A Randomized Control Trial to Compare the Effects of Russian Currents and Strengthening Exercises in Asymptomatic Young Adults

Shivani Chowdhury Salian (PT) [1], Nikita Hingane [2], Sujata Yardi [3]

[1]Associate Prof, Department of Physiotherapy, Padmashree, Dr. D. Y. Patil University

[2]Physiotherapist, MPT (Musculoskeletal), Colorado Springs, Colorado, USA

[3]Director and Professor, Department of Physiotherapy, Padmashree. Dr. D. Y. Patil University

Abstract: ***Study Design:*** ***Unicentre, Sequential, randomized controlled experimental clinical open label trial.*** ***Objective:*** ***To examine the effectiveness of Russian current and MacQueen's progressive resistance exercise for quadriceps femoris muscle bilaterally.*** ***Background:*** ***Russian forms of electrical stimulation became popular to a large extent as a result of the activities of Kots, who claimed force gains of up to 40% in elite athletes as a result of what was then a new form of stimulation. EMS in combination with voluntary exercise has also been shown significantly effective in increasing strength in asymptomatic subjects and in those recovering from reconstructive surgery. Comparing studies and drawing valid conclusions concerning the use of EMS is difficult because of inadequate standardization of experimental procedures. This study, therefore, was prompted to assess the effects of Russian currents and to compare strength training modes on improving Quadriceps muscle strength and width in asymptomatic young adults.*** ***Methods:*** ***63 physiotherapy students, 18 to 25 years, studying in Department of physiotherapy, Pad. Dr.D.Y.Patil University, selected randomly, out of which there were only 3 male subjects. a period of 1 year. The subjects were assigned randomly to one of the three groups (n=21, N=63); receiving - Russian currents only, Exercise only, and combination of both. Isometric strength of the bilateral quadriceps femoris muscle was obtained using the hand-held Baseline Push-pull Dynamometer. Ultrasound cross-sectional images of the quadriceps muscle at mid-thigh level bilaterally were obtained from the Department of Radiology, D Y Patil Hospital and Research Centre. The Intervention groups obtained electrical stimulation of the muscle. For strengthening group, MacQueen's progressive resistance regimen was used. At the end of six weeks the isometric strength and ultrasonographic width measurements for Quadriceps femoris muscle bilaterally were obtained for each subject.*** ***Analysis and Result:*** ***All analysis was conducted with SPSS, Version 16.0. P was set at 0.05 and differences were considered significant if p< 0.05. There was a statistically significant difference in the ultra-sonographic width and isometric strength of quadriceps femoris muscle measured bilaterally in all the three experimental groups. Combination therapy is more effective than electrical muscle stimulation alone or strength training exercises alone in increasing the width of Quadriceps muscle. However, there is no statistical difference between the three groups in increasing the strength of Quadriceps muscle bilaterally.*** ***Conclusion:*** ***This clinical trial provides evidence that the three techniques employed in our study viz., Electrical Muscle Stimulation (Russian Currents), strength training exercises and combination of both are effective in improving the muscle strength as well as the width of quadriceps femoris muscle bilaterally in asymptomatic young adults. Furthermore, this study has challenged the findings of many authors claiming that Russian Currents when combined with exercises does not provide the desirable effects in young healthy athletes. From the results, combination therapy is more effective than electrical muscle stimulation alone or strength training exercises alone in increasing the width of quadriceps muscle. However, there is no statistical difference between the three groups in increasing the strength of quadriceps muscle bilaterally. Therefore, we would rightly place strength training exercises regimen as the supreme most technique to increase muscular strength in asymptomatic young adults.***
Level of Evidence: ***Therapy, level I***

Keywords: Quadriceps Femoris muscle, Russian Currents, MacQueen's Progressive Resistance Exercise, ultrasound imaging techniques, asymptomatic healthy individuals.

1. Introduction

Electrical stimulation is the use of electricity to obtain desired physiologic responses for the assessment or care of diseases and injuries in humans. Electrical muscle stimulation or electric motor stimulation (EMS) is the application of electric current to elicit a muscle contraction. Contraction of the muscle with EMS is different than the voluntary contraction of the muscle initiated by the central nervous system[30]. Electrical stimulation is used extensively in physiotherapy and "Russian currents" have been advocated for use in increasing muscle force[40, 41]. This form of electrical stimulation seems be least understood in terms of physiological effects.

Russian currents are alternating currents (AC) at a frequency of 2.5 KHz that are burst modulated at a frequency of 50 Hz with a 50% duty cycle. The stimulus is applied for a 10-second "on" period followed by a 50-second "off" or rest period, with a recommended treatment time of 10 minutes per stimulation session[40].

This stimulation regimen (called the"10/50/10" regimen), applied once daily over a period of weeks, has been claimed to result in force gains, but many of the claims appear to be anecdotal22. Selkowitz40 has reviewed the experimental evidence in the English-language literature for increasing muscle force by use of Russian electrical stimulation. He concluded that there is convincing evidence for increased muscle force, but little evidence that the force gains were greater than those produced by voluntary exercise or a combination of exercise and electrical stimulation. He also noted that the studies he reviewed may not have had sufficient statistical power to distinguish among the conditions that were compared. He also contended that there is insufficient evidence to distinguish force enhancements produced using Russian electrical stimulation from those produced by other forms of electrical stimulation. In recent years however, researchers have shown renewed interest in EMS technique as means for improving the strength capability of muscles both normal as well as diseased. Particularly the interest was sparked since the Russian investigator Kots presented his findings on superiority of EMS to voluntary exercise in developing muscle strength. Dr Kots has claimed rapid and significant strength gain in highly trained athletes undergoing EMS based programes22.

