Effect of Russian Current and Angle Specific Isometric Exercise on Quadriceps Femoris Muscle Torque

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ABSTRACT

This study was conducted to investigate and compare the effect of Russian current and angle specific isometric exercise on quadriceps femoris muscle maximum voluntary isometric torque (MVIT). Total of sixty healthy males with mean age (24±1.4 years), mean height (162±5.4cm), and mean weight (72.5±4.1 Kg) participated in the study. The subjects were randomly divided into four equal groups. Group I (exercise group) trained with angle specific resisted isometric exercise at angle 90 degree knee flexion, group II (Russian current group) trained with Russian current, group III trained with both exercise and Russian current applied at alternate separate sessions, group IV trained with exercise superimposed with Russian current. The schedule of training was six days/week for six weeks. Measurements of maximum voluntary isometric torque were conducted pre and post administration of the programs. Analysis of the data revealed that there was significant increase in MVIT of post measurements compared to the pre measurement in all groups (P<0.0001). The percentage of change in MVIT (MVIT%) of the four studied group were 28.5%, 27.5%, 37.5%, and 41.7% respectively. Comparisons between groups showed that there was non-significant increase of torque in group I (exercise group) than in group II (Russian group) (P>0.05). Combined exercise and Russian current in groups III and IV resulted in a significantly higher torque than those recorded in groups I and II after exercise or Russian alone (P<0.001). Also training with exercise superimposed with Russian current in group IV caused significantly higher MVIT than those in group III trained with combined exercise and Russian current at alternate separate sessions day (P<0.05). In conclusion Russian current and angle specific isometric exercise are equally effective in increasing muscle strength. Combined Russian current and angle specific isometric exercise are more efficient in increasing muscle strength than using each alone. Exercise superimposed with Russian current achieves the highest strength gain.

Key words: *Russian current, exercise, and muscle strength.*

INTRODUCTION

Strengthening a weak muscle is essential target in the rehabilitation of orthopedic and sports related injuries[12,17,18]. On attempting to increase muscle strength, physiotherapists use voluntary resisted exercise and/or neuromuscular electrical stimulation as both of them have been reported to be efficient in increasing muscle strength[6,11,13,19].

Although the preference of resisted voluntary exercise in muscle reeducation, electrical stimulation has proven to improve muscle strength and highly recommended in conditions where voluntary movement is inhibited[17]. Researches have been conducted to clarify the effect of different types of exercises and electrical stimulation and comparing between them to reach to high level of strength gain. The results swing between the significant increase in strength by exercise than electrical stimulation, the presence of non-significant difference, or even the superior effect of electrical stimulation[8,10,14]. Other studies recommend the use of combined exercise and electrical stimulation to ensure full recruitment of all motor units[13,20]. A common problem in

drawing comparisons among these studies is the variety of the types and parameters used. Based on that, caution should be taken in drawing conclusion from these studies as the results depend on the type and intensity of the exercise used and the type and parameters of the electrical stimulation used.

Russian current is a medium frequency current with a frequency 2500Hz which are burst modulated at a frequency of 50 Hz[27]. The current has been advocated increasing muscle strength in healthy athletic subjects. The pioneer work of Kots, (1971) a Russian researcher, laid the foundations for the use of Russian current in physical therapy. The basic research were conducted in Soviet Union on athletic subjects with emphasizing on building muscle bulk and muscle force. It was reported that, the current could produce stimulation of normally innervated muscle and resulting in strength gains of 30 to 40 % in athletic subjects[22]. Of all types of electrical stimulating currents, Russian currents seems to be the least subjected to investigations and researches, which limits its use in clinical sitting. This perhaps because the original work by Kots was published in Russian language and not available in English language until recently. Since that a raising interest of the current has increased[20,27].

Studies have been conducting to clarify the effect of Russian current on muscle strength in healthy non-athletic subjects. The reported results suggested that stimulation with Russian current induced a training stimulus of 30 to 66 % of maximum voluntary contraction and could be used to increase muscle strength in healthy subjects[23,26].

Furthermore, recently numbers of studies comparing Russian current with other types of electrical stimulation were conducted. They suggested that Russian current is more effective and produced higher torque than interferential current and monophasic pulsed current. Also there was no significant difference between Russian current and biphasic pulsed current[4,7,9,15,24].

