Comparison of Different Quadriceps Femoris Isometric Strengthening Methods in Healthy Young Women

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Running Tittle: Comparison of Different Quadriceps Strengthening

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ABSTRACT

Background: It has been reported in previous studies that more motor units are fired with electrical stimulation than voluntary muscle contraction, and even high intensity currents provide 10-30% more contractions than voluntary muscle contraction.

Objective: 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 (mean age=21.02 ± 1.27). Before and after the training, the dominant side QF isometric muscle strength of participants was assessed with the Isokinetic Dynamometer (Humac Norm Testing Rehabilitation System, CSMI Medical Solutions, USA). The peak torque and average torques of the participants were recorded after the test. The training was planned as HVPG current for the the first group (n = 16), as Russian current for the second group (n = 15) and as isometric strengthening for the third group (n = 15). All treatments were performed under physiotherapist supervision for a total of 15 sessions for 3 days a week for 5 weeks.

Results: The peak torque and average torque delta values were calculated to determine the increase in isometric muscle strength of Quadriceps Femoris. No statistical difference was found between the groups when the peak torque and average torque delta values were compared ($p > 0.05$).

Limitations: The number of participants and duration of follow-up were inadequate to determine can help to future resarchs.

Conclusions: The highest rate of change belongs to the HVPG group in terns of increasing the Quadriceps Femoris isometric muscle strength, therefore, we recommend that it is preferred in clinical practice.

Keywords: Quadriceps femoris, isometric force, HVPG, Russian current, Exercise

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] A 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 QF muscle strength of healthy subjects. [7-11]

Faradic current, Russian current and HVPG currents are frequently used clinically for the purpose of strengthening the healthy muscle by electric stimulation. If the frequency of the current is high enough, tetanic muscle contraction can be obtained, 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 (1000µs) and the short number of pulses (1-60 pulses / sec). [13] 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.

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 maximal voluntary contraction of the muscle by 40% This technique provides maximum strength gain without fatigue due to long rest period.[13]

HVPG current is a new form of neuromuscular electrical stimulation. This current began to be widely used in the 1970's.[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 tolarated. The greatest advantage of the HVPG current is that it has a higher electrical motion gain than other methods. Thanks to this low impedance due to its superiority, it penetrates the skin more easily and depolarizes the nerve fibers and provides continuity of tissue healing. [16-17] When compared to other neuromuscular stimulators, high-voltage intermittant current has the advantage of high electrical mobility which is the voltage. Due to its low impedance, it penetrates the skin more easily and can be better tolarated. Because of the high voltage, the 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 a spesific muscle or muscle groups. It has been reported that the contraction should be continued for 3-10 seconds in order to increase the strength.[19-20]

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. (2011) applied isometric exercise training and Russian flow to strengthen the QF muscle and assessed the strength increase as concentric force in isokinetic system while Silva et al. (2018) has performed isometric and eccentric force evaluation in isokinetic system after eccentric training with NMES and NMES alone.[7,8] Romero et al. (1982) found that isometric muscle strength increased by 31% in the isokinetic system after electrical stimulation in healthy subjects.[21] However, we did not find a study evaluating the isometric strength increase of the QF muscle with isokinetic system by applying two different NMES and isometric exercise methods. For this reason, we used methods that increase muscle isometric strength, such as Russian current, HVPG current and isometric exercise, to increase QF muscle strength in healthy women and evaluated we evaluated isometric force parameter wiht the isokinetic system.

MATERIALS AND METHODS

Forty-six healthy women (mean 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 with the Isokinetic Dynamometer (Humac Norm Testing Rehabilitation system, CSMI Medical Solutions, USA). Participants were divided into three groups for training purposes (Figure 1). The training was performed on the dominant side QF muscle. The training was planned as HVPG current for the 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. Russion 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 3 days a week for 5 weeks. Demographic data are given in Table 1.

Inclusion criteria for the study:

- 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 from the study:

- 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:

- Those who can not complete the assessment.
- Those who have any disease status in the evaluation and training process.
- Those who have started to do sport regularly during the training period.
- Those whose date were incomplete.
- Those who do not participate 75% of the training.

The ethical approval of the study was taken at the Ethics Committee of Non-Interventional Clinical Researches of Pamukkale University at the meeting no. 08 dated 06.06.2017. All participants were informed verbally and an informed consent form was signed.

Evaluation

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 same with QF isometric muscle strength measurement protocols. Then participants QF isometric muscle strength was measured by three 10-second maximal isometric contraction. 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:

HVPG, was applied by using “Endomed 982”. The instrument was automatically set to a pulse rate of 100 µs while the pulse frequency was set to 60 pulses / sec. In order to avoid fatigue, the intermittant form of the current was selected and the transition time / rest time was set to 4 sec. impulse / 12 sec. 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 6 * 8 cm carbonated electrodes was placed in the distal portion of the vastus medialis, while the other one was placed in the proximal portion of the vastus lateralis. This placement was intended to stimulate a large proportion of the muscle fibers of the QF muscle.[22] The HVPG was applied for a total of 20 minutes. Current intensity was increased to obtain optimal muscle contraction.

