OTJHS
Online Turkish Journal of Health Sciences

e-ISSN: 2459-1467

OTSBD
Online Türk Sağlık Bilimleri Dergisi

Online Turkish Journal of Health Sciences 2023;8(3):350-357 *Online Türk Sağlık Bilimleri Dergisi 2023;8(3):350-357*

The Effects of Eccentric-Concentric Isokinetic Muscle Strength Training on Quadriceps Femoris Muscle Architecture, Muscle Strength and Proprioception in Healthy Young People

Eksentrik-Konsentrik İzokinetik Kas Kuvveti Eğitiminin Sağlıklı Gençlerde Kuadriseps Femoris Kas Mimarisi, Kas Kuvveti ve Propriyosepsiyon Üzerine Etkileri

[1]Tuba İNCE PARPUCU, [2]Zeliha Candan ALGUN, [3]Uğur TOPRAK, [4]Sefa TÜRKOĞLU

[1]Suleyman Demirel University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Isparta, Türkiye
[2]Istanbul Medipol University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, İstanbul, Türkiye
[3]Eskişehir Osmangazi University, Faculty Of Medicine, Department of Radiology, Eskisehir, Türkiye
[4]Suleyman Demirel University, Faculty Of Medicine, Department of Radiology, Isparta, Türkiye

Tuba İnce Parpucu: https://orcid.org/0000-0002-1942-6453
Zeliha Candan Algun: https://orcid.org/0000-0002-2476-6567
Uğur Toprak: https://orcid.org/0000-0002-1244-2485
Sefa Türkoğlu: https://orcid.org/0000-0002-9623-0083

ABSTRACT

Objective: This study aimed to compare and evaluate the efficacy of eccentric and concentric training on quadriceps femoris muscle architecture, muscle strength and proprioception in healthy young people.
Materials and Methods: Sixty healthy subjects were divided into two groups concentric training (n=30), and eccentric training (n=30). The outcome measurements were Quadriceps Femoris (QF) muscle architecture, muscle strength and knee proprioception. The training was carried out on the subjects' dominant side leg (right), and the participants were trained three times a week for 12 weeks. The measurements were applied before and after training. QF muscle architecture was assessed by using ultrasonography. Isokinetic muscle strength and knee proprioception were assessed with the isokinetic dynamometer.
Results: The results showed a significant increase in QF architecture, muscle strength and knee proprioception after the training in the two groups ($p<0.05$). When we compared the training groups, there were no differences regarding the outcome of all variables between groups ($p>0.05$).
Conclusion: Training techniques, including eccentric and concentric training, positively affected QF muscle architecture, muscle strength, and knee proprioception ($p<0.05$), but there is no superiority between each other ($p>0.05$).
Keywords: Eccentric training, muscle architecture, muscle strength, quadriceps femoris, proprioception

ÖZ

Amaç: Bu çalışmanın amacı sağlıklı kişilerde eksentrik ve konsentrik eğitimlerin kuadriseps femoris kasının kas mimarisi, kas kuvveti ve propriosepsiyona etkilerini değerlendirmek ve karşılaştırmaktır.
Materyal ve Metot: 60 sağlıklı kişi konsentrik (n=30) ve eksentrik (n=30) kas eğitimi olarak iki gruba ayrıldı. M. Quadriseps Femoris (QF) kas mimarisi, kas kuvveti ve diz propriosepsiyonu değerlendirildi. Eğitim dominant taraf bacak (sağ) üzerinde uygulandı ve katılımcılar haftada 3 kez, 12 hafta boyunca eğitime devam etti. Değerlendirmeler eğitim öncesi ve eğitim sonrası olarak yapıldı. QF kas mimarisi ultrason ile değerlendirildi. Kas kuvveti ve diz propriosepsiyonu izokinetik dinamometre ile değerlendirildi.
Bulgular: Bu çalışmanın sonuçlarına göre QF kas mimarisi, kas kuvveti ve diz propriosepsiyonu her iki grupta benzer şekilde artış gösterdi ($p<0,05$). Eğitim gruplarını karşılaştırdığımızda tüm değerlendirme sonuçları açısından her iki grup arasında fark bulunmadı ($p>0,05$).
Sonuç: Sonuçlar eksentrik ve konsentrik eğitimlerin QF kas mimarisi, kas kuvveti ve diz propriosepsiyonu üzerine pozitif etkilerinin olduğunu ($p<0,05$), fakat birbirleri üzerine üstünlüklerinin olmadığını işaret etmiştir ($p>0,05$).
Anahtar Kelimeler: Eksentrik eğitim, kas mimarisi, kas kuvveti, quadriseps femoris, propriosepsiyon