The results of studies using EMS have been reported widely in the scientific literature. EMS has been shown to increase strength in asymptomatic subjects 2,4,11,23,24,25,29,31,41 EMS in combination with voluntary exercise has also been shown significantly effective in increasing strength in asymptomatic subjects 16, 20 and in those recovering from reconstructive surgery 38, 43,48,49,18 reported positive effects of EMS on width measurement12. Studies on patient group have had more positive results showing electrical stimulation to be an effective rehabilitation modality. However 25,7,5,27 demonstrated no. Studies not only claimed that the electrically generated force was greater than that generated voluntarily but also that this occurred without producing pain. This claim has not been entirely supported either; in one careful study which assessed torque values and pain scores 12, 3 the assertions were definitely refuted. Many investigations have determined that electrical muscle stimulation leads to muscle hypertrophy but not to any greater degree than voluntary activity5. Questions remain, however, as to whether and to what extent “Russian currents” may be more effective in improving the muscle strength in asymptomatic healthy individuals. In the past, the use of Progressive Resistance Exercise for the restoration of the muscle power and volume after injury was first described by De Lorme in 1945. The poundage is determined by testing the Repetition Maximum (RM) for a given number of repetitions 26.

Imaging techniques are available which permit the estimation of the cross sectional area of individual muscles or muscle groups. Ultrasound has been used in many morphometric studies of the human quadriceps muscle. Ultrasound cross-sectional images in this study were obtained using Siemens Acuson X 300 sonography machine16.

Comparing studies and drawing valid conclusions concerning the use of EMS is difficult because of inadequate standardization of experimental procedures. Also most of the studies have been performed without benefit of an electrical stimulator. This study, therefore, was prompted to assess the effects of Russian currents and to compare it with strength training modes of quadriceps muscle strength and changes in the cross-sectional area of the same.

The past studies aimed and looked at the effects of electrical stimulation causing an increase in the strength of the muscles and the ones which measured changes in the circumferential girth of the quadriceps muscle not yielding many changes. While our study looked at not only increments in the strength but also the cross sectional area of quadriceps muscle. This would definitely enable therapists to mark their priorities pertaining to rehabilitation goals in sports personnel as well as patient population.

1.1 Design

A randomized controlled trial was conducted. Informed consent was obtained from all participants, and the study protocol was conducted according to the Declaration of Helsinki. The protocol was approved by the Ethics department of Pad. Dr. D. Y. Patil University, Nerul, Navi Mumbai, before starting the study.

1.2 Participants

Sixty three young asymptomatic participants aged between 22 to 25 years, were recruited for the study from January 2012 to February 2013. Before enrolling the subjects for the study they were made to sign a subject information sheet and a written consent was obtained from each subject before proceeding with the procedures. Subjects with any neurological and orthopaedic impairment and any subject presenting with contraindication for electrical muscle stimulation were excluded from enrolling for the study. Each patient underwent subjective and physical examination performed by a physiotherapist experienced in Musculoskeletal Physiotherapy and was evaluated for inclusion/exclusion in the study. The experiment was carried out in the musculoskeletal department of the Physiotherapy institute itself. Pre-test evaluation was carried out prior to beginning the experiment and after the allocation of groups.

1.3 Objectives

In the current study we tested the hypothesis that would evaluate the efficacy of Russian currents alone, in changing the isometric strength and the cross sectional area of quadriceps muscle. Progressive resistance exercise alone (MacQueen’s) on quadriceps Femoris muscle strength and width and combination of Russian currents and strengthening exercises on Quadriceps Femoris strength and cross sectional area, in asymptomatic young adults.

2. Materials and Methodology

Assessment of the recruited subjects was done using a Hydraulic Baseline push-pull Dynamometer. Ultrasonographic images were procured through the Radiology Department in of Pad. Dr. D. Y. Patil Hospital and Research Centre, Nerul, Navi Mumbai. A dual channel Chattanoga Combo machine was incorporated for application of Russian currents, while a Quadriceps strengthening- Leg extension chair was used for strengthening regime.

Methodology: (refer Fig-1) All the necessary approvals were taken from the Ethics department of Pad. Dr. D. Y. Patil University, Nerul, Navi Mumbai, before starting the study. The subjects were assigned randomly to one of the three groups; for allocation of the participants, a computer-generated randomly selected subset of subjects was used.
Randomization

