



# Effect of electrical stimulation with high voltage pulsed galvanic current and Russian currents on lactic acid accumulation: a preliminary study

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## Research Report

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**Purpose:** The purpose of this study was to compare the effects of electrical stimulation with two different currents on lactic acid accumulation. **Material and methods:** Twenty healthy male volunteers participated in this study, and were equally divided into high voltage pulsed galvanic current (HVPGC) and Russian currents groups. In both groups, electrical stimulation was applied to the quadriceps muscle of the dominant leg. A regime of ten stimulus repetitions for 5 sec followed by 5 sec of rest to HVPGC group, and a regime of ten stimulus repetitions for 10 sec followed by 50 sec of rest to Russian currents group were applied. Subjects' blood lactic acid levels were determined before, in the middle and immediately after the electrical stimulation and at the 3<sup>rd</sup> and 5<sup>th</sup> min of recovery period. **Results:** 2 x 5 ANOVA with repeated measures indicated significant time effects in the blood lactic acid levels ( $F=4.901$ ;  $p<0.05$ ) and no significant group x time interaction. **Conclusion:** These results suggest that two different electrical stimulation currents were not different in lactic acid accumulation.

**Key words:** Electric stimulation, Muscle fatigue, Lactic acid, Russian current, Galvanic current.

## Yüksek voltaj kesikli galvanik akım ve Rus akımları ile stimülasyonunun laktik asit birikimine etkisi: bir ön çalışma

**Amaç:** Bu çalışma iki farklı akımla uygulanan elektrik stimülasyonunun laktik asit birikimi üzerine etkisinin karşılaştırılması amacıyla yapıldı. **Gereç ve yöntem:** Çalışmaya 20 sağlıklı erkek gönüllü katıldı ve denekler yüksek voltajlı kesikli galvanik akım (YVKGA) ve Rus akımları olarak iki eşit gruba ayrıldı. Her iki grupta elektrik stimülasyonu dominant taraf quadriceps femoris kasına uygulandı. YVKGA grubuna 5 saniye dinlenmeyi takiben 5 saniye uyarı ile 10 tekrarlı, Rus akımı grubuna ise 50 saniye dinlenme 10 saniye uyarı ile 10 tekrarlı olarak elektrik stimülasyonu verildi. Olguların kan laktik asit seviyeleri elektrik stimülasyonundan önce, uygulamanın ortasında, hemen sonrasında ve toparlanmanın üçüncü ve beşinci dakikalarında belirlendi. **Sonuçlar:** 2 x 5 tekrarlı ölçümlerde ANOVA analizi kan laktik asit düzeylerinde zaman etkisinin anlamlı olduğunu gösterirken ( $F=4.901$ ;  $p<0.05$ ) ve grup x zaman etkileşimi anlamlı bulunamadı. **Tartışma:** Bu sonuçlar iki farklı elektrik stimülasyonu akımının laktik asit birikimi üzerinde farklılık oluşturmadığını gösterdi.

**Anahtar kelimeler:** Elektrik stimülasyonu, Kas yorgunluğu, Laktik asit, Rus akımı, Galvanik akım.

Electrical stimulation is an extensively used technique to improve muscular strength based on transcutaneous electrical stimulation of intramuscular motor fibers. Many studies have indicated the effect of this method in orthopaedic rehabilitation and physical therapy allowing reduced muscle atrophy and weakness.<sup>1,2</sup> It is generally accepted that electrical stimulation is complement to traditional training for increasing the muscle strength in healthy subjects; some studies found an improvement in muscle strength,<sup>3,4</sup> while some studies did not find any change in muscular strength after electrical stimulation application.<sup>5</sup>

