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Simultaneous Electrical Stimulation of Multiple Muscles Reduces Blood Glucose Level in Healthy Adults

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Abstract
Aim & Objective: The aim of this study was to examine the effects of 30-minute simultaneous stimulation using Russian current on selected physiological parameters in a pretest posttest experimental design.

Methods: 10 healthy male sports players aged 18-24 years were selected & given stimulation over 8 large muscles using Russian current of frequency 25100 Hertz (Hz) sweep 50 Hz. Heart rate, Respiratory rate, blood pressure, oral temperature, Blood glucose and Blood lactate were recorded at pre-stimulation, immediately after stimulation and at 5 minute and 20 minutes post stimulation phase.

Results: One-way repeated measure ANOVA with post hoc t test was the tool of statistical analysis with level of significance set at $p < 0.05$. Significant differences were observed in the parameters of blood glucose and blood lactate level only. Mean blood glucose level pre stimulation, immediately post stimulation, 5-minute post stimulation and 20-minute post stimulation were 99.00 ±17.15, 81.80±15.74, 89.10±17.56 and 93.90 ± 18.15 respectively. The corresponding figures for blood lactate were 2.83±0.80, 6.19± 3.61, 4.60±1.60 and 3.97±1.75. Significant difference was found between the blood glucose and blood lactate level ($p<0.05$) only between pre stimulation and immediate post stimulation period.

Conclusion: It can be concluded that simultaneous electrical stimulation of 8 large muscles for 30 minutes using Russian currents brings about a drop in blood glucose level along with elevation of blood lactate without significantly affecting heart rate, blood pressure and oral temperature in healthy young adults. This hints at the possibility of using this modality as tool to achieve glycemic control.

1. Introduction

Electrical muscle stimulation is used routinely in clinical practice, to produce muscle contraction in the conditions where active contraction is desired but cannot be produced by patients. Therapeutic electrical stimulation utilizes electric pulse of various duration and frequencies that cause excitation of peripheral nerve and subsequently muscle tissue (Hamada, 2004). Development of sophisticated medium frequency. Electrical Stimulation (ES) equipment's permitting comfortable simultaneous stimulation of several healthy innervated muscles has ignited interest in using this modality as an alternative to active voluntary exercise for muscle strengthening (Porcari et al, 2002). Medium frequency-based stimulators are now used routinely in fitness centers and health clubs as inch loss fat loss machine obesity reduction

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clinic. Use of electrical stimulation to facilitate recovery following exhaustive workout has also been reported (Cramp et al, 2002). Recent reports also hint at the possibility of using ES to achieve glycemic control in DM (Hamada et al, 2003; Kawaguchi et al, 2011; Miyamoto et al, 2012). Despite these widespread claims there exist scarcity of information with regards to immediate effect of multi muscle electrical stimulation on various physiological and biochemical parameters. If multi muscle electrical stimulation is to be used as an alternative to the active exercise program it is necessary that the effects of Electrical Stimulation on physiological parameters are established. The aim of this study was to examine the effects of multi muscle electrical stimulation of 30-minute duration on Heart rate, Respiratory rate, Blood pressure, oral temperature, Blood glucose and Blood lactate.

2. Methodology

Sample consisted of 10 healthy male sports players aged 18-24 yrs selected randomly from a list of 30 volunteers. Subjects were active sports men who were practicing 3-4 times per week for the last 2 years. Cardio–pulmonary and Musculo–skeletal conditions, that might limit the execution of high intensity exercise and the consumption of any medication /supplement one month prior to the experiment were ruled out using a screening questionnaire which was adapted after Smith et al (2010). All subjects signed informed consent form. Study protocol was approved by the institutional ethical committee of Punjabi university Patiala vide letter no 40/DLS/HG.

Intervention: Pre-posttest design was used in this study. 8 muscle groups of lower limbs were simultaneously subjected to electrical stimulation with Russian current of frequency 2500 Hz sweep 50 Hz for 30 minutes in supine position using 8 channel electrical stimulator (TORC-841, make–Johari digital Healthcare Ltd, Jodhpur, India an ISO Certified unit).

