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A COMPARISON OF DIFFERENT QUADRICEPS FEMORIS ISOMETRIC STRENGTHENING METHODS IN HEALTHY YOUNG WOMEN

ORIGINAL ARTICLE

ABSTRACT

Purpose: This study was planned to compare the effectiveness of high voltage pulsed galvanic (HVPG) stimulation, Russian current and isometric exercise on quadriceps femoris (QF) isometric muscle strength in healthy young women.

Methods: Forty-six healthy young women were included in the study. Before and after the training, the dominant side QF isometric muscle strength of participants was assessed with the isokinetic dynamometer. The peak torque and average torques of the participants were recorded after the test. The training was planned as HVPG current group (n=16), Russian current group (n=15) and isometric strengthening group (n=15). All treatments were performed under physiotherapist supervision for a total of 15 sessions for three days a week for five weeks.

Results: The quadriceps isometric muscle strength was significantly increased in all groups in terms of peak torque and average torque values after training compared to pre-training values ($p<0.05$). No statistical difference was found between the groups when the peak torque and average torque delta values were compared ($p>0.05$).

Conclusion: The highest rate of change belongs to the HVPG group in terms of increasing the QF isometric muscle strength. Therefore, we recommend using it in clinical practice.

Key Words: Exercise; Torque; Quadriceps Femoris; Electrical Stimulation.

SAĞLIKLI GENÇ KADINLARDA FARKLI QUADRİSEPS FEMORİS İZOMETRİK KUVVETLENDİRME YÖNTEMLERİNİN KARŞILAŞTIRILMASI

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Bu çalışma sağlıklı genç kadınlarda yüksek voltajlı galvanik stimülasyon, Rus akımı ve izometrik egzersizin quadriseps femoris (QF) izometrik kas kuvveti üzerine etkinliğini karşılaştırmak amacıyla planlandı.

Yöntem: Kırkaltı sağlıklı genç kadın çalışmaya dahil edildi. Eğitimden önce ve sonra, katılımcıların dominant taraf QF izometrik kas kuvveti izokinetik dinamometre ile değerlendirildi. Katılımcıların zirve tork ve ortalama tork değerleri test sonrası kaydedildi. Eğitim YVGS akım grubu (n=16), Rus akım grubu (n=15) ve izometrik kuvvetlendirme grubu (n=15) olarak planlandı. Tüm uygulamalar haftada üç gün beş hafta boyunca toplamda 15 seans fizyoterapist gözetimi altında gerçekleştirildi.

Sonuçlar: QF izometrik kas kuvveti, antrenman öncesi değerlere göre antrenman sonrası zirve tork ve ortalama tork değerleri bakımından tüm gruplarda anlamlı olarak arttı ($p<0,05$). Zirve tork ve ortalama tork değerleri karşılaştırıldığında gruplar arasında herhangi bir istatistiksel fark bulunmadı ($p>0,05$).

Tartışma: QF izometrik kas kuvvetini arttırma açısından en yüksek değişim oranı YVGS grubuna aittir, bu nedenle klinik uygulamada tercih edilmesini önermekteyiz.

Anahtar Kelimeler: Egzersiz; Kuvvet; Quadriseps Femoris; Elektrik Stimülasyonu.

INTRODUCTION

Neuromuscular electrical stimulation (NMES) is a non-invasive treatment modality that stimulates motor neurons with low-amplitude electrical currents to induce voluntary muscle contractions (1,2). Healthy muscle strength can be improved by active exercise against resistance or by NMES. There are many articles in the literature about increasing muscle strength, whether exercise is more effective than electrical muscle stimulation or electrical muscle stimulation than exercise and no clear consensus has been reached on which is more effective (3-6). In many studies, electrical stimulation was applied either alone or combined with exercise to improve quadriceps femoris (QF) muscle strength of healthy subjects (7-11).