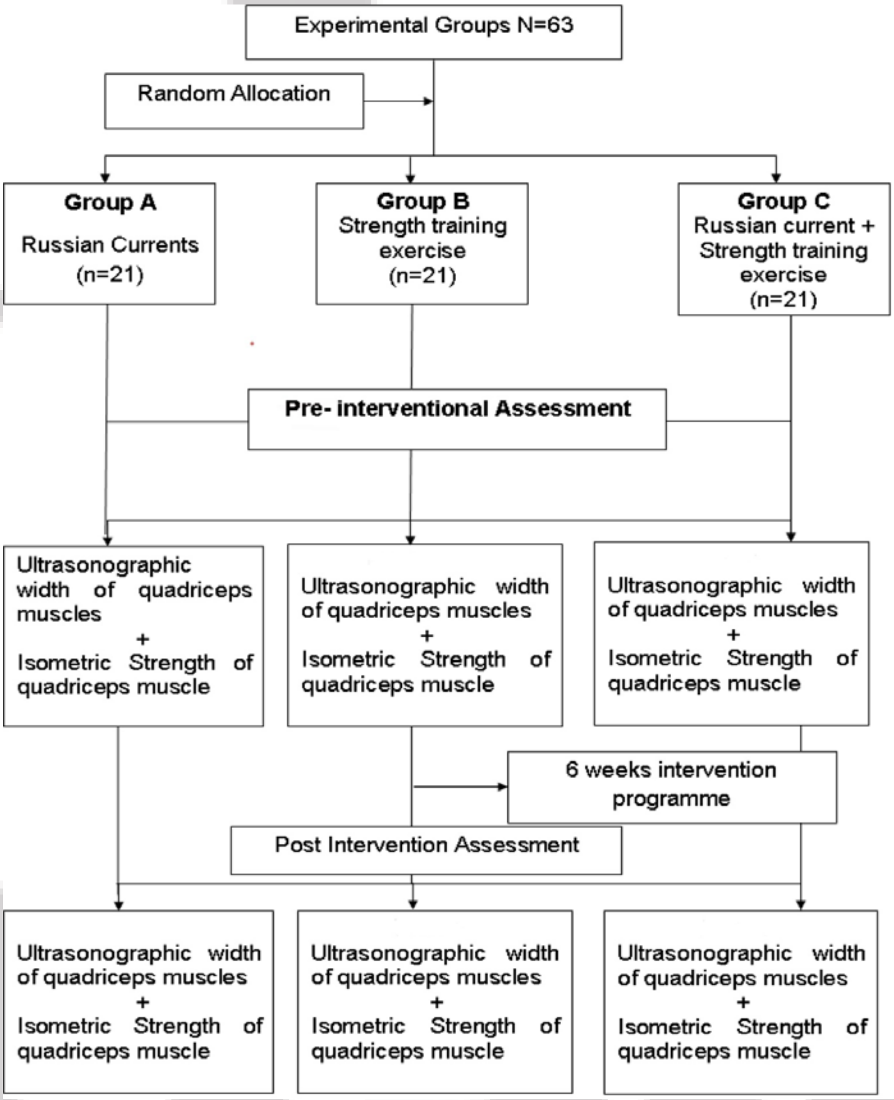
After the completion of all baseline measurements the subjects were assigned randomly to one of the three groups; using a computer generated randomly selected subset of subjects was used. (http://www.graphpad.com/quickcalcs/randomize1.cfm)

- **Group A-** Russian currents only.
- **Group B**- Exercise only.
- **Group C-** Russian + Exercise only.

Table 1: Demographic information of subjects enrolled in the experiment

Descriptive Statistics*			
	Group A – Russian Currents	Group B – Exercise	Group C Russian Currents + Exercise
	n=21	n=21	n=21
Age	22.33333 ±0.912871	22.52381 ±0.511766	22.38095238 ±0.669043382
BMI	23.66364 ±4.536366	23.23763 ±2.85364	21.43039357 ±1.759561798

Abbreviations: BMI, Body Mass Index; n, Number of subjects
*Data presented as Mean ± SD



Flowchart 1: Methodology Flowchart

The experiment was carried out in the musculoskeletal department of the Physiotherapy institute itself. Pre-test evaluation was carried out prior to beginning the experiment and after the allocation of groups. Demographic details (Table 1) of each and every subject were collected using the subject evaluation sheet.

2.1 Outcome Measures

The subjects underwent the following evaluation tests:

1. ***Isometric strength***: Isometric strength of the bilateral Quadriceps femoris muscle in Kg was obtained using the Hydraulic hand-held Baseline Push-pull Dynamometer. The subject was seated on a quadriceps strengthening chair. The dynamometer was placed just above the ankle joint inferiorly over the shin of the tibia[6]. All subjects attempted three maximum isometric contractions; the highest value was recorded and used in the analysis [46,7]. (Figure: 2)

Figure 2: Isometric strength assessment using push pull dynamometer.

2. ***Ultrasonography imaging:*** Ultrasound cross-sectional images were obtained using Siemens Acuson X 300 ultrsonography machine from the Department of Radiology, D Y Patil Hospital and Research Centre. Repeated single sweep scans were taken with 8 MHz transducer, until the image resolution was adequate for identifying the subcutaneous fat muscle and the muscle bone interfaces. The thickness of the quadriceps muscle in cm was determined by measuring the distance directly perpendicular to the horizontal surface of the limb between the femur and the muscle fat interface. (Figure: 3)

The readings were taken at mid-thigh level bilaterally[16,42,45] the isometric strength and ultrasonographic measurements of width of Quadriceps femoris muscle bilaterally were obtained for each subject at baseline and at the end of six weeks. The sequence of testing for the outcome measures was randomized among participants.

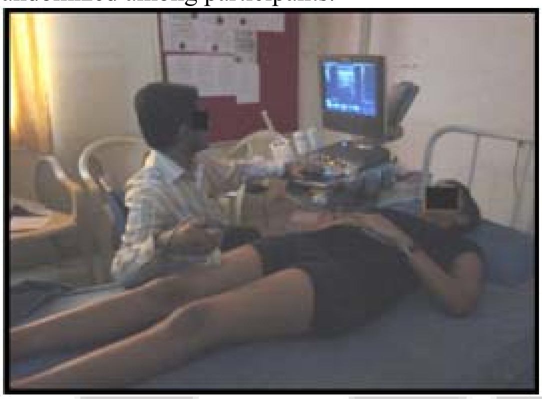


Figure 3: Assessment of width of Quadriceps muscle measured using Ultrasonography imaging technique.