Sorumlu Yazar / Corresponding Author:
Tuba İnce Parpucu
Suleyman Demirel University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Post Code: 32020 City: Isparta, Türkiye.
Tel: +90 505 645 98 62
E-mail: fzttubaince@gmail.com

Yayın Bilgisi / Article Info:
Gönderi Tarihi/ Received: 31/03/2023
Kabul Tarihi/ Accepted: 29/05/2023
Online Yayın Tarihi/ Published: 06/09/2023

Atıf / Cited: İnce Parpucu T and et al. The Effects of Eccentric-Concentric Isokinetic Muscle Strength Training on Quadriceps Femoris Muscle Architecture, Muscle Strength and Proprioception in Healthy Young People. *Online Türk Sağlık Bilimleri Dergisi* 2023;8(3):350-357. doi: 10.26453/otjhs.1274774

INTRODUCTION

Gaining better muscle strength depends on a more active life in healthy people because it leads to the formation of better muscular function.[1] Muscular strength is defined as the force generated with a maximal effort by a muscle or group of muscles against resistance. Sufficient muscle strength better protects the person against joint and muscle injuries.[2,3] Therefore, it is important to implement strength training programs within the scope of preventive physiotherapy in healthy people as well. Isometric, concentric, eccentric, and isokinetic exercises are the main exercises to improve muscle strength.[4] Isokinetic exercises increase muscle strength the most. With isokinetic devices, the maximum load can be imposed on the muscle at predetermined fixed angular velocities. These systems allow the implementation of concentric and eccentric training of muscles.[5-7]

Knowledge of the architectural features of the muscle, the basic element of muscle function, will enable effective evaluation and improvement of muscle function. Muscle architecture enables the muscle development process to be understood and interpreted macroscopically.[8] It is known that muscle strength training programs cause changes in muscle structure. It has been reported that both eccentric training and concentric plus eccentric training increase fascicle length.[9] Trainings, including resistance training exercises and eccentric strengthening programs, have been observed to result in increased muscle cross-sectional area and fibre length.[8]

Proprioception can be defined as the combined stimuli from mechanoreceptors in the joint capsules, tendons, ligaments, muscles, and skin being transmitted to the central nervous system.[10] The proprioceptive sense includes joint position sensation and kinesthesia and ensures dynamic joint stability by contributing to the muscle reflex and motor planning necessary to achieve nerve-muscle control.[11] The scientific literature suggests that proprioception and postural stability are also extremely important for preventing sports injuries. Studies have also reported that proprioception is considerably associated with the performance of elite athletes.[12]

Despite many studies, controversy remains regarding the effects of different types of resistance training on muscle strength and hypertrophy.[13,14] The purpose of this study was to determine the effect of eccentric-concentric isokinetic muscle strength training on muscle architecture, muscle strength, and proprioception of healthy quadriceps femoris muscle and to compare this training program on proprioception, muscle architecture, and strength.

MATERIALS AND METHODS

Ethics Committee Approval: The study was approved by the Clinical Research Ethics Committee of Suleyman Demirel University, Faculty of Medicine (Date: 08.02.2017, decision no. 72867572.050.01-29921). The study was carried out following the international declaration, guidelines, etc.

Study Design and Data Collection: The exclusion criteria were severe pain, acute injuries of muscle-tendon structures, nonconformity of the participant during the test, cases with insufficient soft tissue healing, the presence of severe effusion and severe limitation of joint movement, the presence of an orthopedic illness in the knee or ankle, and the presence of a systemic disease that prevents performance on the isokinetic dynamometer. In addition, volunteer participants were encouraged to stay away from all sports activities and strengthening methods that could affect the increase in muscle strength during the program.