Faradic current, Russian current, and high voltage pulsed galvanic (HVPG) currents are frequently used clinically to strengthen the healthy muscle by electric stimulation. If the frequency of the current is high enough, tetanic muscle contraction can be obtained, the same as in maximal voluntary contraction by stimulation (12). According to a study by Kots, high-intensity currents have been claimed to provide 10-30% more contractions than voluntary muscle contractions. Faradic current is not preferred in our study because of the length of the transition period (1000 µs) and the short number of pulses (1-60 pulses). In this study, the Russian current and another high-intensity current, HVPG current, were selected from the high-intensity currents as Kots proposed, in order to strengthen the healthy muscle (13).

Russian currents are a high-frequency current of 2500 Hz and reduce the resistance of the skin, and it would penetrate deeper and reach deeper motor nerves. Kots has stated that in professional athletes, Russian current practice can increase the maximal voluntary contraction of the muscle by 40%. This technique provides maximum strength gain without fatigue due to long rest period (13).

The HVPG current is a new form of neuromuscular electrical stimulation. This current began to be widely used in the 1970s (14). It has been shown that when the voltage is increased and the transition period of the electric current is reduced, deeper tissues can be excited without undergoing damage (15). In the case of HVPG current applications, there is less tissue resistance or reaction capacity than low voltage applications. This feature is the theoretical explanation for that HVPG is more effective and can be better tolerated. The most significant advantage of the HVPG current is that it has a higher electrical motion gain than other methods. Due to low impedance, it penetrates the skin more quickly and depolarizes the nerve fibers and provides continuity of tissue healing (16,17). When compared to other neuromuscular stimulators, the intermittent high-voltage current has the advantage of high electrical mobility, which is the voltage. Its low impedance enables for more quick penetration to skin and better toleration. Because of the high voltage, skin resistance reduces spontaneously (11).

Isometric or static strength training is exercises performed without joint movement and changing muscle length during muscle contraction. Strength increase depends on the amount and duration of contraction, the intensity of contraction, the intensity of training, and the joint angle (18,19). Isometric training can increase strength in specific muscle or muscle groups. In addition to gains in muscle strength, isometric exercises can also lead to an increase in muscle mass and improvements in bone strength (20). It has been reported that the contraction should be continued for 3-10 seconds in order to increase the strength (19,21).

When we review the literature, we see that NMES and different exercise programs are widely used to strengthen QF muscles in healthy individuals. However, these studies differ from our study. Baskan et al. applied isometric exercise training and Russian flow to strengthen the QF muscle and assessed the strength increase as a concentric force in the isokinetic system while Silva et al. has performed isometric and eccentric force evaluation in isokinetic system after eccentric training with NMES and NMES alone (7,8). Romero et al. found that isometric muscle strength increased by 31% in the isokinetic system after electrical stimulation in healthy subjects (22). However, we did not find any study evaluating the isometric strength increase of the QF muscle with the isokinetic system by applying two different NMES and isometric exercise methods. For this reason, we used methods of Russian current, HVPG current, and isometric exercise to increase QF muscle strength in healthy women and evaluated isometric force using the isokinetic system.

METHODS

Subjects

Forty-six healthy women (age=21.02±1.27 years) were included in the study between 18-30 years of age. Participants' QF isometric muscle strength (torque measurements) was assessed twice before and after training using the Isokinetic Dynamometer (Humac Norm Testing Rehabilitation system, CSMI Medical Solutions, USA). The controlled clinical trial with three intervention groups was conducted according to the standards of the Declaration of Helsinki (Figure 1). The training was performed on the dominant side QF muscle. The training was planned as HVPG current for the first group (n=16), as Russian current for the second group (n=15) and as isometric strengthening for the third group (n=15). HVPG current was applied for 20 minutes. Russian current was applied for 10 minutes for the second group. The strengthening exercises in the third group were applied as 10 maximal contractions of 10 seconds and 10 seconds between each contraction. Both exercise and stimulation applications were performed after the body and knee were positioned and stabilized at 75° flexion and 60° flexion angle, respectively. All treatments were performed under physiotherapist supervision for a total of 15 sessions for three days a week for five weeks. Demographic data are given in Table 1.