3. Intervention

3.1 Electrical stimulation

The subjects of Group A and Group C underwent muscle stimulation using a Chattonoga Combo machine that provided Russian electrical stimulation. The stimulator produced 50 burst per second i.e. 10 ms burst of 25 cycles each with 10 ms intervals between each burst, with a 50% duty cycle. The stimulus is applied for a 10-second “on” period followed by a 50-second “off” or rest period, with a recommended treatment time of 10 minutes per stimulation session. This stimulation regimen called the “10/50/10” regimen[50,43,3]. One stimulating electrode was placed over the femoral triangle at the upper anterior one-third of thigh and strapped with micropore tape, while the other electrode was placed distally over the thigh 5-7 cm proximal to upper border of patella [35,47,7]. Square flexible conductive rubber electrodes were used, and an aquasonic gel was used between the skin and electrode as conducting medium. The current intensity was regulated for maximum tetanic contraction within the limits of tolerance for each subject. There were 3 sessions a week over a 6- week period.

Figure 4: Electrical Stimulation

3.2 Strength training Program

The strengthening program included MacQueen’s progressive resistance regimen which included the use of 10RM. It included 40 lifts with 10RM over a period of 6 weeks. 10RM was progressed every 1-2 weeks[26]. The subject was positioned as shown in the figure to the right.

3.3 Post Intervention

At the end of six weeks the isometric strength and ultrasonographic measurements of width of Quadriceps femoris muscle bilaterally were obtained for each subject.

3.4 Statistical Analysis

All analysis was conducted with SPSS for Windows, Version 16.0. The Kolmogorov-Smirnov test showed a normal distribution of the data. Comparison of isometric strength and ultrasonographic girth within the same group was done by paired T-Test. Similarly for comparison between the groups of Russian current only, exercise only and Russian current + exercise; one way ANOVA was performed. A Bonferoni correction for multiple comparisons was used for post HOC analysis. P was set at 0.05 and differences were considered significant if P value was less than 0.05.

3.5 Results (Refer table 8, table 9, table 10 & table 11)

A total of 63 age and sex matched, asymptomatic subjects between the age group of 18-25 years satisfied all eligibility criteria, agreed to participate, and were randomized to the control Group B (n = 21) or experimental A (n = 21) or experimental group C (n = 21) FIGURE 1 provides a flow diagram of subject recruitment and retention through the study. Results obtained from the statistical analysis revealed a statistically significant difference in the isometric strength and ultrasonographic width denoting the cross-sectional area of Quadriceps femoris muscle bilaterally in all the three groups individually.

Figure 5: Ultrasound images of width of Rt. Quadriceps Pre and Post intervention showing pre intervention width as 22.4 mm and post intervention as 24 mm

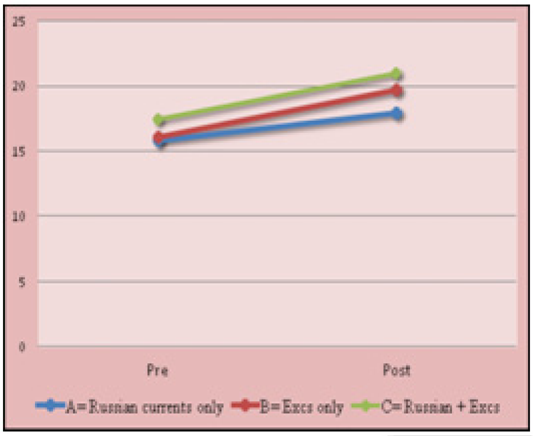
Figure 6: Ultrasound images of width of Lt. Quadriceps Pre and Post intervention showing pre intervention width as 22.5mm and post intervention as 27.4 mm

Table 2: Mean and Standard Deviation of Isometric Strength of left Quadriceps femoris muscle.

Isometric Strength Left Quadriceps			
		Mean (Kg)	*Standard deviation*
Group A	Pre	15.9048	4.35781
	Post	18	4.24264
Group B	Pre	15.7143	3.1803
	Post	18.7619	3.12897
Group C	Pre	16.5714	3.64104
	Post	20.4762	4.14269

Table 3: Mean and Standard Deviation of Isometric Strength of Right Quadriceps femoris muscle.

Isometric Strength Right Quadriceps			
		Mean (Kg)	*Standard deviation*
Group A	Pre	15.8095	3.94486
	Post	18	3.52136
Group B	Pre	16.0952	2.99841
	Post	19.7143	3.36367
Group C	Pre	17.4286	3.47234
	Post	20.9524	3.98091



The readings showing extremely significant values, p=0.00 for ultrasonographic readings and p=0.003 for isometric strength of quadriceps muscle bilaterally in all the three groups. For comparison between the groups of Russian current only, exercise only and Russian current + exercise; one way ANOVA was performed. A Bonferoni correction for multiple comparisons was used for post HOC analysis. It is also evident that there is a statistical significant difference between the Combination therapy group C and the other two groups in increasing the ultrasonographic width of Quadriceps muscle bilaterally. Thus, we accept the alternative hypothesis that Combination therapy is more effective than electrical muscle stimulation alone or strength training exercises alone in increasing the width of Quadriceps muscle. There is no statistical difference between the three groups in increasing the strength of Quadriceps muscle bilaterally.

4. Discussion

This randomized controlled trial examined the efficacy of Russian currents compared to strengthening exercises for improving Quadriceps muscle strength and width in asymptomatic young adults. A total of 63 age and sex matched, asymptomatic subjects between the age group of 18-25 years were recruited and assigned randomly to the three groups. The results of isometric strength of Quadriceps femoris muscle was assessed objectively with the help of Push- pull dynamometer and the width of the muscles measured ultrasonographically confirmed the significant gains in this study in all the three defined groups.