The previous studies conducted to compare the effect of Russian current and exercise were limited and the results were conflicting[10,21,22]. This perhaps because of the concentration of the researches on determining the effect of Russian current and comparing its effect to other types of electrical stimulation. kots it was reported that Russian current might have superior effect than exercise as it can induce torque up to 110:130% of the maximum voluntary torque. Also the author reported that for optimal force enhancing a regimen of Russian current combined with voluntary contraction with electrical stimulation sessions separate from bouts of voluntary exercise. Again it should be remembered that the study was conducted on athletic subjects[27].

A study was conducted to compare the effect of Russian current and exercise in strengthening thigh muscle after cruciate ligament surgery and suggested that Russian current can achieve higher strength gains than voluntary exercise[10]. In the other hand, subsequent studies reported that exercise was more effective than Russian current in improving strength after anterior cruciate ligament surgery[21,22].

So questions remain, however, as to whether and to what extent Russian current may be effective in improving muscle strength and is there a difference between Russian current and exercise.

In the light of the previously presented literature, more studies would appear to be needed to investigate and compare the effect of Russian current and exercise to improve muscle strength. So the current study was designed to clarify the potential benefit of

Russian current compared to exercise, through measuring MVIT pre and post four types of training protocols: Russian current alone, angle specific isometric exercise alone, combined exercise and Russian current applied at alternate separate sessions, and exercise superimposed with Russian current.

MATERIALS AND METHODS

Subjects

Sixty healthy male subjects with age 19:26 years and mean age (24±1.4 years), height 160:175 cm and mean (162±5.4 cm), and weight 65:85Kgand mean (72.5±4.1 Kg) volunteered to participate in the study. Subjects were undergraduate and postgraduate students of the Faculty of Physical Therapy, Cairo University. All subjects were free from neurological, musculoskeletal impairment of the lower limbs or previous surgery in the lower limbs. All subjects were not to engage in any form of strenuous activities throughout the period of the study. Subjects were refrained from intake of caffeine drink for 24 hours prior to testing.

Subject were randomly divided into four equal group each containing 15 subjects. *Group I*: exercise group, *group II*: Russian current group, *group III*: received combined Russian current and exercise program., and *group IV*: exercise superimposed with Russian current.

The study was conducted in July through October 2002, at the Faculty of Physical Therapy, Cairo University. The measurement of MVIT was done in the Physical Therapy Department, Police Hospital, El-Agouza.

Instrumentation

1. Electrical stimulator (Phyaction 787) was used to deliver the Russian current.
2. Arkon Rehabilitation System was used to train subjects on angle specific isometric exercise.
3. Universal goniometer was used to determine the angle of knee joint during exercise. A standard transparent plastic goniometer 18 cm long with 360 degrees scale and one degree increments.
4. MERAC isokinetic system was used to measure the torque produced by subjects.

Testing procedures

For each subject, measurement of maximum voluntary isometric torque (MVIT) of the quadriceps muscle of the dominant lower limb was conducted pre and post the completion of 6 weeks program of angle specific isometric exercise and/or Russian current electrical stimulation.

Maximum voluntary isometric torque (MVIT)

Each subject was familiarized with the testing procedures. The apparatus was calibrated on a regular basis according to the manufacture manual. The subject was seated on the apparatus chair with hip 120 degrees flexion and knee at 60 degrees flexion. The subject trunk, and the tested limb was stabilized by the system pads and belts. The fulcrum of the lever arm was aligned with the lateral epicondyle of femur and the inferior portion of the shin. The resistance pad was adjusted at 5 cm superior to the right medial malleolus. The subject performed three trials of 5 seconds maximum voluntary isometric contraction with 1-minute rest between trials. The subject was asked to maximally extend the knee joint while verbal encouragement was done. The MVIT was recorded and averaged for the three trials [15].

Training procedures

- Training programs of angle specific isometric exercise and /or Russian current

electrical stimulation were delivered to subjects in the four groups with a schedule of six days per week for six weeks.

- Subjects in group one trained with angle specific exercise program alone and subjects in group two trained using Russian current alone. While subjects in group three trained with combination of exercise and Russian current stimulation each was delivered at separate alternate sessions that's to say each was delivered for 3 days per week and subjects in group four trained with angle specific isometric exercise superimposed with Russian current.