Outcome Measurements: 60 subjects completed the program. The study included participants who were right limb-dominant. In the study groups, the participants' dominant extremity's quadriceps femoris muscle was studied. Participants were divided into; an eccentric (ECC) exercise group (30 participants) and a concentric (CON) exercise group (30 participants). A strength training program comprising 3 sets with 10 repetitions a day, 3 days a week for a total of 12 weeks, was conducted.

A form was created to evaluate the age, educational status, sex, height, weight, dominant lower extremity, and type of strength training program of the participants. All participants were evaluated twice before and after strength training with the following assessment methods.

In this study, we evaluated the pennation angle of the vastus lateralis muscle and the anteroposterior diameter, namely, the thickness of the muscle using the Toshiba Aplio 500 ultrasound system. Participants were evaluated after being rested for 10 min before the ultrasonography. In addition, it was ensured that the participants did not engage in intense physical activity 48 h before the evaluation. Three images were obtained for each region.[4] The evaluation was performed on the patient lying with the knee in extension and the muscles relaxed.[15-17] Images were obtained at the midline from between the trochanter major and the lateral condyle of the femur.[17,18]

The isokinetic muscle strength test was performed at a velocity of 60°–240°/s at concentric/concentric mode during the concentric strength testing and at a velocity of 60°–120°/s at eccentric/eccentric mode during the eccentric strength testing. [6,19]

Proprioception measurements in the knee joint were performed using an isokinetic dynamometer. In evaluating knee joint proprioception, the joint position sense was measured using the active and passive methods. Values recorded when the targeted angle of 30°, 45°, and 75° was reached were recorded as deviation values. [19]

The isokinetic exercise program was applied to the dominant right knee of the participants. An isokinetic exercise program comprising 3 sets of 10 repetitions and 90 s of rest period after each set of 10 repetitions was implemented at an angular velocity of 180°/s in the concentric exercise group and at an angular velocity of 120°/s to the eccentric exercise group.[6]

Statistical Analysis: The *t*-test or Mann–Whitney U test was used for comparing the pre-training parameters of patients in the two exercise groups after the data was tested for normal distribution. In comparing pre-training and post-training differences in the exercise groups, the Wilcoxon test was separately used in the eccentric and concentric groups for data not following normal distribution, and the repeated measures analysis of variance was used for data following normal distribution.[20] The evaluations were made using the SPSS 20 software, and a p-value of <0.05 was considered statistically significant.

RESULTS

The present study investigated the effects of 12 weeks of eccentric and concentric isokinetic muscle strength training on muscle architecture, muscle strength, and proprioception of healthy quadriceps femoris muscle.

There was no statistically significant difference between the eccentric and concentric groups for age, (ECC; 22.77±1.45, CON; 22.07±1.14) gender (ECC; female:n;14, CON; male:n;16) and body mass index (ECC; 22.92±3.11, CON; 21.66±2.77) (p>0.05).

There was a statistically significant difference between the pre-training and post-training active proprioception at 30 degrees (AP30) (p=0.048) and active proprioception at 75 degrees (AP75) (p=0.0001) values of the participants in the eccentric exercise group. Post-training AP30 and AP75 values were significantly decreased compared to pre -training values (p<0.05). However, there was no statistically significant difference between active proprioception at 45 degrees (AP45) values (p=0.280). There was a statistically significant difference between the pre-training and post-training passive proprioception at 30 degrees (PP30) (p=0.0001), passive proprioception at 45 degrees (PP45) (p=0.003) and passive proprioception at 75 degrees (PP75) (p=0.001) values of the participants in the eccentric exercise group. There was a significant decrease in all post-training values compared with the pre-training values (Table 1).

There was a statistically significant difference between the pre-training and post-training AP45 (p=0.001) and AP75 (p=0.039) values of the participants in the concentric exercise group. Post-training AP45 and AP75 values decreased significantly compared to pre-training values (p<0.05). However, there was no statistically significant difference between AP30 values (p=0.163). There was a statistically significant difference between the pre-training and post-training PP30 (p=0.004), PP45 (p=0.003

Table 1. Comparison of proprioceptive sense measurements of participants in the eccentric exercise group before and after training.