Statistically, there was a significant difference in the ultrasonographic width and isometric strength of Quadriceps femoris muscle bilaterally in all the three groups. (Tables 8, 9, 10). One way ANOVA and Post HOC analysis showed there exists a statistical significant difference between the combination therapy group C and the other two groups in terms of increment of ultrasonographic width of quadriceps muscle bilaterally. However there is no statistical difference between the three groups in increasing the isometric strength of quadriceps muscle bilaterally. On an average the group who received Russian currents (group A) alone showed an improvement of 7.4% on right and 7.9% on left side as compared to exercise only group (group B) which showed an improvement of 5% on right and 4.3% on left whereas the group which performed strengthening exercises as well as received Russian currents for Quadriceps femoris muscles showed an improvement of 14.2% on right and 14.4% on left in the width of Quadriceps femoris muscles measured objectively ultrasonographically. Also isometric strength assessed using push-pull dynamometer showed an average improvement of 12.6% on right and 11.4% on left in the group A whereas group B showed an improvement of 18.2% on right and 16.6% on left and group C showed an average of 16.9% on right and 18.1% on left.

Table 4: Mean and Standard Deviation of Ultrasonographic width of left Quadriceps muscle.

Ultrasonographic Width Left Quadriceps			
		Mean (mm)	Standard deviation
Group A	Pre	2.1238	0.57263
	Post	2.3	0.56833
Group B	Pre	2.1333	0.69306
	Post	2.2143	0.63347
Group C	Pre	2.1714	0.53679
	Post	2.5238	0.51274

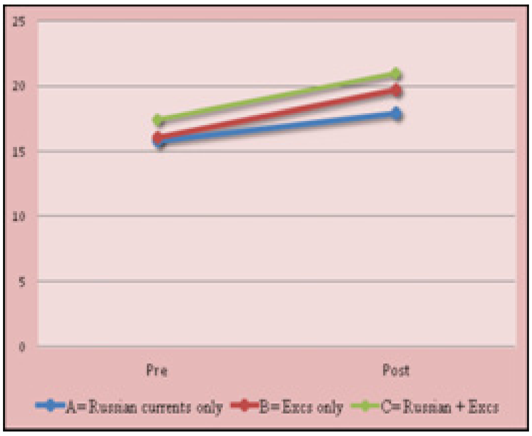


Table 5: Mean and Standard Deviation of Ultrasonographic width of Right Quadriceps femoris muscle

Ultrasonographic Width Right Quadriceps			
		Mean (mm)	Standard deviation
Group A	Pre	2.1381	0.45329
	Post	2.3095	0.48156
Group B	Pre	2.1333	0.67552
	Post	2.2381	0.64612
Group C	Pre	2.1524	0.5046
	Post	2.5	0.50398

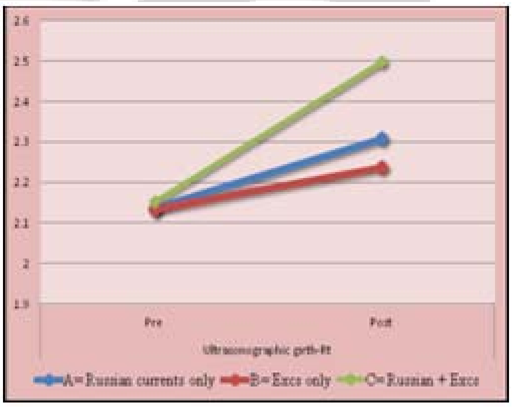
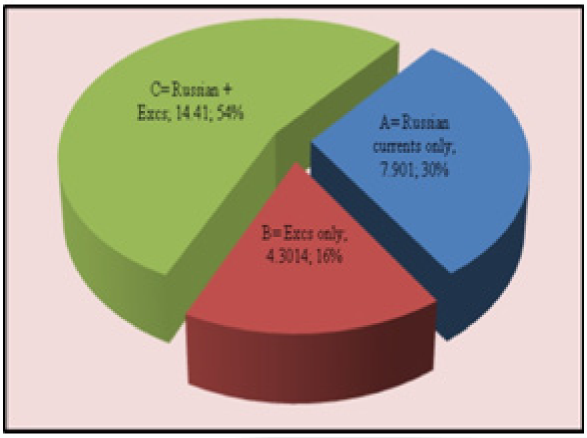


Table 6: Mean and Standard Deviation of percentage difference of Ultrasonographic width of left and right Quadriceps femoris muscle

		Mean	Standard
%differer	Russian currents	7.901	4.76944
	Exercise alone	4.301	8.41522
	Exercise + Russian	14.41	6.18737
%differer	Russian currents	7.435	3.83436
	Exercise alone	5.090	4.50944
	Exercise + Russian	14.20	5.67354



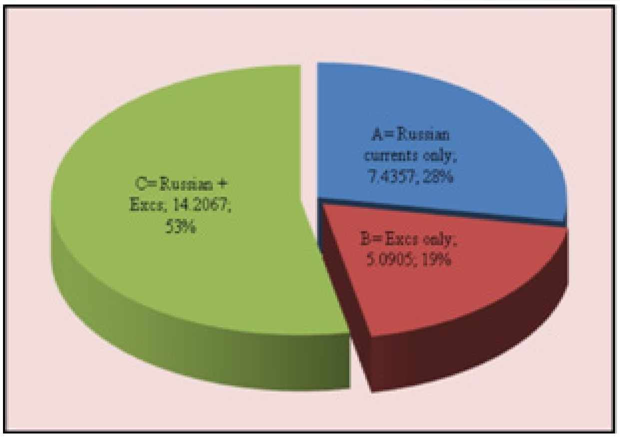
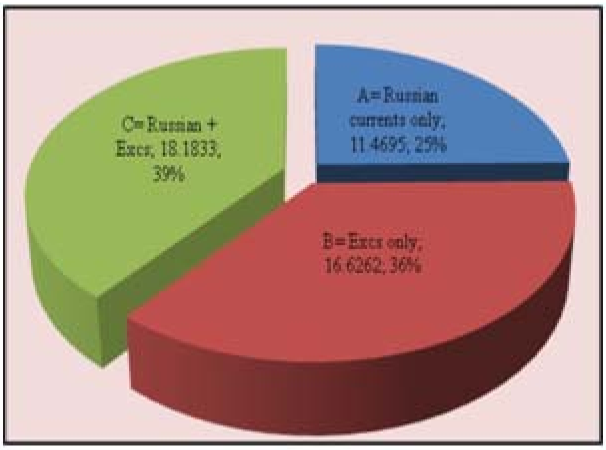