Russian current stimulation

Current Parameters: the parameters of the Russian current used in the study were identical to that reported by Kots, as presented in the literature. The current was polyphasic sinusoidal waveform, with frequency 2500 Hz modulated at 50 Hz bursts, pulse duration 0.4 msec, with surge 50%. The current was applied for 10 seconds "on" period followed by 50 seconds "off" period and treatment time 10 minutes, the current intensity was increased to the tolerable limit for each subject[27].

Electrodes placement: The subject was in sitting position on a chair with knee joint angle 90 degree flexion. Prior to electrodes placement, the area of the skin under electrodes was cleaned with alcohol. Two standard carbonized rubber electrodes of equal size (7.5x10.5 cm) with sponge pads soaked in tap water were used to stimulate the QF muscle of the dominant lower limb. One electrode was placed over the motor point of vastus medialis and the other electrode was placed over the motor point of vastus lateralis. Electrodes were secured in position using Velcro straps[16].

Angle specific isometric exercise program

The subjects was trained with Arkon Rehabilitation System. The subject was seated on the system chair with back support permitting hip flexion 120 degree. The trunk and thigh and lower leg were secured with straps. The leg hanged with knee joint 90 degree flexion as determined by universal goniometer. It was reported that for increasing isometric knee extension torque throughout the entire range of motion is to exercise with the quadriceps femoris muscle in the lengthened position at 90-degree knee flexion[2]. The lower leg was secured to the lever arm resistance bad with straps about the subject's ankle.

The subject was asked to extend the knee and move against the apparatus pad and perform 3 boots of 10 repetition of maximal voluntary isometric contractions of the quadriceps each one for 10 seconds and 1 minute rest between each contraction and 10 minutes rest between each bout[2].

Exercise with superimposed Russian current

During superimposed contraction, the application of Russian current and voluntary isometric contraction were simultaneous. The subjects in group four trained with both angle specific isometric exercise and Russian current. The subject was seated on the Arkon Rehabilitation System's chair with the same position and procedures used during the isometric exercise. Then the electrodes were secured in position as during Russian current application. The subject was asked to maintained maximum isometric contraction of the quadriceps muscle for 10 second and at the same time the intensity of Russian current was switched on to the tolerable level. Then relaxed during the off 50 second of the current and repeated for 10 trials with a total duration of 10 minutes[20].

Data Analysis

Scores of the MVIT of the quadriceps muscle of all four groups were measured pre and post intervention. The data were expressed

as means and standard deviation. The percentage of change of MVIT referred to in the current study as (MVIT%) was calculated for each subject in all studied groups using the following formula: (post MVIT - pre MVIT) / pre MVIT. The mean and standard deviation of MVIT % of each group was determined to compare changes of MVIT between groups.

A paired t-test comparing pre and post measurement was conducted for each group to determine the effect of the applied program. One way ANOVA test was performed to determine differences in MVIT% among the studied groups. If there was significant difference in the ANOVA test, further Bonferroni post hoc pair-wise comparisons were conducted to examine differences between each pair of groups. Level of significance was set at ($P < 0.05$).

RESULTS

The results of the maximum voluntary isometric torque (MVIT) recorded pre and post training of exercise or Russian current both alone or together shown in table (1) and figures (1) revealed that there were significant increase of MVIT of post measures as compared to pre measures in all studied groups ($P < 0.0001$).

Table (1): Maximum voluntary isometric torque (Nm) of the studied groups.

	Group I		**Group II**		**Group III**		**Group IV**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Mean	183.6	238.3	180	230	176.4	240.4	185	258.8
SD	12.3	15.5	14.7	22.7	14.2	18.4	16.3	18.6
MVIT % mean	28.5%		27.5%		37.5%		41.7%	
t	15.7		13.3		16.4		18.2	
P	<0.0001*		<0.0001*		<0.0001*		<0.0001*	

*Significant

When calculating the mean of the percentage of increase of MVIT (MVIT% mean) of the studied groups, the highest percent was recorded for group IV which trained with exercise superimposed with Russian current 40.7%, followed by group III which trained with exercise and Russian current at alternate days 37.5%. While both group I, which trained with exercise only and group II trained with Russian current only recorded lower percent 28.5% and 27.5% respectively table (1) and fig.(2).