Inclusion criteria for the study were a willingness to participate in the study, not having knee complaints such as pain, lockout, morning arrest, swelling, difficulty in walking, not having any orthopedic or neurological disability. Exclusion criteria were exercising regularly for the last six months, presence of cardiovascular, pulmonary, orthopedic, and neurological problems which may prevent exercise. The criteria for dismissing from the study were unable to complete the assessment, having any disease status in the evaluation and training process, starting to do sport regularly during the training period, having incomplete data, and unable to participate in 75% of the training.

The ethical approval of the study was taken at the Ethics Committee of Non-Interventional Clinical Researches of Pamukkale University (Approval Date: 06.06.2017 and Approval Number: 2017-8). All participants were informed verbally, and an informed consent form was signed.

Procedures

Muscle Strength, Isokinetic Strength Measurement

The dominant side QF isometric muscle strength (torque measurements) of the participants was assessed with the Isokinetic Dynamometer (Humac Norm Testing Rehabilitation System, CSMI Medical Solutions, USA). Before the test, participants were subjected to a standard warm-up of 5 minutes, and evaluations were carried out using a standard seat. The back of the seat was angled 105° backward to provide 75° flexion at the body. The knee was positioned at an angle of 60° and was fixed with bands around the body, waist, hip, and ankle. Participants had no previous experience with isokinetic dynamometer testing. Therefore, it was started with a trial whose protocols were the same with QF isometric muscle strength measurement protocols. Then, participants' QF isometric muscle strength was measured by three 10-second maximal isometric contractions. Rest periods of 3 seconds between each contraction were given. Each participant held the sides of the seat with both hands during the test. Verbal encouragement was made throughout the whole test to obtain maximum strength from the participants. The peak torque and average torques of the participants were recorded after the test.

High Voltage Pulsed Galvanic Current

The HVPG was applied by using Endomed 982 (Enraf Nonius Sonic Unit, the Netherlands). The instrument was automatically set to a pulse rate of 100 μs while the pulse frequency was set to 60 pulses/s. In order to avoid fatigue, the intermittent form of the current was selected, and the transition time/rest time was set to 4 s impulse/12 s. The total output voltage of the device ranged from 0 to 500 volts, and the current intensity was increased until the sensible contraction of the applied muscle was achieved without causing too much sense of discomfort. Stimulation was performed after the body and knee were positioned and stabilized at 75° flexion and 60° flexion angle, respectively. One of the 6x8 cm carbonated electrodes was placed in the distal portion of vastus medialis muscle, while the other one was placed in the proximal portion of the vastus lateralis muscle. This placement was intended to stimulate a large proportion of the muscle fibers of the QF muscle (23). The HVPG was applied for a total of 20 minutes. The amplitude was increased until a contraction can be seen without any discomfort to the patient (24).

Russian Current

In the treatment with the Russian current, a protocol developed by Kots, also known in the literature as "Russian Technique," was used. In the treatment with the Russian movement, a protocol developed by Kots, also known as "Russian Technique," was used in the literature. There were 10 muscle contractions per treatment session in this protocol. Each contraction lasted for 10 seconds, and resting time of 50 seconds was given for the next contraction (transition: rest ratio was 1/5) (13). Russian current Endomed 982 (Enraf Nonıus Sonic Unit, the Netherlands) was applied using a model device at a frequency of 2500 Hz with a transition time of 400 µs. The position of the participants in the application and the placement of the electrodes were the same as the other application. The current intensity was increased until tetanic muscle contraction was obtained.

Isometric Exercise

Isometric exercises can be performed without the need for equipment. Compared to concentric contraction, the force that is released during maximum isometric contraction is greater than the force that occurs during the maximum concentric contraction. The most crucial advantage of isometric exercises is that the angle of articulated joint gains strength in the range of ±10° (25).

The body and knee of the participants in the isometric exercise group were positioned and stabilized at 75° flexion and 60° flexion angle, respectively as in the stimulation groups. Participants were asked to do 10 repetitions as 10 seconds of maximum voluntary contractions and 10 seconds of rest (11). Moreover, participants were performed isometric contractions by pushing against the other leg with maximum effort in the supine position.