Parameters	Before Training		After Training		p*
	Mean± SD	Median (Min-max)	Mean ± SD	Median (Min-max)	
AP30	3.43±3.98	2 (0-14)	1.73±2.36	1 (0-10)	0.048
AP45	3.00±2.75	2 (0-9)	2.33±2.81	1.5 (0-11)	0.280
AP75	4.33±4.61	3 (0-22)	1.60±2.61	0.5 (0-12)	0.0001
PP30	2.40±2.27	2 (0-10)	0.70±1.02	0 (0-4)	0.0001
PP45	1.27±1.28	1 (0-5)	0.43±0.97	0 (0-5)	0.003
PP75	2.57±2.42	2 (0-10)	0.70±1.12	0 (0-4)	0.001

SD: Standard Deviation; Min: Minimum; Max: Maximum; AP30: Active proprioception at 30 degrees; AP45: Active proprioception at 45 degrees; AP75: Active proprioception at 75 degrees; PP30: Passive proprioception at 30 degrees; PP45: Passive proprioception at 45 degrees; PP75: Passive proprioception at 75 degrees; *: Wilcoxon Test.

and PP75 (p=0.0001) values of the participants in the concentric exercise group. There was a significant decrease in all post-training values compared with the pre-training values (Table 2).

There was no statistically significant difference between the eccentric and concentric groups regarding pre-training and post-training changes in the AP30 (p=0.561), AP45 (p=0.202), AP75 (p=0.243), PP30 (p=0.649), PP45 (p=0.262) and PP75 (p=0.539) parameters. Negative values in the descriptive statistics show that a decrease has occurred after training (Table 3).

Table 2. Comparison of proprioceptive sense measurements of participants in the concentric exercise group before and after training.

Parameters	Before Training		After Training		
	Mean± SD	Median (Min-max)	Mean ± SD	Median (Min-max)	p*
AP30	3.37±2.78	2.5 (0-9)	2.34±2.19	2 (0-8)	0.163
AP45	3.60±3.31	3 (0-14)	1.55±2.18	1 (0-8)	0.001
AP75	3.63±3.25	2.5 (0-14)	1.93±1.71	2 (0-5)	0.039
PP30	2.60±2.50	2 (0-10)	0.93±1.36	0 (0-5)	0.004
PP45	2.07±1.74	1.5 (0-7)	0.59±1.24	0 (0-5)	0.003
PP75	3.63±3.75	3 (0-15)	0.83±1.04	0 (0-4)	0.0001

SD: Standard Deviation; Min: Minimum; Max: Maximum; AP30: Active proprioception at 30 degrees; AP45: Active proprioception at 45 degrees; AP75: Active proprioception at 75 degrees; PP30: Passive proprioception at 30 degrees; PP45: Passive proprioception at 45 degrees; PP75: Passive proprioception at 75 degrees; *: Wilcoxon Test.

The 60-degree quadriceps femoris concentric peak torque (QCON60) (GxT; F (1,58)=0.371, p=0.545), 60-degree quadriceps femoris eccentric peak torque (QECC60) (GxT; F (1,58)=0.840, p=0.363), 240-degree quadriceps femoris concentric peak torque (QCON240) (GxT; F (1,58)=1.303, p=0.258) and 120-degree quadriceps femoris eccentric peak torque (QECC120) (GxT; F (1,58)=1.982, p=0.165) values showed a similar level of increase in the eccentric and concentric exercise groups. Therefore, the interaction term was not statistically significant (p>0.05).
There was a statistically significant difference in terms of an increase between the pre-training and post-training QCON60 (T; F (1,58)=39.677, p=0.0001), QECC60 (T; F (1,58)=48.466, p=0.0001), QCON240 (T; F (1,58)=69.268, p=0.0001) and QECC120 (T; F (1,58)=34.106, p=0.0001) values in both groups. No statistically significant difference was found in terms of QCON60 (G; F (1,58)=0.007, p=0.934), QECC60 (G; F (1,58)=0.051, p=0.822), QCON240 (G; F (1,58)=0.199, p=0.657) and QECC120 (G; F (1,58) =0.116, p=0.735) measurements between the eccentric and concentric exercise groups (Table 4).
A similar increase was observed in the muscle thickness (MT) values of the eccentric and concentric exercise groups. Therefore, the interaction term was not statistically significant (Group × Time; F (1.58)

Table 3. Descriptive statistics and comparison of pre-training and post-training changes (differences) in the two groups (eccentric and concentric).

