	0.334†
E_120EXPTW	1.28±0.33	1.26	1.15±0.41	1.17	0.230†
E_150FLPTW	2.57±0.70	2.43	2.34±0.74	2.47	0.242†
E_150EXPTW	1.25±0.29	1.27	85.31±36.77	71.75	0.228†
E_180FLPTW	2.53±0.68	2.43	1.13±0.41	1.15	0.321†
E_180EXPTW	1.20±0.30	1.18	2.33±0.80	2.43	0.471†

SD, standard deviation; BMI, body mass index; C, concentric; E, eccentric; FL, flexion; EX, extension; PT, peak torque; PTW, peak torque/body weight.
$P<0.05$, statistically significant differeneces. †Independent two samples *t*-test. ‡Mann–Whitney *U*-test result.

https://doi.org/10.12965/jer.2346236.118

evaluated at the 0.05 significance level.

RESULTS

There was no significant difference found between the training types of the individuals included in the study in terms of gender ($P = 0.777$). The baseline measurements of the participants according to their training types are summarized in Table 1. No significant difference was determined between those with concentric and eccentric training in terms of age, body weight and body mass index ($P = 0.781$, $P = 0.212$, $P = 0.943$). The height of the individuals in the eccentric group was higher than those in the concentric group ($P = 0.040$) (Table 1). The pretraining peak torque of the extensor muscles at angular velocity of 30 and 60°/sec between those who received concentric and eccentric training was found to be different, being more in the concentric group ($P = 0.048$, $P = 0.021$). These two measurements were found to be higher in the concentric group than in the eccentric group. No difference was seen between the two groups in terms of other measurements ($P > 0.05$) (Table 1).

The difference between pre- and posttraining measurements of the concentric and eccentric training groups were analyzed, and the results were summarized in Tables 2 and 3, respectively. There was no difference between pre- and posttraining measurements in the concentric training group ($P > 0.05$) (Table 2). In the eccentric training group, the pre- and posttraining eccentric muscle strength of the knee flexors and extensors at angular velocity of 90°/sec, the eccentric strength of the knee extensors at angular velocity of 120°/sec, and the eccentric muscle strength of the knee flexors at angular velocity of 180°/sec were found to be different and showed increase after the training ($P = 0.032$, $P = 0.049$, $P = 0.041$, $P = 0.032$). There was no difference between the other pre- and posttraining measurements in the eccentric training group ($P > 0.05$) (Table 3).

DISCUSSION

The aim of the study is to determine whether concentric and eccentric isokinetic training performed at certain angular velocities in sedentary individuals is effective only in the angular velocities and contraction type in which the training is performed, or at other angular velocities and contraction types that are not being trained. In the result of the study, it was concluded that 6 weeks of concentric training did not increase concentric and eccentric isokinetic muscle strength, while 6 weeks of eccentric training increased the eccentric muscle strength of knee flexors and extensors at angular velocity of 90°/sec, eccentric strength of knee extensors at angular velocity of 120°/sec, and eccentric muscle strength of knee flexors at angular velocity of 180°/sec but did not increase concentric muscle strength.