Statistical Analysis

It was estimated that when 42 subjects were included in the study because of the power analysis performed (14 subjects in each group), 95% confidence and 90% power would be obtained. The data were analyzed using SPSS (SPSS Statistics for Windows, version 21.0 (SPSS Inc., Chicago, IL. , USA) program. The Shapiro Wilk test was used to test whether the data was appropriate for normal distribution. Continuous variables were given as mean±standard deviation, and categorical variables were given as number and percentage. Wilcoxon test was used for the data obtained at baseline and the end of the fifth week, and the Kruskal Wallis test was used to compare delta values. Significance level was accepted as $p<0.05$ in statistical test results.

RESULTS

The study included 46 young women with a mean age of 21.02±1.27 years, which was planned to compare the efficacy of HVPG, Russian currents, and exercise on quadriceps muscle strength enhancement in healthy women. However, 32 women completed the protocol (Figure 1). No

Table 1: Subject Characteristics.

Variables	HVPG (n=11) Mean±SD	Russian Current (n=11) Mean±SD	Isometric Exercise (n=10) Mean±SD	p
Age (Years)	20.63±1.68	21.09±0.94	21.20±1.13	0.074
Weight (kg)	59.18±12.15	56.45±8.39	58.10±9.67	0.776
Height (m)	1.64±0.59	1.63±0.51	1.61±0.69	0.603
BMI (kg/m²)	21.82±4.09	20.99±2.60	22.31±3.65	0.845

HVPG: High Voltage Pulsed Galvanic, BMI: Body Mass Index.

Table 2: Intragroup Analysis for Pre-Post Quadriceps Isometric Muscle Strength.

Variables	HVPG (n=11)			Russian Current (n=11)			Isometric Exercise (n=10)		
	Pre-Training	Post-Training	p	Pre-Training	Post-Training	p	Pre-Training	Post-Training	p
Peak Torque	157.00±25.13	172.18±27.41	**0.013***	147.63±30.21	157.18±29.79	**0.029***	156.60±26.90	164.10±28.38	**0.014***
Average Torques	138.54±28.30	154.81±27.92	**0.007***	130.54±29.45	141.45±30.72	**0.006***	137.50±26.00	148.90±28.22	**0.007***

*p<0.05. Wilcoxon Signed Rank Test. HVPG: High Voltage Pulsed Galvanic.

injuries were reported related to training. The participation rate in the treatment sessions was 95%. There was no statistically significant difference between the demographic data of the groups (p>0.05) (Table 1).

Results of comparison of post-training and delta values of groups

The quadriceps isometric muscle strength was significantly increased in all groups in terms of peak torque and average torque values after training compared to pre-training values (p<0.05) (Table 2). When comparing the peak torque and average torque delta values, it was found that there was no statistical difference between the groups in terms of peak torque (p=0.691) and average torque (p=0.901) delta values. The highest increase was found in the HVPG stimulation group (Table 3).

DISCUSSION

We found that three different methods were effective in increasing isometric muscle strength, but not superior to each other, in the result of this study evaluated by isokinetic method on isometric QF muscle strength of three different methods, HVPG, Russian currents and isometric exercise in healthy women participants.

In the literature, electrical stimulation in healthy individuals provided an increase in muscle strength (7-10,26-30). It has been determined that type II muscle fiber is selectively increased following muscle stimulation by electrical stimulation. Type II muscle fibers have more specialized resistance than type I muscle fibers, and selective increase in type II muscle fiber increases general muscle strength. In addition, a high amount of activity can be loaded into the muscles by activating large-scale motor units during muscle activation with electrical stimulation (31). Isometric exercise increase the motor unit synchronization 5%. Therefore, a higher power increase can be provided by increasing muscle potency (32).

Strength training can cause additional complications such as muscle spasms, fatigue and delayed muscle pain. It has been reported in the literature that 10 applications may be performed 2 or 3 times a week to reduce possible side effects (21). It has also been reported that in a study examining the effect of the frequency of exercise on muscle strength increase, three times a week, electrical stimulation was caused a significant increase (33). We planned our treatment to reduce these side effects to be three days a week with 10 repetitions.