Before and After	ECCENTRIC		CONCENTRIC		
Education Difference	**Mean ± SD**	**Median (Min-max)**	**Mean±SD**	**Median (Min-max)**	**p***
Difference _AP30	-1.70±4.23	-1 (-10 – 9)	-0.93±3.27	-1 (-9 – 7)	0.561
Difference _AP45	-0.66±3.88	-0.5 (-7 – 9)	-2.07±3.15	-1 (-13 – 3)	0.202
Difference _AP75	-2.73±3.44	-2 (-10 – 5)	-1.69±3.94	-1 (-12 – 4)	0.243
Difference _PP30	-1.70±2.25	-1.5 (-9 – 2)	-1.59±2.78	-1 (-10 – 4)	0.649
Difference _PP45	-0.83±1.44	-1 (-5 – 3)	-1.41±2.26	-1 (-7 – 4)	0.262
Difference _PP75	-1.87±2.76	-1 (-9 – 3)	-2.69±4.01	-2 (-14 – 4)	0.539

SD: Standard Deviation; Min: Minimum; Max: Maximum; AP30: Active proprioception at 30 degrees; AP45: Active proprioception at 45 degrees; AP75: Active proprioception at 75 degrees; PP30: Passive proprioception at 30 degrees; PP45: Passive proprioception at 45 degrees; PP75: Passive proprioception at 75 degrees; *: Wilcoxon Test.

Table 4. Comparison of pre-training and post-training values of isokinetic muscle strength measurements in the eccentric and concentric exercise groups.

Parameters	Groups	TIME (T) Before Training	After Training	Statistics
QCON60, Mean ± SD	Eccentric	129.23±51.28	157.60±49.08	G; F (1,58)=0.007, p=0.934
	Concentric	130.63±55.33	154.00±59.62	T; F (1,58)= 39.677, p=0.0001
				GxT; F (1,58)= 0.371, p=0.545
QECC60, Mean ± SD	Eccentric	140.07±44.15	164.80±41.82	G; F (1,58)=0.051, p=0.822
	Concentric	134.00±39.14	166.23±45.29	T; F (1,58)= 48.466, p=0.0001
				GxT; F (1,58)= 0.840, p=0.363
QCON240, Mean ± SD	Eccentric	74.53±31.93	93.60±32.89	G; F (1,58)=0.199, p=0.657
	Concentric	73.40±28.32	87.87±29.75	T; F (1,58)= 69.268, p=0.0001
				GxT; F (1,58)= 1.303, p=0.258
QECC120, Mean ± SD	Eccentric	152.90±48.24	174.47±53.71	G; F (1,58)=0.116, p=0.735
	Concentric	150.33±42.36	185.60±62.58	T; F (1,58)= 34.106, p=0.0001
				GxT; F (1,58)= 1.982, p=0.165

SD: Standard Deviation; T: Time; GxT: GroupxTime; QCON60: 60-degree quadriceps femoris concentric peak torque; QECC60: 60-degree quadriceps femoris eccentric peak torque; QCON240: 240-degree quadriceps femoris concentric peak torque; QECC120: 120-degree quadriceps femoris eccentric peak torque.

=0.008, p=0.931). In both groups, there was a statistically significant difference in terms of an increase between pre-training and post-training MT values (Time; F (1.58)=5.415, p=0.023). No statistically significant difference was found between the eccentric and concentric exercise groups regarding MT measurements (G; F (1,58)=0.116, p=0.734). The pennation angle (PA) values displayed a similar level of decrease in the eccentric and concentric exercise groups. Therefore, the interaction term was not found to be statistically significant (Group × Time; F (1.58)=0.019, p=0.891). There was a statistically significant difference in decreasing the pre-training and post-training PA values in both groups (Time; F (1.58)=5.149, p=0.027). No statistically significant difference was found between the eccentric and concentric exercise groups in terms of PA measurements (Group; F (1.58)=0.009, p=0.926) (Table 5).

Table 5. Comparison of pre-training and post-training muscle thickness and pennation angle measurement values in the eccentric and concentric exercise groups.