In a study investigating the effect of isokinetic strength training

Table 2. Comparison of pre- and postmeasurements in the concentric group

Variable	Pre		Post		*P*-value
	Mean ± SD	Median	Mean ± SD	Median	
C_30FLPT	78.25 ± 32.81	69.00	84.29 ± 33.15	82.30	0.821†
C_30FLPTW	1.13 ± 0.35	1.06	1.13 ± 0.32	1.10	0.908†
C_30EXPT	146.23 ± 64.82	119.20	165.55 ± 64.84	138.90	0.548†
C_30EXPTW	2.10 ± 0.74	1.90	2.19 ± 0.51	2.09	0.748†
C_ FL_EXRATIO30	55.33 ± 12.36	52.55	51.83 ± 9.90	50.80	0.240†
C_60FLPT	72.63 ± 33.13	63.35	78.69 ± 33.32	71.80	0.653†
C_60FLPTW	1.03 ± 0.35	0.93	1.05 ± 0.32	0.94	0.743†
C_60EXPT	140.02 ± 60.25	110.80	161.08 ± 63.52	136.30	0.408†
C_60EXPTW	2.01 ± 0.66	1.92	2.12 ± 0.47	2.03	0.526†
C_ FL_EXRATIO60	52.54 ± 11.90	51.35	49.67 ± 11.14	46.30	0.384†
C_90FLPT	64.12 ± 29.27	59.00	70.59 ± 29.24	67.30	0.665†
C_90FLPTW	0.91 ± 0.30	0.86	0.94 ± 0.29	0.87	0.776†
C_90EXPT	128.95 ± 56.35	106.10	148.30 ± 55.24	115.60	0.375†
C_90EXPTW	1.85 ± 0.60	1.73	1.97 ± 0.43	1.92	0.399†
C_ FL_EXRATIO90	50.37 ± 9.62	51.40	48.06 ± 10.54	44.90	0.247†
C_120FLPT	59.60 ± 27.22	48.65	65.54 ± 27.28	53.40	0.605†

(*continued*)

Table 2. Comparison of pre- and postmeasurements in the concentric group (Continued)

Variable	Pre		Post		*P*-value
	Mean±SD	Median	Mean±SD	Median	
C_120FLPTW	0.85±0.27	0.80	0.87±0.25	0.79	0.691†
C_120EXPTW	117.17±53.81	93.20	135.66±54.27	101.80	0.327†
C_120EXPT	1.67±0.55	1.58	1.79±0.43	1.67	0.331†
C_ FL_EXRATIO120	52.26±10.15	53.40	48.95±8.78	48.90	0.243†
C_150FLPT	53.59±25.26	42.95	61.49±28.13	50.40	0.513†
C_150FLPTW	0.76±0.26	0.70	0.81±0.26	0.76	0.572†
C_150EXPT	104.37±47.07	79.10	122.76±50.90	93.60	0.310†
C_150EXPTW	1.49±0.46	1.43	1.62±0.40	1.56	0.311†
C_ FL_EXRATIO150	51.98±10.79	51.05	50.57±11.11	50.30	0.679†
C_180FLPT	51.91±24.18	42.75	59.64±23.25	50.10	0.413†
C_180FLPTW	0.74±0.23	0.74	0.79±0.19	0.73	0.391†
C_180EXPTW	99.29±45.74	78.35	111.42±40.75	92.10	0.451†
C_180EXPT	1.41±0.45	1.43	1.49±0.35	1.43	0.447†
C_ FL_EXRATIO180	53.24±9.67	52.85	54.70±11.63	51.90	0.877†
E_30FLPT	164.10±64.89	158.10	198.10±64.10	176.10	0.263†
E_30FLPTW	2.37±0.78	2.21	2.68±0.78	2.60	0.339†
E_30EXPT	89.90±32.98	91.85	101.12±37.14	91.30	0.532†
E_30EXPTW	1.29±0.37	1.28	1.36±0.41	1.33	0.742†
E_ FL_EXRATIO30	189.65±56.64	180.80	204.19±51.80	210.50	0.095†
E_60FLPT	178.60±67.56	170.00	198.13±60.72	188.40	0.683†
E_60FLPTW	2.57±0.75	2.45	2.69±0.74	2.63	0.886†
E_60EXPT	91.79±34.23	96.35	107.09±42.17	109.30	0.416†
E_60EXPTW	1.32±0.38	1.28	1.43±0.43	1.34	0.535†
E_ FL_EXRATIO60	205.96±66.95	200.85	194.88±47.94	193.20	0.555‡
E_90FLPT	175.96±65.49	161.00	199.36±61.54	191.40	0.495†
E_90FLPTW	2.53±0.72	2.47	2.69±0.65	2.73	0.624†
E_90EXPT	88.61±31.32	88.85	106.05±46.62	93.90	0.520‡
E_90EXPTW	1.28±0.34	1.27	1.41±0.42	1.30	0.229†
E_ FL_EXRATIO90	208.09±66.45	199.60	198.96±50.55	202.70	0.908†
E_120FLPT	179.12±66.07	180.35	200.89±62.27	197.40	0.539†
E_120FLPTW	2.59±0.76	2.54	2.70±0.59	2.53	0.789†
E_120EXPT	88.61±31.74	93.50	101.53±42.92	91.60	0.393†
E_120EXPTW	1.28±0.33	1.26	1.35±0.35	1.23	0.702‡
E_ FL_EXRATIO120	211.33±61.98	194.05	206.94±50.18	196.60	0.945†
E_150FLPT	177.80±63.02	164.60	196.80±58.69	194.80	0.619†
E_150FLPTW	2.57±0.70	2.43	2.65±0.59	2.71	0.849†
E_150EXPT	85.86±27.28	85.45	101.10±39.83	93.90	0.498‡
E_150EXPTW	1.25±0.29	1.27	1.34±0.31	1.27	0.347†
E_ FL_EXRATIO150	213.66±58.86	217.90	201.87±44.67	196.00	0.640†
E_180FLPT	175.08±62.45	180.75	193.33±61.12	174.60	0.740†
E_180FLPTW	2.53±0.68	2.43	2.63±0.63	2.62	0.656†
E_180EXPT	82.59±27.83	83.00	97.25±41.33	86.40	0.231†
E_180EXPTW	1.20±0.30	1.18	1.28±0.34	1.20	0.298†
E_ FL_EXRATIO180	213.26±51.13	212.50	207.70±49.63	192.10	0.711†