For the electrical stimulation, among clinical stimulators most commonly used currents are faradic, Russian and high voltage pulsed galvanic current (HVPGC). It has been indicated that Russian and HVPGC provide better patient tolerance, can reach to higher intensities without pain formation and can result in stronger contractions by affecting deeper areas.<sup>6</sup> The advantage of ultrashort pulse duration of HVPGC relates to stimulation of sensory nerve fibres. The chance for stimulating A - delta and C sensory axons decreases, thus increasing patient comfort. Current density also affects patient comfort by influencing sensation arising from electrical stimulation.<sup>7</sup> The main physiological effect of Russian current is at the cellular level but indirectly the tissue, segmental and systemic levels may also be affected.<sup>8</sup> In HVPGC on the other hand, the major direct physiological responses are the electrochemical changes that occur at the cellular and tissue levels. The change of skin pH under the electrodes causes a reflex vasodilatation, thus indirectly increasing arterial blood flow to the skin.<sup>6</sup>

Muscle fatigue is defined as impairment in the force-generating ability of muscle associated with recent contraction.<sup>9</sup> It is a complex multifactorial phenomenon and has been associated with impairment of function at a number of sites from central to peripheral activation.<sup>10,11</sup> The classic approach used identify the cause of muscle fatigue has been to distinguish between neural and muscular mechanisms. This can be accomplished, for example, by applying on electrical stimulus to

the peripheral nerves and either comparing the decline in muscle force during a voluntary contraction with that evoked by the imposed electrical stimulation.<sup>12,13</sup> As known, the underlying mechanisms of fatigue have evoked much interest for a long time and its significance lies not only in the function of healthy skeletal muscle, but also in unhealthy muscle. One of the causes of peripheral fatigue is the accumulation of lactic acid in the muscle that results in increased hydrogen ion concentration which in turn results in decreased action potentials, changes in sarcoplasmic release of calcium and decreased activities of muscle enzymes.<sup>10,14</sup> As a result, strength of muscle contraction decreases which is the first indication of muscular fatigue.<sup>15</sup>

Responses of a healthy muscle to short and long-term electrical stimulation are similar to responses given to an exercise. In contractions that occur as a result of electrical stimulation more muscle fibers are activated at the same time with stronger contractions compared to voluntary contractions.<sup>16,17</sup> During electrical stimulation the asynchronous and orderly recruitment of motor units are absent and may contribute to the increased fatigue observed with electrical stimulation when compared with voluntary effort.<sup>18</sup> Several studies have demonstrated that in both voluntary and electrically stimulated short duration high intensity exercise, protocols that produce the greatest metabolic changes also produce the greatest fatigue.<sup>11,19</sup>

Electrical stimulation is often used in the rehabilitative settings for training of paralyzed muscles. One of the major problems with applying electrical stimulation is a rapid onset of fatigue in the paralyzed muscles.<sup>20-21</sup> However, activation with electrical stimulation will inherently cause more fatigue than contractions of voluntary effort. This is probably due to the repetitive synchronous stimulation of fast and slow motor units during electrical stimulation in apparent disregard for the size principle regarding the orderly recruitment of motor units as well as the inability to recruit additional motor units to offset fatigue.<sup>21</sup>

Researchers have attempted to identify preferred stimulation settings in terms of comfort, force of contraction and muscle fatigue, which is

defined as a decrease in the force generating ability of a muscle resulting from recent activation.<sup>22</sup> Torque produced by contracting muscle declines with time and numbers of contractions. This decrement of torque produced by contracting muscle(s) is referred to as fatigue.<sup>6</sup> The results of a study by Snyder-Mackler et al indicated that differences exist among the torque generating capabilities of various stimulators, with phase charge an important determining factor.<sup>23</sup> The exact mechanisms of muscle fatigue are complex and not fully understood.<sup>24</sup> However a great deal of evidence exists which suggests that accumulated lactate and the associated hydrogen, ions are at least partially responsible for slowing recovery from fatigue.<sup>25</sup> To our knowledge the only study that investigated the effects of electrical stimulation on lactic acid accumulation used surge mode faradic currents in rabbits and found no significant increase in lactic acid concentration after 60 min of electrical stimulation.<sup>26</sup> However to our knowledge no study investigated the effects of HVGPC and Russian currents on lactic acid accumulation in healthy human subjects.