Parameters	Group	TIME Before Training	After Training	Statistics
MT, Mean ± SD	Eccentric	17.15±4.03	18.12±3.22	G; F (1,58)=0.116, p=0.734
	Concentric	16.89±3.38	17.79±4.07	T; F (1,58)= 5.415, p=0.023
				GxT; F(1,58)= 0.008, p=0.931
PA, Mean ± SD	Eccentric	10.53±3.70	9.43±2.76	G; F (1,58)=0.009, p=0.926
	Concentric	10.67±3.55	9.42±2.96	T; F (1,58)= 5.149, p=0.027
				GxT; F (1,58)= 0.019, p=0.891

SD: Standard Deviation; MT: Muscle thickness; PA: Pennation angle.

DISCUSSION AND CONCLUSION

The differential impact of ECC or CON on strength gains is still a debatable issue, while the mechanisms regulating these adaptations have not yet been fully elucidated. Analysis of studies in the literature on concentric-eccentric strength increase after concentric-eccentric isokinetic exercise training revealed different results. Within the ponder by Bagheri et al. offbeat workout comes about in a more noteworthy increment in maximal isometric deliberate compression of the quadriceps muscle after 12 weeks of concentric and unconventional isokinetic workout preparing.[21] Douglas et al. reported that eccentric training could elicit greater improvements in muscle strength and mechanical muscle function than concentric or concentric-eccentric resistance training.[21] Conversely, a group of researchers have demonstrated that a similar increase occurred in the muscle strength of both the concentric and eccentric groups after concentric and eccentric isokinetic exercise training.[13,14,23,24] Similarly, in our study, as in most studies reported in the literature, the eccentric and concentric peak torque strength values of the concentric and eccentric isokinetic exercise training groups showed a similar level of increase in both groups after 12 weeks of isokinetic muscle strength training.

There is ongoing controversy as to whether differences exist in the hypertrophic response to concentric vs. eccentric actions.[24] Only one study among muscle architecture studies conducted on the quadriceps muscle by evaluating the anatomical cross-sectional area of the muscle has revealed a difference between eccentric and concentric exercise training groups. In that study by Higbie et al., the anatomical cross-sectional area of the muscle was found to be greater in the eccentric group than in the concentric.[25] Other studies showed a similar increase in MT in the concentric and eccentric exercise training groups.[14,24,26] Our study has also found similar results to the literature and revealed that a similar level of increase occurred in the MT of the concentric and eccentric isokinetic exercise training. This suggests that this result is associated with the eccentric and concentric peak torque strength values having a similar level of increase in both groups. The findings indicate the importance of including eccentric and concentric actions in muscle strength programs, as both effectively increase muscle hypertrophy.

We observed different results when we analysed muscle architecture studies in the literature in which PA was evaluated. In their study published in 2007, Blazevich et al. reported that PA increased similarly in the concentric and eccentric exercise groups.[27] Conversely, Quinlan et al. have detailed in their study conducted in 2021 that the PA of the vastus lateralis muscle increased and that this increment was greater in the concentric exercise group than in the eccentric exercise group.[26] The studies of Raj et al. and the studies of Baroni et al. showed that there was no change in the pennation angle after the eccentric exercise training program.[28,18] Unlike the literature, a similar level of decrease occurred in PA values of the eccentric and concentric exercise groups in our study. We attribute this situation to different results in the literature.

Until now, many studies have investigated the effect of different training modules on position sense, but the majority focused on rehabilitation from myoskeletical injuries. Unfortunately, the reports in healthy individuals on the impact of exercise on position sense are limited. Methenitis et al. reported that no significant changes were found in knee joint position sense for both concentric or eccentric groups.[29] In Shiravand et al. research, a factually noteworthy decrease was similarly found in the margin of error for proprioception after training compared with pre-training in the eccentric and concentric groups.[30] The results of our study are also similar; a factually noteworthy diminish similarly found in the margin of error for proprioception after training compared with pre-training in the eccentric and concentric groups. Because motor control loss in the knee joint is the most important cause that triggers proprioception loss, improved proprioception is an expected outcome of increased muscle strength. We believe that increasing the concentric and eccentric muscle strength increases the motor control and improves proprioception. We attribute the lack of proprioception difference between the two groups to the fact that there is no noteworthy contrast between the concentric and eccentric training groups in evaluating our other muscle strength and architecture parameters.