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 a resting time of 50 seconds were given for the next contraction (transition: rest ratio was 1/5).[13] Russian current “Endomed 982” 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 same as the the other application. Current intensity was increased until tetanic muscle contraction was obtained.

Isometric Exercise:

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.

Statistical analysis:

The data was analyzed by SPSS (version 21.0) packet 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. The Wilcoxon test was used for the data oblatined at baseline and at the end of 5th 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. But 32 women completed the protocol (Fig. 1). No injuries were reported related with 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

It was 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, it has been shown in many studies that electrical stimulation in healthy individuals provided an increase in muscle strength.[7-10, 23-25] 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.[26] It has also been reported that with isometric exercise the motor unit synchronization can be increased by 5%, thus a higher power increase can be provided by increasing muscle potency.[27]

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.[20] 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 casused significant increase.[29] 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.[30] In another study, Currier et al. (1983) performed 15 sessions of 3 sessions per week for 5 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 clinical biomechanical laboratory and the results were reported to be similar.[10]

Taspinar et al. (2011) 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.[8]

In studies that the evaluations were performed with the isokinetic system; Bircan et al. (2002) applied strenght training on QF muscle strenght 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.[31] Unlike our study, low and medium frequency currents were used in this study and the change in muscle isotonic strength was evaluated with the isokinetic system. Baskan et al. (2011) 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 was applied to improve the healthy QF muscle and isometric and eccentric strength increases in the isokinetic system were 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. It has been reported in the literature that electrical stimulation may increase the isometric strength at different levels. [32,33]

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 important 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 elderly people who are difficult to communicate, can not concentrate enough to exercise. Isometric exercise; have 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 that it creates less 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 that it can be preferred in clinical practice. We believe that it is necessary to plan studies with more sessions to determine the superiority of the applications relative to each other.

CONCLUSION

We determined the isometric strength increase in healthy QF by both NMES 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.

References

1- Maffiuletti NA, Zory R, Miotti Det al. Neuromuscular adaptations to electrostimulation resistance training. *Am J Phys Med Rehabil* .2006; 85: 167 175.

2- Miller M, Downham D and Lexell J. Superimposed single impulse and pulse train electrical stimulation: a quantitative assessment during submaximal isometric knee extension in young, healthy men. *Muscle Nerve* .1999; 22: 1038–1046.

3- Currier DP, Mann R. Muscular strength development by electrical stimulation in healthy induviduals. *Phys Ther* .1983, 63(6):915-21.

4- Massey BH, Nelson RC, Sharkey BCet al. Effects of high frequency electrical stimulation on the size and strength of skeletal muscle. *J Sports Med Phys Fitness.* 1965,5:136-144.

5- Eriksson E, Haggmark T, Kiessling KHet al. Effect of electrical stimulation on human skeletal muscle. *Int J Sports Med*. 1981,4:18-22.

6- Halbach JW, Straus D. Comparison of electro-myo stimulation to isokinetic training in increasing power of the knee extensor mechanism. *J Orthop Sports Phys Ther.* 198,2:20-24.

7- Baskan E, Cavlak U, Yildiz HH. Comparison of electrical stimulation and isometric training on isokinetic strength of knee extensors: A randomized clinical trial. *Pak J Med Sci* .2011;27(1):11-15

8- Taspınar F, Bas Aslan U, Taspınar B. Evaluating the effects of different strength training techniques on anthropometric structure and endurance of healthy quadriceps femoris muscle. *J Med Sci*. 2011, 11: 274-279.

9- Silva CFG, Silva FXL, Vianna KBet al. Eccentric training combined to neuromuscular electrical stimulation is not superior to eccentric training alone for quadriceps strengthening in healthy subjects: a randomized controlled trial. *Braz J Phys Ther.* 2018, https://doi.org/10.1016/j.bjpt.2018.03.006

10- Laughman, RK, Youdas JW, Garrett TR, Chao EY. Strength changes in the normal quadriceps femoris muscle as a result of electrical stimulation. *Phys Ther.* 1983, 63.4: 494-499.

11- Mohr T, Carlson B, Sulentic C, Landry R. Comparison of isometric exercise and high volt galvanic stimulation on quadriceps femoris muscle strength. *Phys Ther.* 1985, 65.5: 606-609.