Figure 7: Comparison of percentage difference of Ultrasonographic width of Left and Right Quadriceps between the three groups

Table 7: Mean and Standard Deviation of percentage difference of isometric strength of left and right Quadriceps femoris muscle

		Mean (Kg)	*Standard Deviation*
% difference of Left Isometric strength	Russian currents alone	11.4695	13.40382
	Exercise alone	16.6262	6.05707
	Exercise + Russian currents	18.1833	12.50128
% difference of Right Isometric strength	Russian currents alone	12.6219	12.77388
	Exercise alone	18.2157	9.15587
	Exercise + Russian currents	15.8614	12.02051



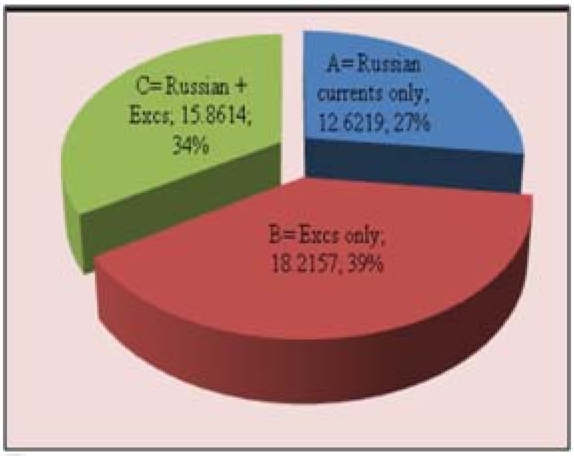


Figure 8: Comparison of percentage difference of Isometric Strength of Left and Right Quadriceps between the three groups

5. Isometric Strength

These results confirmed the findings of Halbach and Straus [13] who examined isokinetic peak torque produced by a volitional exercise group and by an EMS group. Torque was produced by knee extensors at an angular velocity of 120degrees/sec. The EMS group received a half-wave pulse of 50 Hz, with a 10-sec contraction period and a 50-sec rest period between each stimulus. Ten repetitions were given to each subject during each session, with the knee positioned in 45º of flexion while exercising with isometric maximum voluntary contraction (MVC). The isokinetic group increased their torque by 42% and the EMS group by 22% Similarly, Eriksson and co-workers [9] reported significant gains (16%) in peak torque for the leg receiving EMS. The Quadriceps femoris muscle was stimulated using square waves of 0.5 ms in pulse duration, at a frequency of 200 Hz. They applied EMS for 15 sec, followed by 15 sec rest between bursts of stimuli, for total stimulation period of 6 min. A control group, which performed dynamic exercise for a similar period of time, showed gains in torque scores of up to 27%, which again ascertains the superiority of exercise over EMS.

The use of currents in improving the muscle strength was further demonstrated in patients following surgery where Delitto et al [8] compared force gains produced by Russian EMS with gains produced using voluntary exercises following ACL surgery. The electrically stimulated group showed higher force gains than the group that received voluntary exercise. However a combination of both the types of treatment was not assessed.

On the contrary Romero and co-workers [37] whose study included of stimulating bilateral Quadriceps femoris muscle groups in young adult women for 10 sessions over a 5- week period, using surged faradic current of 2000 Hz with 4 sec of EMS, followed by 4 sec of rest, for a total of 15 min of EMS session, measured MVC which increased by 31% in the non-dominant leg and 21% in dominant leg. A control group did not demonstrate significant difference in mean peak torque values between pre-test and post test measurements, also Ikai [15] et al and Johonsson [17] et al demonstrated increases in strength with the application of electrical stimulation.

Table 8: Pre and Post Ultrasonographic width and isometric strength in group A

	t	Sig. (2-tailed)
Pair 1 Pre Right USG width- Post Right USG width.	-9.295	0
Pair 2 Pre left USG width- Post left USG width.	-7.4	0
Pair 3 Pre Right Isometric strength – Post Right Isometric strength.	-4.806	0
Pair 4 Pre Left Isometric strength – Post Left Isometric strength.	-3.44	0.003

The tension developing capacity of muscle during voluntary isometric exercise is a function of both the number of motor units that are recruited and the varying frequency of discharge of
the recruited alpha motor neurons13. During 50% of maximum voluntary contraction (MVC), all motor units of the activated muscle have been recruited [33]. As the muscular tension increases from 50-100% the motor unit discharge frequency similarly increases, affecting the tension. The alpha motor neurons of active motor units discharge asynchronously to permit a smooth contraction [36]. Motor unit recruitment patterns are related to the type of muscle contractions. The tonic or Type I or slow twitch motor units have lower firing frequency than the phasic or fast twitch or Type II motor units[14,30].