In conclusion, the present study has limitations. This limitation is the absence of a control group. In our study, it was observed that compared with the initial values, the post-exercise training values of all measurement parameters increased in both groups regardless of the training. This demonstrates that eccentric and concentric isokinetic strength training is effective in strengthening the quadriceps femoris muscle in healthy young individuals and that it is effective on muscle architecture and joint position sensation as well, which supports several previous studies performed in this regard. In addition, our study shows that eccentric and concentric isokinetic strength training in healthy young individuals has a similar effect on the quadriceps femoris muscle strength, muscle architecture, and joint position sensation. We accept that the results acquired from the research will act as a guideline for increasing the physical fitness of healthy individuals and athletes and determining the rehabilitation program for those with pathological conditions.

Ethics Committee Approval: The study was approved by the Clinical Research Ethics Committee of Suleyman Demirel University, Faculty of Medicine (Date: 08.02.2017, decision no. 72867572.050.01-29921). The study was carried out in accordance with the international declaration, guidelines, etc.

Conflict of Interest: No conflict of interest was declared by the authors.

Author Contributions: Concept – TIP, ZCA; Supervision – TIP, ZCA UT, ST; Materials – TIP, ZCA UT, ST; Data Collection and/or Processing – TIP, ZCA UT, ST; Analysis and/or Interpretation – TIP; Writing – TIP.

Peer-review: Externally peer-reviewed.

Acknowledgements: The authors thank everyone who participated in the study.

Other Information: The study was produced from PhD Thesis entitled "Sağlıklı Genç Bireylerde Quadriceps Femoris Eksentrik-Konsentrik İzokinetik Kas Kuvvet Eğitiminin Kas Mimarisi, Kas Kuvveti, Propriosepsiyon ve Fonksiyona Etkisi".

REFERENCES

1. Telci EA, Aslan UB, Cavlak U. Sağlıklı quadriseps femoris kasında hand-held dinamometrenin intrarater ve interrater güvenirliği: kas kuvvetinin etkisi. Journal of Marmara University Institute of Health Sciences. 2011;1(2):124-128.
2. Otman SA, Köse N. Tedavi hareketlerinde temel değerlendirme prensipleri. 11th Ed. Ankara, Hipokrat Kitabevi; 2019.
3. Kumar S. Introduction and terminology. In: Muscle Strength (Ed. S Kumar). 1st Ed. CRS Pres LLC. Florida. USA, 2004.
4. Gelecek N, Tomruk M. Dirençli egzersizler. 1st