SD, standard deviation; C, concentric; E, eccentric; FL, flexion; EX, extension; PT, peak torque; PTW, peak torque/body weight; FL/EXRATIO, flexion extension ratio.
†Independent two samples *t*-test. ‡Mann–Whitney *U*-test result.

https://doi.org/10.12965/jer.2346236.118

Table 3. Comparison of pre- and postmeasurements in the eccentric group

Variable	Pre		Post		*P*-value
	Mean±SD	Median	Mean±SD	Median	
C_30FLPT	83.68±33.01	73.65	77.29±29.79	79.30	0.668†
C_30FLPTW	1.10±0.25	1.08	1.04±0.25	1.08	0.713†
C_30EXPT	146.95±81.66	127.60	156.50±67.91	138.60	0.682†
C_30EXPTW	1.93±0.82	2.05	2.18±0.64	2.08	0.323†
C_FL_EXRATIO30	57.83±31.76	49.90	49.36±8.06	50.60	0.959‡
C_60FLPT	80.08±33.60	75.35	70.99±29.74	67.30	0.480†
C_60FLPTW	1.02±0.30	1.03	1.00±0.32	1.07	0.978†
C_60EXPT	142.01±75.70	123.20	152.68±62.70	135.90	0.598†
C_60EXPTW	2.03±0.59	2.08	2.13±0.57	2.12	0.823†
C_FL_EXRATIO60	70.76±53.25	50.30	46.33±7.82	46.00	0.282†
C_90FLPT	65.35±28.95	59.85	65.71±28.95	62.80	0.812†
C_90FLPTW	0.89±0.27	0.91	0.89±0.28	0.86	0.740‡
C_90EXPT	130.07±68.25	114.50	140.48±61.55	111.60	0.599†
C_90EXPTW	1.68±0.67	1.78	1.96±0.58	1.91	0.175†
C_FL_EXRATIO90	53.48±27.95	46.20	47.18±7.77	46.15	0.569†
C_120FLPT	63.03±29.38	56.80	64.69±29.13	53.80	0.685†
C_120FLPTW	0.82±0.30	0.81	0.90±0.29	0.87	0.573‡
C_120EXPTW	121.67±61.87	109.25	133.07±60.63	101.80	0.533†
C_120EXPT	1.57±0.61	1.61	1.85±0.56	1.72	0.150†
C_FL_EXRATIO120	54.18±26.27	47.90	49.99±7.15	50.20	0.967†
C_150FLPT	56.39±23.04	52.60	60.05±29.14	46.20	0.583†
C_150FLPTW	0.75±0.26	0.73	0.83±0.28	0.77	0.277†
C_150EXPT	110.62±54.15	95.75	118.19±52.92	89.10	0.588†
C_150EXPTW	1.44±0.54	1.54	1.64±0.47	1.65	0.183†
C_FL_EXRATIO150	53.72±27.10	45.80	51.72±10.58	50.55	0.567†
C_180FLPT	51.62±25.16	46.95	58.37±28.33	50.10	0.525†
C_180FLPTW	0.68±0.30	0.66	0.81±0.26	0.74	0.253†
C_180EXPTW	95.08±51.83	80.80	108.38±49.14	84.60	0.461†