The purpose of this study was therefore, to compare the effects of electrical stimulation with HVGPC and Russian currents on lactic acid accumulation. The significance of the study is that the findings may help in the determination of proper electrical stimulation for muscle strengthening in patients with muscle weakness that occurred as a result of muscle paralysis and chronic diseases in clinical settings.

## Material and methods

### Subjects:

A total of 20 sedentary males participated in this study voluntary and were equally divided into two experimental groups as HVGPC group (N=10) and Russian current group (N=10).

Subjects had no history about the neurological problems, fracture, muscle and ligament problems of lower extremity. All subjects read and sign an informed consent form approved by Faculty of Health Sciences Project Committee of Başkent University. Physical characteristics of the subjects

were given in Table 1.

### Electrical Stimulation:

In both groups, the quadriceps muscle of the dominant leg was stimulated either with HVGPC or Russian current. Subjects were seated in a custom-built chair with the hip at 80 degrees and the knee secured at 60 degrees of flexion. The dominant leg was secured to a rigid lever arm with an inelastic strap in an effort to ensure that the extensors could perform only isometric contractions. It has been indicated that the quadriceps femoris muscle performs highest muscular force at 60 degrees of knee angle.<sup>6</sup>

In both groups the bipolar technique was used; the active electrode (5×7.5 cm) was placed at 5-7 cm proximal to the patella and the dispersive electrode (5×7.5 cm) was placed 10-12 cm distal to the inguinal area.<sup>6</sup>

In the HVPGC group, electrical stimulation was applied by Biomedical Life System GV350 HVPGC unit with a voltage of 100 volts (Biomedical Life Systems, USA). In the unit, a frequency of 100 pps and a pulse duration of 200 µsec were used to produce a tetanic muscle contraction. In the Russian current group, electrical stimulation was applied with Endomed 982 that includes Russian currents (Enraf Nonius, Holland). In the unit, a continuous sine wave output of about 2500Hz is modulated to yield 50 bursts per second. Pulse duration of 400 µsec was used.

### Procedure:

For the HVPGC group a regime of ten stimulus repetitions of 5 sec followed by 5 sec of rest was applied and for the Russian current group a regime of ten stimulus repetitions of 10 sec followed by 50 sec of rest was applied. For both groups amplitude was increased according to the muscular contraction and patients' tolerance.

Each subject came to the laboratory, sit comfortably and rested for 10 minutes at the experiment chair before the beginning of the experiment. After the resting period and immediately before beginning the experiment, blood samples were taken from the earlobe and analyzed by using the YSI Sport 1500 L-Lactate analyzer with a cell lysing agent (Yellow Springs Instruments, Yellow Springs, OH, USA) for determination of resting blood lactic acid levels.

Blood samples were also taken at the middle (at the end of 5<sup>th</sup> contraction), at the end of the stimulation (at the end of 10<sup>th</sup> contraction) and at the 3<sup>rd</sup> and 5<sup>th</sup> minutes of recovery period to determine the effects of these two currents on lactic acid accumulation. Lactate concentrations were also determined during the recovery period because it is known that there is a time lag for the diffusion of the lactate from the active muscles and redistribution within the body and in order to determine the peak lactate concentration in the blood samples have to be taken at intervals during the first 5 to 10 min of the recovery.<sup>26</sup>

#### Statistical analysis:

Comparisons in blood lactic acid levels before, in the middle and after the electrical stimulation between HVPGC and Russian groups were analyzed using 2×5 (Group×Time) analysis of variance with repeated measured. Least significant difference post hoc tests were used to isolate pair wise differences when there was a significant F ratio. The level of significance was set at  $p<0.05$ .

**Table 1. The physical characteristics of subjects in HVPGC and Russian groups.**

	HVPGC (N=10) X±SD	Russian (N=10) X±SD
<b>Age</b> (yrs)	30.1±4.7	29.9±3.5
<b>Height</b> (cm)	175.8±7.4	180.3±7.6
<b>Body weight</b> (kg)	78.3±11.2	81.7±10.5
<b>BMI</b> (kg/cm <sup>2</sup> )	25.3±3.3	25.12±2.6

BMI: Body mass index.