Ed. O'TIP Kitabevi ve Yayıncılık; 2016;5-37.
5. Ratamess NA, Beller NA, Gonzalez AM, et al. The effects of multiple-joint ısokinetic resistance training on maximal ısokinetic and dynamic muscle strength and local muscular endurance. Journal of Sports Science and Medicine. 2016;15:34-40.
6. Şahin Ö. Rehabilitasyonda izokinetik değerlendirmeler. Cumhuriyet Tıp Dergisi. 2010;32:386-396.
7. Souza-Teixeira F, Paz JA. Eccentric resistance training and muscle hypertrophy. J Sport Med Doping Stud. 2012;1:2161-0673.
8. Fırat T, Delioğlu K. Kas mimarisi temelli fizyoterapi ve rehabilitasyon. 1st Ed. Hipokrat Kitabevi; 2016:203-210.
9. Potier TG, Alexander CM, Seynnes OR. Effects of eccentric strength training on biceps femoris muscle architecture and knee joint range of movement. Eur J Appl Physioly. 2009;105:939-944.
10. Johansson H, Pedersen J, Bergenheim M, Djupsjobacka M. Peripheral afferents of the knee: their effects on central mechanisms regulating muscle stiffness, joint stability, and proprioception and coordination. In: Lephart SM, Fu FH, editors. Proprioception and neuromuscular control in joint stability. Illinois: Human Kinetics; 2000:5-22.
11. Erden Z. Dizin farklı açılarında eklem pozisyon hissi farklı mıdır? Joint Dis Rel Surg. 2009;20 (1):47-51.
12. Ribeiro F, Oliveira J. Aging effects on joint proprioception: the role of physical activity in proprioception preservation. Eur Rev Aging Phys Act. 2007;4:71-76.
13. Franchi MV, Reeves ND, Narici MV. Skeletal muscle remodeling in response to eccentric vs. Concentric loading: Morphological, molecular, and metabolic adaptations. Front Physiol. 2017;8:447.
14. Ünlü G, Çevikol C, Melekoğlu T. Comparison of the effects of eccentric, concentric, and eccentric-concentric ısotonic resistance training at two velocities on strength and muscle hypertrophy. Journal of Strength and Conditioning Research. 2020;34(2):337-344.
15. Franke RA, Baroni BM, Rodrigues R, Geremia JM, Lanferdini FJ, Vaz MA. Neural and morphological adaptations of vastus lateralis and vastus medialis muscles to isokinetic eccentric training. Motriz: Rev Educ Fis. 2014;20(3):317-324. doi:10.1590/S1980-65742014000300011
16. Coratella G, Milanese C, Schena F. Unilateral eccentric resistance training: A direct comparison between isokinetic and dynamic constant external resistance modalities. European Journal of Sport Science. 2015;15(8):720-726.
17. Matta TT, Nascimento FX, Trajano GS, et al. Selective hypertrophy of the quadriceps musculature after 14 weeks of isokinetic and conventional resistance training. Clinical Physiology and Nuclear Medicine. 2017;37:137-142 .
18. Baroni BM, Geremia JM, Rodrıgues R, et al. Muscle archıtecture adaptations to knee extesor eccentric training: rectus femoris vs. vastus lateralis. Muscle & Nerve. 2013;48(4):498-506.
19. Demir HM. kuadriseps ve hamstring kaslarına kinesiotape uygulamasının kas kuvvetine, propriosepsiyona ve sıçramaya etkisi. Süleyman Demirel Üniversitesi Tıp Fakültesi Spor Hekimliği Anabilim Dalı, Uzmanlık Tezi. Isparta, Türkiye. 2016.
20. Sümbüloğlu V, Sümbüloğlu K. Sağlık bilimlerinde araştırma yöntemleri. Ankara: Hatiboğlu Yayıncılık;2004:196.
21. Bagheri T, Abedi B, Hedayatpour N. Effects of 12 weeks concentric and eccentric resistance training on neuromuscular adaptation of quadriceps muscle. Journal of Rehabilitation Sciences and Research (JRSR). 2020;12:161-166.
22. Douglas J, Pearson S, Ross A, McGuigan M. Chronic adaptations to eccentric training: A systematic review. Sports Med. 2017;47:917-941.
23. Benford J, Hughes J, Waldron M, Theis N. Concentric versus eccentric training: Effect on muscle strength, regional morphology, and architecture. Transl Sports Med. 2021;4:46-55.
24. Schoenfeld BJ, Ogborn DI, Vigotsky AD, Franchi MV, Krieger JW. Hypertrophic effects of concentric vs. Eccentric muscle actions: A systematic review and meta-analysis. J Strength Cond Res. 2017;31:2599-2608.
25. Higbie EJ, Cureton KJ, Warren GL, Prior BM. Effects of concentric and eccentric training on muscle strength, cross-sectional area, and neural activation. J Appl Physiol. 1996;81:2173-2181.
26. Quinlan JI, Franchi MV, Gharahdaghi N, et al. Muscle and tendon adaptations to moderate load eccentric vs. concentric resistance exercise in young and older males. GeroScience. 2021;43:1567-1584.
27. Blazevich AJ, Cannavan D, Coleman DR, Horne S. Influence of concentric and eccentric resistance training on architectural adaptation in human quadriceps muscles. J Appl Physiol. 2007;103:1565-1575.
28. Raj IS, Bird SR, Westfold BA, Shield AJ. Effects of eccentrically biased versus conventional weight training in older adults. Med Sci Sports Exerc. 2012;44:1167–1176.
29. Methenitis S, Theodorou A, Chatzinikolaou P, Margaritelis N, Nikolaidis M, Paschalis V. The effects of chronic concentric and eccentric trai-

ning on position sense and joint reaction angle of the knee extensors. European Journal of Sport Science. 2023. doi:10.1080/17461391.2023.2184726

30. Shiravand M, Rashedi H, Beigrezai M. A comparison of the effects of long term concentrıc versus eccentrıc exercıse on knee joınt postıon sense of healthy females. Indian Journal of Fundamental and Applied Life Sciences. 2014;4(3):45-49.