C_180EXPT	1.23±0.51	1.27	1.50±0.42	1.48	0.092†
_FL_EXRATIO180	55.78±22.40	49.70	54.21±11.68	54.40	0.819†
E_30FLPT	165.71±73.83	148.85	183.11±71.57	164.10	0.504†
E_30FLPTW	2.18±0.76	2.24	2.59±0.85	2.58	0.171‡
E_30EXPT	81.95±38.41	71.75	91.14±37.54	89.80	0.479†
E_30EXPTW	1.08±0.41	1.01	1.27±0.37	1.36	0.180†
E_FL_EXRATIO30	206.78±42.97	207.80	216.09±78.18	211.00	0.765†
E_60FLPT	165.67±68.06	149.60	189.36±70.27	189.90	0.393†
E_60FLPTW	2.18±0.71	2.30	2.67±0.79	2.71	0.065†
E_60EXPT	82.04±35.22	70.85	97.13±42.93	93.90	0.316†
E_60EXPTW	1.08±0.37	1.02	1.35±0.42	1.28	0.063†
E_FL_EXRATIO60	206.35±45.51	208.90	214.67±90.01	209.30	0.922†
E_90FLPT	171.24±73.97	150.50	204.15±84.14	189.60	0.291†
E_90FLPTW	2.25±0.73	2.28	2.84±0.76	2.92	0.032*,†
E_90EXPT	83.28±35.40	70.85	99.83±47.31	91.60	0.237†
E_90EXPTW	1.11±0.39	1.02	1.38±0.43	1.32	0.049*,†
E_FL_EXRATIO90	210.67±47.28	207.15	224.37±88.44	216.10	0.883†
E_120FLPT	180.11±71.76	167.45	201.83±80.46	197.10	0.507†

(*continued*)

Table 3. Comparison of pre- and postmeasurements in the concentric group (Continued)

Variable	Pre		Post		*P*-value
	Mean±SD	Median	Mean±SD	Median	
E_120FLPTW	2.38±0.79	2.45	2.80±0.69	2.94	0.119†
E_120EXPT	86.67±34.30	79.10	97.72±42.95	83.10	0.243†
E_120EXPTW	1.15±0.41	1.17	1.35±0.37	1.33	0.041*,†
E_FL_EXRATIO120	214.35±55.02	207.45	220.35±76.98	218.50	0.641†
E_150FLPT	176.74±70.08	161.80	183.21±81.60	179.80	0.742†
E_150FLPTW	2.34±0.74	2.47	2.63±0.92	2.82	0.223†
E_150EXPT	85.31±36.77	71.75	87.95±38.63	81.90	0.512†
E_150EXPTW	1.13±0.41	1.15	1.26±0.45	1.35	0.163†
E_FL_EXRATIO150	216.06±55.64	202.90	221.94±75.53	211.30	0.795†
E_180FLPT	174.62±70.06	151.85	206.81±82.79	203.80	0.203†
E_180FLPTW	2.33±0.80	2.43	2.85±0.69	2.92	0.032*,†
E_180EXPT	86.23±38.98	73.10	94.84±43.52	87.60	0.397†
E_180EXPTW	1.13±0.39	1.17	1.30±0.37	1.31	0.091†
E_FL_EXRATIO180	211.38±56.29	198.55	233.53±80.36	236.10	0.675†