When the efficiency of electrical stimulation to muscular functions is examined, the characteristic of the current is an important criterion. When the effect of the biophysical current and the Russian current applied on QF muscle on knee extension torque was compared, it has been found that they created similar effects (34). In another study, Currier et al. (1983) performed 15 sessions of

Table 3: Intragroup Analysis for Maximum Torque and Average Torque Change Values.

Variables	HVPG (n=11) Δ%	Russian Current (n=11) Δ%	Isometric Exercise (n=10) Δ%	p
Peak Torque	-10.14±11.54	-7.11±9.22	-4.00±4.85	0.691
Average Torques	-13.25±17.58	-8.99±9.77	-8.46±6.10	0.901

Kruskal- Wallis Test. HVPG: High Voltage Pulsed, Galvanic Δ%: Percentage Change.

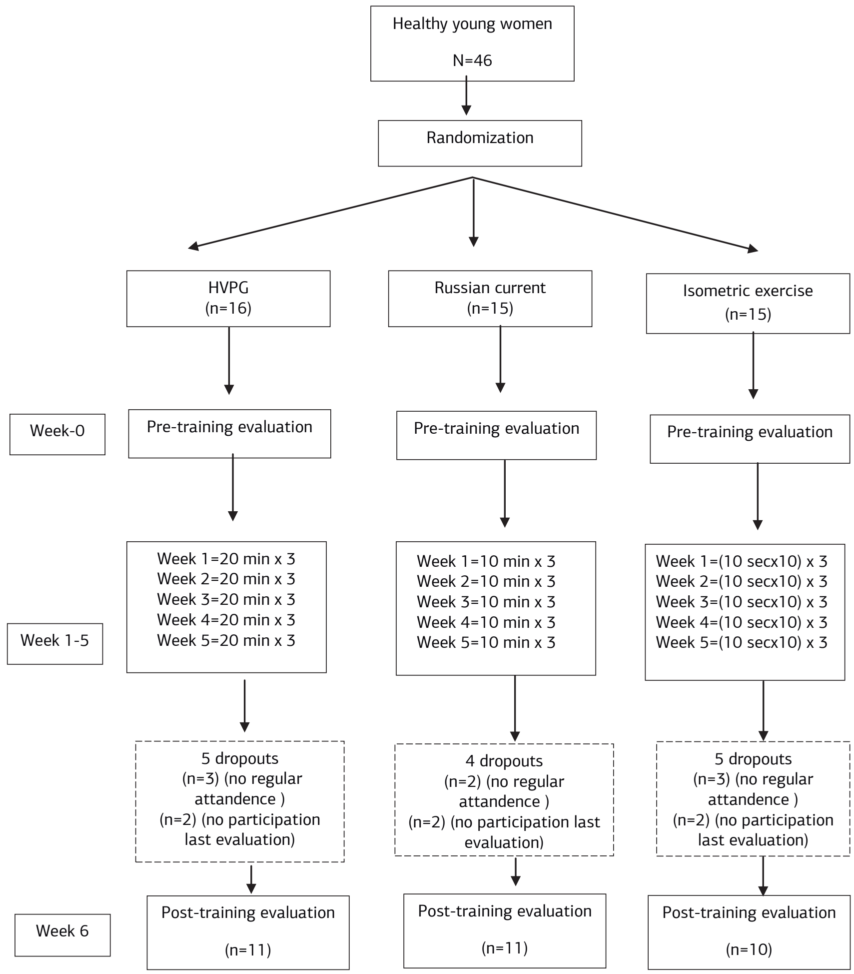

Figure 1: Flowchart of the Study. HVPG: High Voltage Pulsed Galvanic.

three sessions per week for five weeks in total to investigate the effects of electrical stimulation and isometric exercise on QF muscle of healthy individuals. The increase in strength was found in each training groups after the training. However, groups did not have any advantage over each other (3). The effectiveness of strength training on QF muscle with electrical stimulation and voluntary muscle contraction in Mayo Clinic Biomechanical laboratory, and the results were reported to be similar (10).