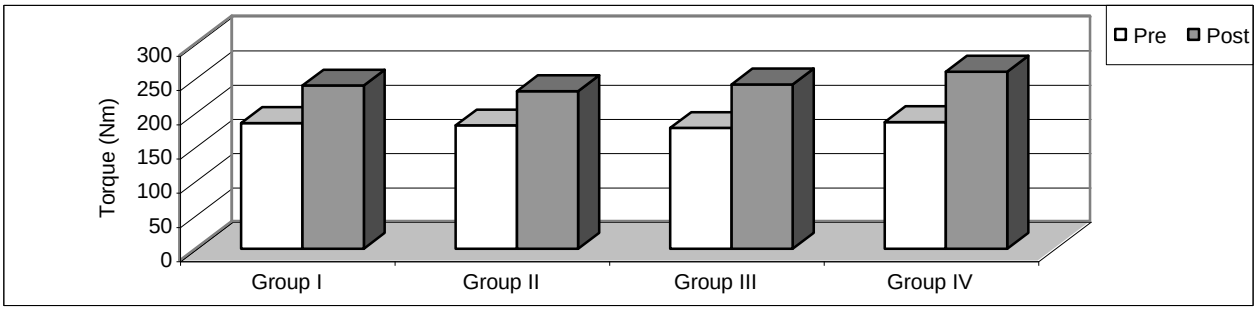

Fig. (1): Maximum voluntary isometric torque pre and post measures of the studied groups.

To determine presence of difference between the studied group the results of the one way ANOVA test demonstrated that there was significant difference in MVIT% among the studied group (P < 0.0001) table (2) and figure (2).

Table (2): ANOVA table for comparison of MVIT % among the studied groups.

Source of Variation	Df	SS	MS	F	*P-value*
Treatment (between columns)	3	2157.1	719.05	39.2	<0.0001*
Residual	65	8889.87	15.891		
Total	59	3047			

*Significant

Bonferroni post hoc pair-wise comparisons were conducted to compare between each two group. The results revealed that, the mean percentage of MVIT of group III and IV were significantly increased than that of group I and group II (P<0.001). While there were non significant increase of group I compared to group II (P>0.05), and significant increase of group VI than group III where (P<0.5) table (3).

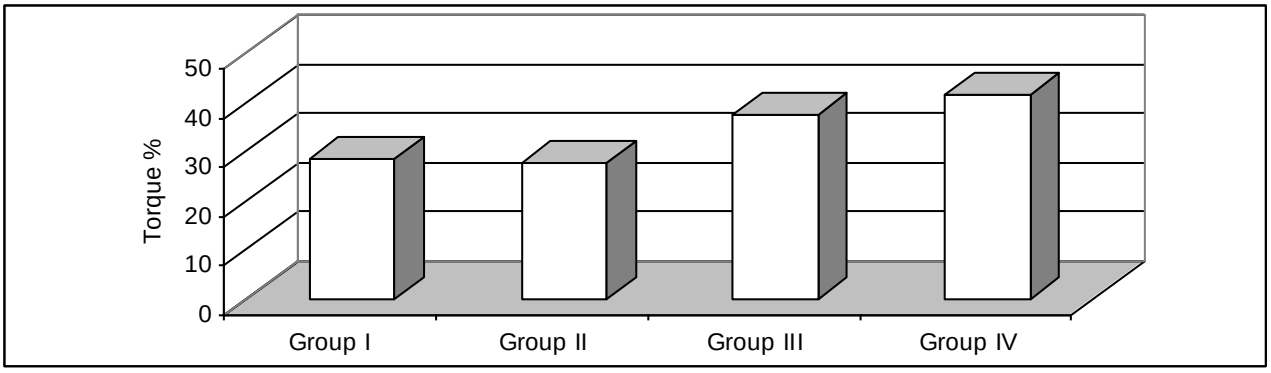

Fig. (2): Percentage of maximum voluntary isometric torque of the studied groups.

Table (3): Bonferroni post hoc pair-wise comparisons of maximum voluntary isometric torque% for the studied groups.