SD, standard deviation; C, concentric; E, eccentric; FL, flexion; EX, extension; PT, peak torque; PTW, peak torque/body weight; FL/EXRATIO, flexion extension ratio.
*$P<0.05$. †Independent two samples *t*-test. ‡Mann–Whitney *U*-test result.

on strength; The subjects were divided into three groups, a group trained with slow angular velocity (60°/sec), another group trained with fast angular velocity (240°/sec), and a control group. Training was performed in the slow and fast angular velocity groups for 2 days, while no training was applied in the control group. Difference was seen in slow angular velocities of the slow angular velocity group and in fast angular velocities of the fast angular velocity group (Brown and Whitehurst, 2003). In a study conducted by examining the effect of isolated concentric and eccentric trainings on quadriceps strength in healthy individuals, it was stated that eccentric muscle strength increased in the eccentric training group and concentric muscle strength increased in the concentric training group (Duncan et al., 1989). In the result of this study, it was determined that there was no difference between pre- and posttraining measurements in the concentric training group, and that 6-week concentric training was not effective in increasing concentric and eccentric muscle strength.

In this circumstance, we think that it is due to the fact that the isokinetic training was performed for 6 weeks, and the 8-week training which is the adaptation process of muscle strength increase, was not completed (Westcott et al., 2009). There are many studies and evidences in the literature that isokinetic concentric training increases isokinetic concentric muscle strength, and the training period widely adopted by these studies is ≥8 weeks (Farthing and Chilibeck, 2003; Wan et al., 2021). In a study conducted on 30 individuals randomly divided into eccentric and concentric groups, it was found that 6 weeks of quadriceps isokinetic eccentric training at 60°/sec angular velocity resulted in higher eccentric peak torque at training velocity, while no significant difference was seen in concentric strength (Sharma et al., 2022).

In a study comparing eccentric (Nordic hamstring) and concentric (Hamstring curl) hamstring strength training, individuals were divided into 2 groups as concentric training group and eccentric training group. In the result of 10 weeks training, an 11% increase in eccentric hamstring torque measured at 60°/sec was found in the Nordic Hamstring group, while no change was observed in the Hamstring Curl group (Mjølsnes et al., 2004). At the same time in this study, an increase was found in the pre- and posttraining eccentric muscle strength of knee flexor and extensors at angular velocity of 90°/sec, the eccentric muscle strength of knee extensors at angular velocity of 120°/sec, and the eccentric muscle strength of knee flexors at angular velocity of 180°/sec in the eccentric group. This suggests that perhaps eccentric training can provide muscle strength increase in a shorter time. The results of our study are in agreement with the results of a study in which for 5 weeks, 2 days a week, compared the effects of concentric and eccentric, concentric-only, and eccentric-only exercises on muscle strength and hypertrophy of elbow flexors.

In the study, they stated that eccentric exercises increase muscle strength and thickness similar to the combination of concentric and eccentric exercises despite half the exercise volume, suggesting that concentric contractions contribute little to the training effects (Sato et al., 2022). However, in this circumstance we think that there is a need for follow-up on these studies. There are many stud-

https://doi.org/10.12965/jer.2346236.118

ies found in the literature on training with isokinetic dynamometers (Roig et al., 2009). In these studies, it is stated that eccentric training may be used especially after injuries (Bishop et al., 1991; Tseng et al., 2020). Nevertheless, the number of studies indicating eccentric training to increase muscle strength is limited and no studies has been found shedding light on the time it takes to increase muscle strength. In this study, it arrives to the conclusion that 6 weeks of eccentric training ensures an increase in strength.