12- Bellew JW, Sanders K, Schuman K, Barton M. Muscle force production with low and medium frequency burst modulated biphasic pulsed currents. *Physiother Theory Pract*. 2014, 30.2: 105-109.

13- Bélanger, A. *Therapeutic electrophysical agents: evidence behind practice*: Philadelphia Wolters Kluwer Health/Lippincott Williams & Wilkins, 2010.

14- Balogun JA, Onilari OO, Akeju OAet al. High voltage electrical stimulation in the augementation of muscle strength: effects of pulse frequency. *Arch Phys Med Rehabil.* 1993,74:910-916.

15- Nelson, R. Hayes K, Currier, D. *Clinical electrotherapy*: Appleton & Lange.1999

16- Werner, Y. The water content of the stratum corneum in patients with bound-water modulator. J Invest Dermatol (in press) atopic dermatitis: Measurement with the corneometer CM, 420.22: 66281-284.

17- Draaijers LJ., Botman YA., Tempelman FR.et al. (2004) Skin elasticity meter or subjective evaluation in scars: a reliability assessment. *Burns.* 2004, 30.2: 109-114.

18- Zuluaga M. Sports physiotherapy: applied science and practice. Churchill Livingstone, 1995.

19- Kishner C, Colby AL Borstad, J. *Therapeutic Exercise. Foundations and Techniques.* F.A. Davis Company. Philadelphia, 2007, 928.

20- Baskan E, Cavlak U, Telli O. The effect of maximal isometric contraction training in various knee positions on physical capacity of healthy Quadriceps Muscle. Sports Medicine Journal 2006, 8:464-469.

21- Romero JA, Sanford TL, Schroeder RVet al. The effects of electrical stimulation of normal quadriceps on strength and girth. *Med Sci Sports Exerc*. 1982, 14.3: 194-197.

22- Bickel CS, Slade JM, Warren GL. Fatigability and variable-frequency train stimulation of human skeletal muscles. *Phys Ther* 2003.83(4);366-73.

23- Gondın, JM. Guette YB, Martın A. Electromyostimulation Training Effects on Neural Drive and Muscle Architecture. *Med. Sci. Sports Exerc.* 2005, 37.8:1291-1299.

24- Holcomb WR. Is Neuromuscular Electrical Stimulation an Effective Alternative to Resistance Training? *Strength Cond J.* 2005, 27.3: 76.

25- Miller M, Flansbjer UB, Downham D, Lexell J. Superimposed electrical stimulation: assessment of voluntary activation and perceived discomfort in healthy, moderately active older and younger women and men. *Am J Phys Med Rehabil,* 2006, 85.12: 945-950.

26- Lake DA. Neuromusculer electrical stimulation and its application in the treatment of sports injuries. *Sports Med.* 1992, 13(5), 320-36.

27- Babault N, Pousson M, Ballay Y, Van Hoecke J. Activation of human quadriceps femoris during isometric, concentric, and eccentric contractions. *J Appl Physiol*. 2001, 91: 2628- 2634.

28- Feigenbaum MS, Pollock ML. Prescription of resistance training for health and disease. *Med Sci Sports Exerc.* 1999,31:38–45.

29- Parker MG, Bennett MJ, Hieb MA, Hollar AC., Roe AA. Strength Response in Human Quadriceps Femoris Muscle During 2 Neuromuscular Electrical Stimulation Programs. *J Orthop Sports Phys Ther*. 2003,33.12:719-726.

30- Holcomb WR., Golestani, S., Hill S. A Comparison of Knee-Extension Torque Production with Biphasic Versus Russian Current. *J Sport Rehabil.* 2000, 9.3: 229-239.

31- Bircan C, Senocak O, Peker Oet al. Efficacy of two forms of electrical stimulation in increasing quadriceps strength: A randomized controlled trial. *Clin Rehabil.* 2002;16(2):194-199.

32- Johnson DH, Thurston P, Ashcroft PJ. The Russian techniques of faradism in the treatment of chondromalacia patellae. *Physiotherapy Canada*. 1977,29:266-268.

33- Massey B, Nelson R, Sharkey B, Comden T. Effect of high frequency electrical stimulation on the size and strength of skeletal muscle. *Sports Med Phys Fit*. 1965, 5: 136-144.