	Mean difference	t	P
Group I Vs Group II	1.001	0.19	>0.05
Group I Vs Group III	8.99	6.17	<0.001*****
Group I Vs Group IV	13.19	9.06	<0.001*****
Group II Vs Group III	10	6.87	<0.001*
Group II Vs Group IV	14.2	9.75	<0.001*****
Group III Vs Group IV	4.2	2.88	< 0.05*

*Significant

DISCUSION

Electrical stimulation and exercise either each alone or combined are frequently used by physiotherapists in clinical sitting to increase muscle strength[11,14,20].

The current study was designed to compare the effect of Russian current and

exercise on quadriceps femoris muscle torque. Furthermore the study used four regimes to increase MVIT of healthy subjects aiming to establish the optimal form of application of Russian current to increase muscle strength.

The results of the current study demonstrated that all the training regimes used produced significant increase of strength, but to a different levels as the increase in MVIT after the four training protocols were 28.5% in exercise group, 27.5% in the Russian current group, 37.5% in the combined exercise and Russian current at alternate separate sessions, and 41.7% in exercise superimposed with Russian current.

Russian current with the parameters used in the study, produce significant increase in MVIT. It was reported that medium frequency current modulated at low frequency would be efficient in increasing muscle strength and yet be relatively pain free which allow more current for stimulation[26]. In consistent with our results, it was reported that Russian current could induce 30 to 66% of maximum voluntary contraction, which constitutes a training stimulus for muscle strengthening[10,23].

Although the significant increase in MVIT scored in the present study after training with Russian current (27.5%), it still lower that reported by Kots. The author claimed that Russian current could induce contractile force 110 to 130% of maximum voluntary contraction and resulting in strength gain up to 40% in athletic subjects[27]. It should be noted that subjects in Kots work were younger (15-17) years of age and athletes motivated for the competition in the Olympic games. In addition the already high level of motor learning and fine motor control of athletes could account in part to the higher gain in muscle strength[20].

The exercise program used in the study was angle specific isometric exercise. Several studies reported benefit of isometric exercise in increasing muscle strength and related the force output to the joint angle[1,17,25]. Recent studies suggested that isometric training of a muscle at specific angle could increase muscle strength not only at the training angle but at other angle in the range and this effect depend on selecting suitable angle for training[3]. This agree with our study as the training of the quadriceps was at 90 degree flexion and produced significant increase in MVIT measured at knee 60 degree flexion.

The subjects in the present study were exercised isometrically at 90 degree flexion. Bandy and Hanten (1993) conducted a study to examine the effect of isometric training of quadriceps femoris muscle at different angles (30,60,90 degree) on torque production and electromyographic activity. They concluded that an efficient method for increasing isometric knee extension torque throughout the entire range of motion is to exercise with quadriceps in the lengthened position and recommended 90 degree knee flexion[2].

The results of the current study demonstrated that, there was non-significant increase of MVIT after exercise compared to Russian current. Training with Russian current results in increase of MFIT by 27.5%, while exercise results in increase of MVIT by 28.5%.

In the original work by kots, it was suggested that Russian current is capable of producing higher strength gain than exercise. The author claimed that Russian current due to its specific parameters which allows greater current intensity with minimum discomfort could achieve maximal motor unit recruitment and therefore allow greater torque production[27].

Comparative studies comparing between Russian current and exercise has been the subject of limited few reported studies all were

conducted to examine the effect of Russian current on force regain following anterior ligament surgery. The results were inconsistent, as only one study reported superior effect of Russian current over exercise[10]. While other two studies reported higher strength gain by exercise than strength gain by Russian current[21,22]. The statistical power of these studies are questionable as they use a small sample number. Also the exercise program was not standard which make comparison not rational.

The current study suggested that a combination of voluntary exercise and Russian current applied on separate sessions or exercise superimposed with Russian current can produce greater MVIT than either intervention used alone. The possible explanation is that exercise and electrical stimulation preferentially recruit different fiber types. Voluntary exercise regimes stimulate slow twitch fatigue resistant muscle fibers an electrical stimulation regimen preferentially recruits the fast twitch muscle fibers[3,]. On this base combined exercise and electrical stimulation could theoretically provide full recruitment of all muscle fibers.

This in agree with kots and co-workers who reported that for maximum strength gain Russian current should be used combined with exercise, although the type of exercise was not addressed. Several studies although using different types of exercise and electrical stimulation other than Russian current reported similar results[20].