Table 9: Pre and Post Ultrasonographic width and isometric strength in group B

	t	Sig. (2-tailed)
Pair 1 Pre Right USG width- Post Right USG width.	-9.295	0
Pair 2 Pre left USG width- Post left USG width.	-7.4	0
Pair 3 Pre Right Isometric strength – Post Right Isometric strength.	-4.806	0
Pair 4 Pre Left Isometric strength – Post Left Isometric strength.	-3.44	0.003

Slow twitch or Type I motor units are recruited first in a voluntary muscle contraction. Electrically stimulated contractions are thought to be characterized by a reversal of the normal motor unit recruitment pattern i.e. selectively activating the Type II motor units[14,30]. In an electrically stimulated muscle contraction, the same frequency of stimulation is delivered to all the activated motor units, and the contractions are relatively synchronous (Tmkcozy A: Functional electrical stimulation. Auto medica 1978). According to Kots maximum voluntary contraction cannot reach 100% of possible muscular tension because of a force deficit i.e. not all motor units are recruited. During volitional effort, not all motor units are recruited, and the motor neuron discharge rate is not maximum (deficit). Electrical stimulation can reduce the force deficit, as it enhances the recruitment of motor units, thereby increasing muscle tension by several percentage points[1].

As far as the combination therapy goes studies by Laughman et al [25] who compared the effectiveness of electronic muscle stimulator in strengthening normal Quadriceps femoris muscle against isometric strengthening exercises. The electrical stimulation and isometric exercise groups had statistically significant increases in Quadriceps femoris muscle torque when compared with the non exercised controls. The result supported the use of this electronic stimulator as an appropriate device for strengthening skeletal muscle without voluntary effort. The output of the stimulator consisted of modulated sine wave with a frequency of 2500 Hz, periodically interrupted creating 50 burst of activity per second. Each burst period composed of 10 ms sinusoidal output followed by 10 ms rest period. The stimulator was designed to deliver 15 seconds of stimulation followed by a 50 second rest period. On the same lines, in our study a combination of Russian currents and exercise is more effective than either intervention used alone. With the combination applied sequentially (voluntary exercise and separate electrical stimulation), the total amount of exercise is greater. The second explanation is that exercise and electrical stimulation preferentially recruit different fibre types. Kots and Xvilon[21] argued that traditional, voluntary exercise regimens promoted increased force production in slow-twitch, fatigue resistant muscle fibers because they are the ones first recruited in a voluntary contraction and there is limited recruitment of fast-twitch fibers in all but the fastest and most forceful voluntary contractions. An electrical stimulation regimen, by contrast, preferentially recruits the fast-twitch muscle fibers, which are innervated by larger diameter motor neurons. On this basis, they contended, an optimal force gain program should include both exercise and electrical stimulation to increase force production of both fibre types [1,30].

6. Ultrasonographic width

Increment in girth measurements of the Quadriceps muscle was looked upon in a study by Williams, Street[49] and Johnson [18] et al who reported positive effects of electrical stimulation on girth measurements, measured circumferentially. The improvement in the girth of the Quadriceps muscle was measured in all the studies only circumferentially. Our research did not yield any results to show studies which measured the actual increment in the width of Quadriceps muscle at the cellular level. The increment of thickness or width of the Quadriceps muscle can be measured by using Ultrasonography imaging techniques26, 27, 28. However authors in the past like Victor Ademola Obajuluwa[47] assessed the effect of electrical stimulation on Quadriceps femoris muscle strength and thigh girth using Myodyne muscle stimulator over a period of 10 weeks. The results showed that muscle strength and hypertrophy may be significantly increased over a 10-week period using electrical stimulation. Similarly Ikai et al and Johonsson et al demonstrated increases in strength with the application of electrical stimulation.

Ultrasonography imaging is slowly gaining momentum to measure the width of skeletal muscle as one of the objective assessment tools in musculoskeletal physiotherapy. Studies in past have shown evident results that measurement tools like MRI show no difference as compared to Ultrasonography imaging. [16]

Table 10: Pre and Post Ultrasonographic width and isometric strength in group C

	t	*Sig. (2-tailed)*
Pair 1 Pre Right USG width- Post Right USG width.	-12.357	0
Pair 2 Pre left USG width- Post left USG width.	-11.834	0
Pair 3 Pre Right Isometric strength – Post Right Isometric strength.	-8.556	0
Pair 4 Pre Left Isometric strength – Post Left Isometric strength.	-9.191	0

Asymptomatic, skeletal muscle undergoes numerous histochemical, physiologic, and morphologic changes when subjected to increased muscular activity by either exercise or chronic electrical stimulation. These changes can certainly be measured as hypertrophy that occurs clinically following any strengthening program. Muscle is a relatively stable tissue, in that it is comprised of differentiated muscle fibres containing post-mitotic nuclei. Growth and repair of muscle is inextricably linked to the action of a group of myogenic precursor cells, called satellite cells. These cells were initially identified in amphibian muscle by Mauro [28] (1961) and are anatomically distinct from the myonuclei, being located between the basal lamina and the sarcolemma of a muscle fibre, (Refer figure 9). The muscle satellite cell fulfils the basic definition of a stem cell in that it can give rise to a differentiated cell type and can maintain itself by self-renewal [32]. Upon activation, most, but not all, satellite cells go through a series of stages where they proliferate, differentiate into myoblasts

Table 11: Comparison of differences between the three groups

Dependent Variable		*Group*	*Group*	*P value*
%difference of Ultrasonographic width of right Quadriceps muscle.	Bonferroni	Russian	Exercise	0.341 Not significant
			Exercise + Russian	0 Extremely significant
		Exercise	Russian	0.341 Not significant
			Exercise + Russian	0 Extremely significant
		Exercise + Russian	Russian	0 Extremely significant
			Exercise	0 Extremely significant
%difference of Ultrasonographic width of left Quadriceps muscle.	Bonferroni	Russian	Exercise	0.251 Not significant
			Exercise + Russian	0.007 Extremely significant
		Exercise	Russian	0.251 Not significant
			Exercise + Russian	0 Extremely significant
		Exercise + Russian	Russian	0.007 Extremely significant
			Exercise	0 Extremely significant
% difference of isometric strength of right Quadriceps muscle.	Bonferroni	Russian	Exercise	0.353 Not significant
			Exercise + Russian	1 Not significant
		Exercise	Russian	0.353 Not significant
			Exercise + Russian	1 Not significant
		Exercise + Russian	Russian	1 Not significant
			Exercise	1 Not significant
% difference of isometric strength of left Quadriceps muscle.	Bonferroni	Russian	Exercise	0.417 Not significant
			Exercise + Russian	0.167 Not significant
		Exercise	Russian	0.417 Not significant
			Exercise + Russian	1 Not significant
		Exercise + Russian	Russian	0.167 Not significant
			Exercise	1 Not significant

and ultimately fuse with existing myofibres to repair damaged muscle and/or facilitate an increase in its size.