## Results

Mean blood lactic acid levels before, in the middle, after electrical stimulation and at the 3<sup>rd</sup> and 5<sup>th</sup> minute of recovery of the HVPGC and Russian current groups are given in Table 2.

According to 2x5 ANOVA with repeated measures significant time effects were found in blood lactic acid levels before, in the middle and immediately after and at 3<sup>rd</sup> and 5<sup>th</sup> minutes of electrical stimulation [ $F_{(4,15)}=4.901$ ,  $\eta^2 = .214$ ,

power = .947;  $p<0.05$ ]. Blood lactic acid levels before electrical stimulation were significantly different from blood lactic acid levels immediately after and at 3<sup>rd</sup> and 5<sup>th</sup> minutes of the electrical stimulation.

Results also indicated that there was no significant group × time interaction [ $F_{(4,15)}=1.158$ ,  $\eta^2=.060$ , power=.346,  $p>.05$ ] between HVPGC and Russian current groups indicating that the change in blood lactic acid levels was not different between the two groups.

**Table 2. Mean blood lactic acid levels before, in the middle, after and at the 3<sup>rd</sup> and 5<sup>th</sup> minute of recovery of the HVPGS and Russian groups.**

	HVPGC (N=10) X±SD	Russian (N=10) X±SD
<b>BLA levels</b> (mmol)		
Before	0.99±0.38	0.74±0.22
Middle	0.75±0.40	0.76±0.34
After	0.72±0.24	0.55±0.22
3 <sup>rd</sup> min recovery	0.71±0.34	0.59±0.29
5 <sup>th</sup> min recovery	0.68±0.41	0.61±0.28

BLA: Blood lactic acid.  
There is a difference between before and 3<sup>rd</sup> min recovery, between before and 5<sup>th</sup> min recovery, in each group ( $p<0.05$ ).

## Discussion

This study is an original study because it compares two different currents and their effect on muscular fatigue and therefore on lactic acid accumulation. Results indicated that the two currents did not result in different with regard to lactic acid accumulation. However in both groups lactic acid concentrations before electrical stimulation were significantly higher than lactic acid concentrations immediately after and at 3<sup>rd</sup> and 5<sup>th</sup> min of recovery between groups. One of the reasons for finding such a decrease may be due to the duration of stimulus-rest ratio. As known in the present study HVPGC was applied with 5 sec of stimulus followed by 5 sec of rest for ten repetitions and Russian current was applied with 10 sec of stimulus followed by 50 sec of rest with

ten repetitions. Therefore the total duration of electrical stimulation might not be effective enough to activate the lactic acid system and hence to lead to increased lactic acid accumulation. In addition, it is also known that blood lactate during exercise is removed by direct oxidation and through conversion to glycogen,<sup>24</sup> which may be the reason for finding lower lactate concentrations immediately after and at 3<sup>rd</sup> and 5<sup>th</sup> min of recovery compared to lactate concentration before electrical stimulation.

Another finding of the present study is the no significant group  $\times$  time interaction between HVPGC and Russian current groups that indicate the change in blood lactic acid levels was not different between the two groups. As indicated Russian and HVPGC currents are among the most commonly used currents because they provide better patient tolerance, reach to higher intensities without pain formation and can result in stronger contractions by affecting deeper areas.<sup>6</sup> Russian current has the major physiological effect at the cellular level,<sup>8</sup> and for HVPGC the major direct physiological responses are the electrochemical changes that occur at the cellular and tissue levels. In addition these two currents are generally applied with different stimulus-rest ratio. Although these two currents are different in terms of duration of application and direct physiological effects, our study indicated that they were not different in terms of lactic acid accumulation.

One of the limitations of our study is the limited number of subjects. From this aspect it can be considered as a preliminary report; further investigations with a higher number of subjects is needed before reporting conclusive results. In clinical settings such as muscle paralysis and chronic diseases, these two currents can be applied for muscle strengthening without formation of muscle fatigue.

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