In this study, the fact that the pretraining peak torque of the extensor muscles at angular velocities of 30°/sec and 60°/sec was different between those who received concentric and eccentric training, and that it was higher in the concentric group may have affected the results of the study. So much so that the pretraining concentric muscle strength was higher at angular velocity of 30°/sec and 60°/sec in the concentric group, and the difference was closed in the eccentric and concentric groups after the training, suggesting that eccentric training may have increased the concentric muscle strength as well. In a similar way to our study, a study in the literature examining the mode-specific effects of eccentric isokinetic training of the hamstrings; the exercise group and the nonexercise group were trained 3 times a week for 6 weeks with 15 maximum eccentric isokinetic contractions at 120°/sec. It was determined that eccentric muscle strength increased significantly at all velocities tested (120°/sec ± 60°/sec), and that concentric strength increased significantly at 120°/sec and 180°/sec in the exercise group, the study came to a conclusion that eccentric isokinetic training at 120°/sec and 180°/sec is not mode-specific (Ryan et al., 1991).

The fact that this study was planned as a 6-week training is a limitation to the study. Also, the difference between the pretraining values of the study's concentric and eccentric groups is another limitation of the study. We think that there is a need for more studies with longer duration and intermediate follow-ups to be done in groups with similar pretraining values.

In conclusion, it was established that 6 weeks of concentric training did not increase concentric and eccentric isokinetic muscle strength, while 6 weeks of eccentric training increased eccentric muscle strength of knee flexors and extensors, but did not increase concentric muscle strength. In line with the results of our study, we think that eccentric training may be preferred in cases where muscle strength increase is desired in a short time.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGMENTS

The authors received no financial support for this article.

REFERENCES

Akima H, Takahashi H, Kuno SY, Masuda K, Masuda T, Shimojo H, Anno I, Itai Y, Katsuta S. Early phase adaptations of muscle use and strength to isokinetic training. Med Sci Sports Exerc 1999;31:588-594.

Bell GJ, Wenger HA. Physiological adaptations to velocity-controlled resistance training. Sports Med 1992;13:234-244.

Bernárdez-Vázquez R, Raya-González J, Castillo D, Beato M. Resistance training variables for optimization of muscle hypertrophy: an umbrella review. Front Sports Act Living 2022;4:949021.

Bishop KN, Duurant E, Allsen PE, Merrill G. The effect of eccentric strength training at various speeds on concentric strength of the quadriceps and hamstring muscles. J Orthop Sports Phys Ther 1991;13:226-230.

Brown L, Whitehurst M. The effect of short-term isokinetic training on force and rate of velocity development. J Strength Cond Res 2003;17:88-94.

Douglas J, Pearson S, Ross A, McGuigan M. Eccentric exercise: physiological characteristics and acute responses. Sports Med 2017;47:663-675.

Duncan PW, Chandler JM, Cavanaugh DK, Johnson KR, Buehler AG. Mode and speed specificity of eccentric and concentric exercise training. J Orthop Sports Phys Ther 1989;11:70-75.

Farthing JP, Chilibeck PD. The effects of eccentric and concentric training at different velocities on muscle hypertrophy. Eur J Appl Physiol 2003;89:578-586.

Handford MJ, Bright TE, Mundy P, Lake J, Theis N, Hughes JD. The need for eccentric speed: a narrative review of the effects of accelerated eccentric actions during resistance-based training. Sports Med 2022;52:2061-2083.

Harris-Love MO, Gollie JM, Keogh JWL. Eccentric exercise: adaptations and applications for health and performance. J Funct Morphol Kinesiol 2021;6:96.

Isner-Horobeti ME, Dufour SP, Vautravers P, Geny B, Coudeyre E, Richard R. Eccentric exercise training: modalities, applications and perspectives. Sports Med 2013;43:483-512.