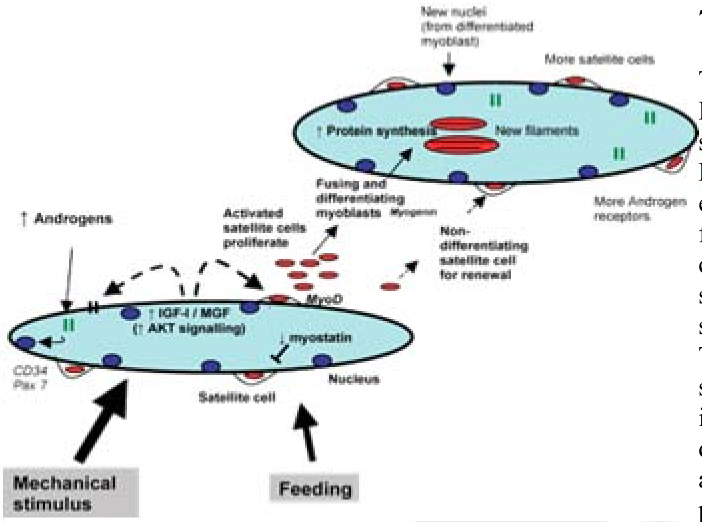


Figure 9: Role of Satellite cells in growth and repair of muscles

7. USG changes that occur in electrically stimulated muscle.

A continuous, low frequency electrical stimulation imposed for several weeks causes the fast muscles to acquire the biochemical and physiologic characteristics of slow muscles.[14] which was demonstrated by Roy and associates[39] that ratio of alpha to beta forms of tropmyosin changes to that ratio characteristic of slow muscles after 3 weeks of electrical stimulation, similarly, Pette and co-workers [34] concluded that, assuming that electrical

stimulation leads to a transformation of the fast fibers into slow, this transformation is accompanied by the formation of an intermediate fiber type that is morphologically equivalent to slow contracting fibers Erickson and Hagginark [10] compared isometric muscle training with electrical stimulation supplementation of isometric muscle training following knee surgery. The electrically stimulated group consistently had better muscle function and the succinct dehydrogenase activity was significantly higher in the stimulated group than in the exercise. The results of the study suggest that EMS of asymptomatic muscles may be effective in preventing the muscular atrophy that occurs in the quadriceps muscle following major surgeries.

Stanish and associates [44] found similar effects with electrical stimulation using medium- frequency (2500 Hz) sinusoidal wave form. The results of the study showed that the decrease in myofibrillar ATPase resulting from immobilization was prevented.

Thus it is empirical that the measurement of the width of the Quadriceps muscle measured by Ultrasonography imaging techniques requires further evidence based research to mark it as an important tool in assessing the changes brought about by electrical stimulation. Also a worldwide shift of treatment techniques from using adjunctive electrical therapy to more manual and real time exercise rehabilitation programs is definitely moving bias towards the latter. This is also evident in our study where best results of improvement at the cellular levels are ascertained in the group of subjects exercising and sweating it out at the gymnasium.

7.1 "10/50/10" regimen

The objective of this regimen was to increase a muscle's Kots' recommendation that this form of electrical stimulation should be used as an adjunct to exercise,[21] Pract Fis Cult.1971;4:66–72 rather than as an alternative to exercise, and with electrical stimulation sessions separate from bouts of voluntary exercise. Kots and Xvilon [21] contended that to increase force production, electrical stimulation should be of non-fatiguing, meaning there should be no decrease in force during the stimulus period. Their argument for a non-fatiguing response was that further stimulation of an electrically fatigued muscle will not increase the muscle's force production capability. The dominant fatigue mechanisms are neurotransmitter depletion and propagation failure at the level of the t-tubule system [20] processes that would not result in increased force production [19,20.] Fatigue induced by voluntary exercise involves much lower nerve fiber firing frequencies [20] and places greater stresses on the contractile components of the muscle fibers. Such stresses are argued to be needed for strengthening [20] Thus; we believe that the choice of a "10/50/10" stimulation regimen to avoid neuromuscular fatigue has a sound physiological basis.

8. Conclusion

It is evident that the three techniques employed in our study viz., Electrical Muscle Stimulation (Russian Currents), strength training exercises and a combination of both i.e. EMS and strength training exercise are effective in improving the muscle strength as well as the width of Quadriceps femoris muscle bilaterally in asymptomatic young adults. However it is also evident that improvement in isometric strength achieved with strength training exercises is more than the former two techniques, whereas combination is responsible for causing an evident increase in the width of Quadriceps femoris muscle bilaterally in asymptomatic young adults. Thus in conclusion we would rightly place strength training exercises regimen as the supreme most technique to increase muscular strength in asymptomatic young adults. Our study has challenged the findings of many authors claiming that Russian Currents when combined with exercises does not provide the desirable effects in young healthy athletes. Further evidence based studies are needed to ascertain the long term increase in the width of a muscle and associate it with strength gain or hypertrophy.

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