When comparing the MVIT of both groups trained with two regimes of combined exercise and Russian current, there was significant increase in MVIT after exercise superimposed with Russian current that those trained with combined exercise and Russian current applied at separate sessions. The explanation to this would be that the exercise superimposed with Russian current could provide greater total amount of muscle activation within the single same session due to activation of both slow and fast muscle fibers at the same time[27]. There is general agreement that a maximum voluntary contraction has a force deficit which mean the inability to maximally recruit all available motor units with 10 to 40% of all available motor units either submaximally recruited or electrically silent[1]. So exercise superimposed with electrical stimulation would correct this deficit by having maximal motor unit recruitment and therefor allowing greater torque production.

It was reported that electrical stimulation imposed on voluntary contraction could induce muscle torque which exceeds the torque induced with maximum voluntary contraction alone or that induced by electrical stimulation alone[13].

Conclusion

From this study, it can be concluded that Russian current and angle specific isometric exercise are equally effective in improving MVIT. Angle specific isometric exercise combined with Russian current is more effective in increasing MVIT over using exercise or Russian current alone. The greatest increase in MVIT is achieved using angle specific isometric exercise superimposed with Russian current.

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الملخص العربي

تأثير التيار الروسي و التمرينات الايسومترية عند زاوية محدده على عزم عضلة الفخذ الرباعية الأمامية

أجريت هذه الدراسة للمقارنة بين التيار الروسي و التمرينات الايسومترية عند زاوية محدده على عزم عضلة الفخذ الرباعية الأمامية. شارك في هذه الدراسة ستون شخصا من الأصحاء تتراوح أعمارهم بين 24 و 30 عاما و أطوالهم بين 160و 175 سم . و أوزانهم بين 65 و 85 كجم قد تم تقسيم العينة إلى أربعة مجموعات: المجموعة الأولى: تم تدريبها بالتمرينات الايسومترية عند زاوية ثنى الركبة 90 درجه و المجموعة الثانية: تم تدريبها بواسطة تنبيه العضلة بالتيار الروسي والمجموعة الثالثة: تم تدريبها بالتيار الروسي و التمرينات معا في جلسات متتالية منفصلة و المجموعة الرابعة: تم تدريبها بواسطة التمرينات المركب فوقها التيار الروسي. استمر البرنامج التدريبي لمدة ستة أسابيع بمعدل ستة جلسات أسبوعيا. تم قياس أقصى عزم إرادي ايسوميترى لعضله الفخذ الاماميه الرباعية قبل و بعد البرنامج التدريبي. أثبتت المعالجة الإحصائية للنتائج وجود زيادة ذات دلالة إحصائية في أقصى عزم إرادي ايسوميترى لعضله الفخذ الرباعية الاماميه فى كل المجموعات بعد التدريب وكانت نسبة الزيادة في أقصى عزم إرادي ايسوميترى لعضله الفخذ الرباعية الأمامية للمجموعات الأربعة بالترتيب كالآتي: 28,5% و 27,5% و 37,5%و 41,7%. عند المقارنة بين المجموعات تبين عدم وجود زيادة ذات دلالة إحصائية في أقصى عزم إرادي ايسوميترى لعضله الفخذ الرباعية الأمامية بين مجموعة التمرينات و مجموعة التيار الروسي ووجود زيادة ذات دلالة إحصائية في الذين تدربوا بالتيار الروسي و التمرينات معا في جلسات متتالية منفصلة و بواسطة التمرينات المركب فوقها التيار الروسي مقارنة بالذين تدربوا بالتمرينات أو التيار الروسي . كما كانت هناك زيادة ذات دلالة إحصائية في المجموعة التي تدربت بواسطة التمرينات المركب فوقها التيار الروسي مقارنة بالذين تدربوا بالتيار الروسي و التمرينات معا في جلسات متتالية منفصلة. و يستخلص من النتائج تساوى كفاءة التيار الروسي و التمرينات الايسومترية عند زاوية محدده في تقوية العضلات. و أظهر التدريب بالتيار الروسي والتمرينات معا في جلسات متتالية منفصلة أو بواسطة التمرينات المركب فوقها التيار الروسي كفاءة في تقوية العضلات اكثر من التدريب بالتمرينات أو التيار الروسي فقط. التدريب التمرينات المركب فوقها التيار الروسي افضل البرامج لزيادة القوه العضلية.