Ivy JL, Withers RT, Brose G, Maxwell BD, Costill DL. Isokinetic contractile properties of the quadriceps with relation to fiber type. Eur J Appl Physiol Occup Physiol 1981;47:247-255.

Lee SEK, Lira CAB, Nouailhetas VLA, Vancini RL, Andrade MS. Do isometric, isotonic and/or isokinetic strength trainings produce different strength outcomes? J Bodyw Mov Ther 2018;22:430-437.

Lesmes GR, Costill DL, Coyle EF, Fink WJ. Muscle strength and power

changes during maximal isokinetic training. Med Sci Sports 1978;10:266-269.

Mjølsnes R, Arnason A, Østhagen T, Raastad T, Bahr R. A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. Scand J Med Sci Sports 2004;14:311-317.

Park JH, Chung SW, Lee SJ, Lee JW, Oh KS. Evaluation of the electromyographic amplitude-to-work ratio in the infraspinatus muscle during external shoulder rotation exercises: a comparison of concentric isotonic and isokinetic exercises. Orthop J Sports Med 2020;8:2325967120932459.

Roig M, O'Brien K, Kirk G, Murray R, McKinnon P, Shadgan B, Reid WD. The effects of eccentric versus concentric resistance training on muscle strength and mass in healthy adults: a systematic review with meta-analysis. Br J Sports Med 2009;43:556-568.

Ryan LM, Magidow PS, Duncan PW. Velocity-specific and mode-specific effects of eccentric isokinetic training of the hamstrings. J Orthop Sports Phys Ther 1991;13:33-39.

Sato S, Yoshida R, Murakoshi F, Sasaki Y, Yahata K, Kasahara K, Nunes JP, Nosaka K, Nakamura M. Comparison between concentric-only, eccentric-only, and concentric-eccentric resistance training of the elbow flexors for their effects on muscle strength and hypertrophy. Eur J Appl Physiol 2022;122:2607-2614.

Schoenfeld BJ, Grgic J, Ogborn D, Krieger JW. Strength and hypertrophy adaptations between low- vs. high-load resistance training: a systematic review and meta-analysis. J Strength Cond Res 2017;31:3508-3523.

Sharma KN, Quddus N, Hameed UA, Khan SA, Kumari A, Alghadir AH, Khan M. Mode-specific effects of concentric and eccentric isokinetic training of the hamstring muscle at slow angular velocity on the functional hamstrings-to-quadriceps ratio-a randomized trial. PeerJ 2022;10:e13842.

Suchomel TJ, Nimphius S, Bellon CR, Stone MH. The importance of muscular strength: training considerations. Sports Med 2018;48:765-785.

Tomberlin JP, Basford JR, Schwen EE, Orte PA, Scott SC, Laughman RK, Ilstrup DM. Comparative study of isokinetic eccentric and concentric quadriceps training. J Orthop Sports Phys Ther 1991;14:31-36.

Tseng WC, Nosaka K, Tseng KW, Chou TY, Chen TC. Contralateral effects by unilateral eccentric versus concentric resistance training. Med Sci Sports Exerc 2020;52:474-483.

Vieira A, Blazevich A, Souza N, Celes R, Alex S, Tufano JJ, Bottaro M. Acute changes in muscle thickness and pennation angle in response to work-matched concentric and eccentric isokinetic exercise. Appl Physiol Nutr Metab 2018;43:1069-1074.

Wan X, Li S, Best TM, Liu H, Li H, Yu B. Effects of flexibility and strength training on peak hamstring musculotendinous strains during sprinting. J Sport Health Sci 2021;10:222-229.

Westcott WL, Winett RA, Annesi JJ, Wojcik JR, Anderson ES, Madden PJ. Prescribing physical activity: applying the ACSM protocols for exercise type, intensity, and duration across 3 training frequencies. Phys Sportsmed 2009;37:51-58.

https://doi.org/10.12965/jer.2346236.118