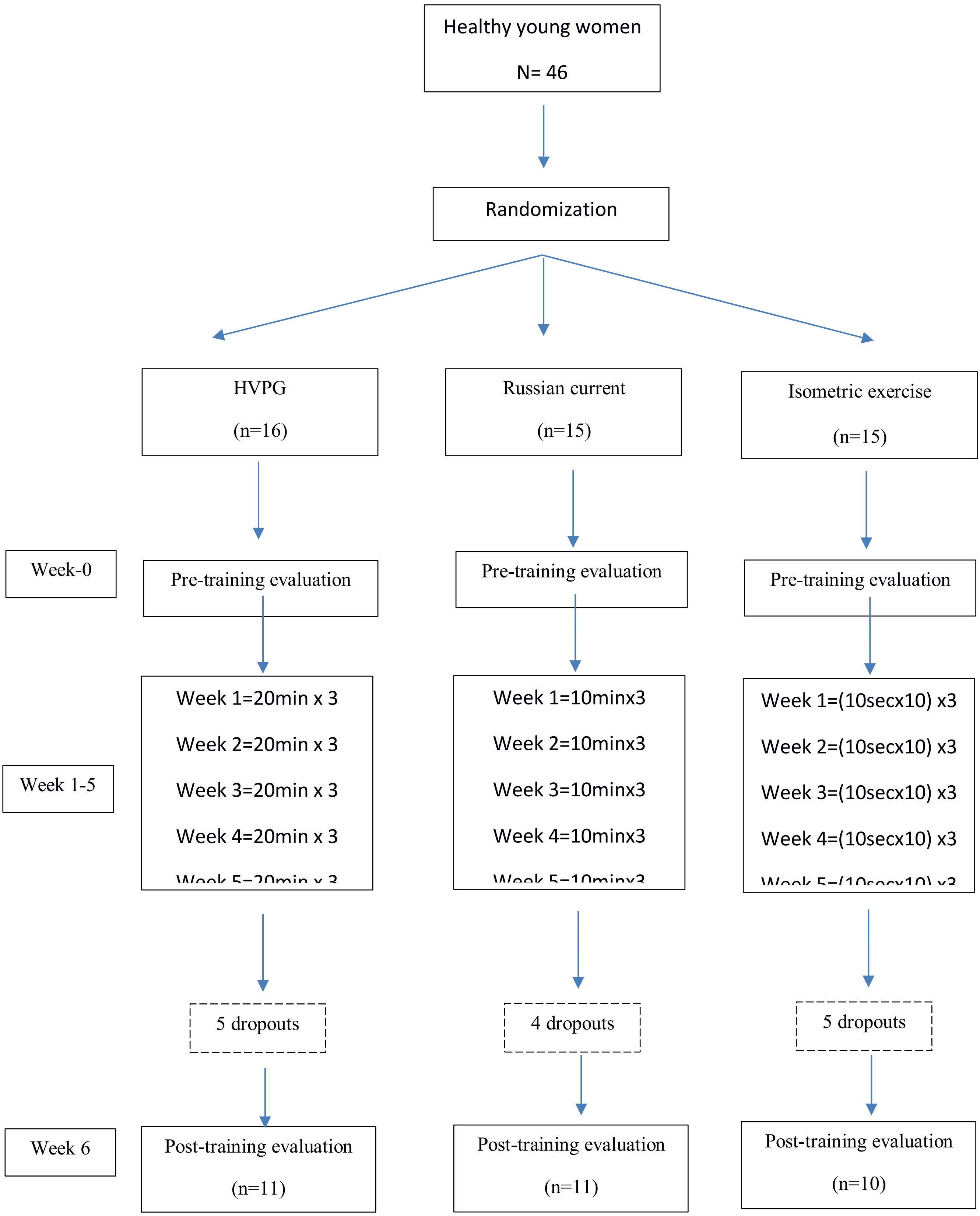

Figure1: Flowchart of the study.

Table 1: Demographic data

	HVPG (n=11)	Russian current (n=11)	Isometric exercise (n=10)
Age (Years)	20.63± 1.68	21.09 ± 0.94	21.2 ± 1.13
Weight (kg)	59.18 ± 12.15	56.45 ± 8.39	58.1 ± 9.67
Height (m)	1.64 ± 0.59	1.63 ± 0.51	1.61 ± 0.69
BMI (kg/m²)	21.82 ± 4.09	20.99 ± 2.60	22.31 ± 3.65

BMI: Body mass index, HVPG: High Voltage Pulsed Galvanic

Table 2: Intragroup analysis for pre-post quadriceps isometric muscle strength

	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 ± 25.13	172.18 ± 27.41	0.013*	147.63 ± 30.21	157.18 ± 29.79	0.029*	156.60 ± 26.9	164.1 ± 28.38	0.014*
Average torques	138.54 ± 28.3	154.81 ± 27.92	0.007*	130.54 ± 29.45	141.45 ± 30.72	0.006*	137.5 ± 26	148.9 ± 28.22	0.007*

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

Table 3: Intragroup analysis for maximum torque and average torque delta values

	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	-4.0±4.85	0.691
Average torques	-13.25±17.58	-8.99±9.77	-8.46±6.1	0.901

HVPG: High Voltage Pulsed,Galvanic Δ%: percantage change Kruskal- Wallis Test