Taspinar et al. emphasized that electrical stimulation alone is not enough to increase muscle strength and that training programs involving voluntary muscle activation should be included in the rehabilitation program while there are studies in the literature reporting that electrical stimulation and exercise practices have similar effects (9).

In studies that the evaluations were performed with the isokinetic system, Bircan et al. applied strength training on QF muscle strength with interferential current and low frequency biphasic symmetrical current and have reported after four weeks of training that there was an increase in strength in both groups but no difference between the groups (35). Unlike our study, low and medium frequency currents were used in this study, and the change in isotonic muscle strength was evaluated with the isokinetic system. Baskan et al. obtained progression in terms of muscular strength, performance and isotonic muscle strength in the isokinetic system in both groups after Russian current and maximal voluntary isometric exercise on healthy QF muscle and have reported that both applications had no superiority to each other (7). The stimulation and exercise method used in this study is similar to ours; however, despite isometric training was given in order to increase strength, it was seen that isotonic strength in the isokinetic system was evaluated. In addition, in a recent study in the literature, eccentric training with and without NMES has been applied to improve the healthy QF muscle and isometric and eccentric strength increases in the isokinetic system have been evaluated (9). In our study, we evaluated the effect of 5-week isometric exercise and two different neuromuscular electrical stimulation applications on isometric force with the isokinetic system. Electrical stimulation may increase the isometric strength at different levels (4,36).

In the literature, it is seen that NMES and exercise applications are used to increase the strength in healthy QF, and the results created by NMES and exercise were similar. Our results are also parallel to this similarity.

We believe that the individual's current situation and needs are essential in deciding between the choice of NMES or exercise. For example, we believe that the use of NMES may be the reason for preference in preserving the functional state of the muscles in some cases such as surgical or traumatic conditions that require the immobilization process, in young children and older adults who are difficult to communicate, cannot properly concentrate on exercise. Isometric exercise has some advantages such as not requiring equipment, providing an increase in strength without adding the burden on joints in the early period after the injury, prevention of atrophy in long immobilization situations, especially in elderly individuals.

In the literature, it seems appropriate to use the HVPG current among the other currents to increase muscle strength due to the fact that it creates less variation compared to other currents on the biophysical properties of the skin such as skin temperature and elasticity (11). In our study, we did not obtain superiority between the two currents we used, Russian and HVPG. However, HVPG group has the highest rate of change in QF isometric muscle strength increase. Therefore; we recommend using it in clinical practice. The fact that our applications were made for five weeks, and the number of repeats in isometric exercise may be a limitation to show which groups are superior. We believe that it is necessary to plan studies with more sessions to determine the superiority of the applications relative to each other.

We determined the isometric strength increase in healthy QF by both HVPG and Russian current applications and isometric exercise method as a result of our study, and we see that these three applications have similar effects in terms of isometric muscle strength. Increased isometric muscle strength is an important parameter to maintain joint stability and to maintain muscle strength during injuries or early postoperative period and should be included in training and assessment methods..

Sources of Support: None.

Conflict of Interest: The authors declare no conflict of interest.

Ethical Approval: The study protocol was accepted by the Ethics Board for Clinical Research at Pamukkale University (Approval Date: 06.06.2017 and Approval Number: 2017-8).

Informed Consent: A written informed consent form was obtained from all participants.

Peer-Review: Externally peer-reviewed.

Author Contributions: Concept - BBÇ, EGK, FA; Design - BBÇ, EGK, FA; Supervision - BBÇ, FA; Resources and Financial Support - EGK, MB, FÜ; Materials - BBÇ, FA, FÜ; Data Collection and/or Processing - EGK, MB; Analysis and/or Interpretation - BBÇ, EGK, MB; Literature Research - BBÇ, EGK, MB; Writing Manuscript - BBÇ, EGK; Critical Review - BBÇ, EGK, FÜ.

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