Preparation of patient: subjects were asked to refrain from taking any food one hour prior to stimulation. On arrival subjects took 15 minutes of rest in the calm and quiet room in supine position with head well supported on pillow. Thereafter the stimulation sites were prepared by cleaning the skin with spirit to reduce the skin resistance. Aqueous ECG gel was smeared on the Electrodes surface. Two electrodes each was placed and secured with elastic strap on the muscle belly of Deltoid, Calf, Quadriceps and Glutei of both sides (Figure1). Subjects were explained that he would receive mild tingling sensation along with twitching of the muscle during 30 minutes session of electrical stimulation. They were further instructed to report immediately any untoward sensation and discomfort. Intensity of current was adjusted according to subject's comfort level to produce visible muscle contraction. Subjects were made to rest for additional 20 minutes after cessation of stimulation.

Outcome measures: Outcome measures were recorded pre-stimulation, immediate post stimulation, 5 minute and 20 minutes after cessation of stimulation. Heart rate was recorded using stethoscope. Clinical thermometer, mercury sphygmomanometer, and ordinary watch were used to measure oral temperature, blood pressure and respiratory rate respectively using standard clinical methods. 5µl of capillary blood samples was drawn by finger prick to determine lactate and sugar concentration in blood using a portable blood lactate analyzer- lactate scout make and portable clinical glucometer (Figure2).

Figure1: Subject showing electrode placement

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Figure2: Blood glucometer & blood lactometer

Data analysis: one-way repeated measure ANOVA with post hoc t test was the tool of statistical analysis with level of significance set at $p < 0.05$.

3. Result:

Table 1 presents the descriptive statistics and F ratio for the test of difference among variables across different points of measurement. Significant group differences were observed in the parameters of blood glucose and blood lactate but not in other outcome measures. The post hoc analysis showed significant difference ($p<0.05$) between pre stimulation and immediate post stimulation means of blood glucose and blood lactate level. The differences across other point of measurement were not significant. The blood glucose level drops significantly to 17.37% immediately after stimulation which returns to the base line level after 5 minute of post stimulation and remains so after 20 minutes of stimulation (figure3). Blood lactate rose to 118.72% which return to the near base line after 5

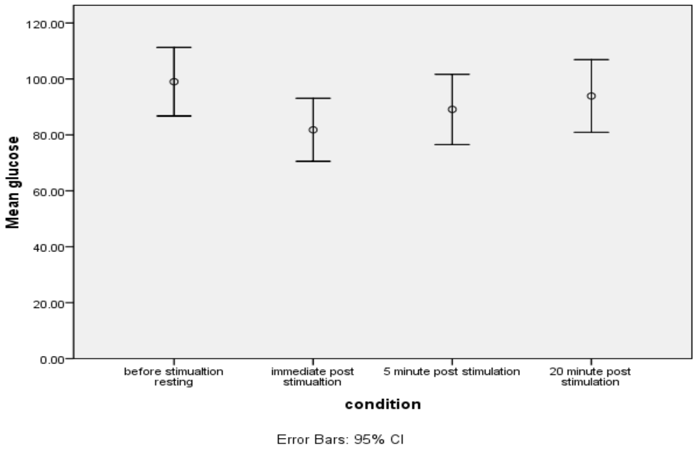

Figure 3: Shows reduction in blood glucose level post stimulation

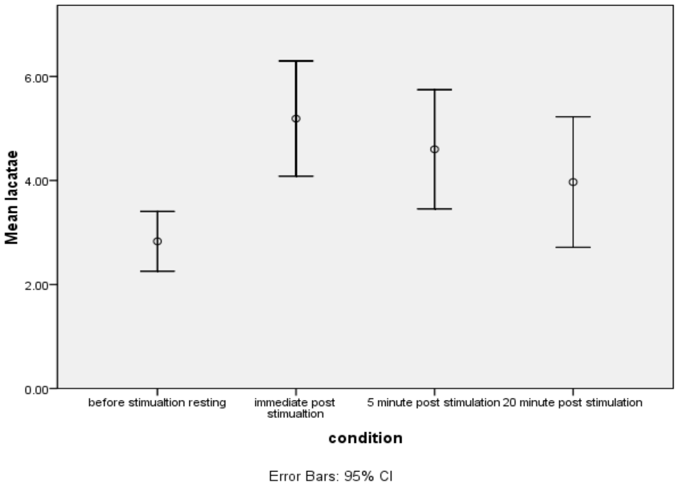

Figure 4: Shows elevation in blood lactate level post stimulation

Table 1: Presents the descriptive statistics and F ratio for the test of difference among variables across different points of measurement

VARIABLE	Pre stimulation A Mean ± SD	Immediate post B Mean ± SD	5 min post C Mean ± SD	20 min post D Mean ± SD	F
HEAR RATE (beat /min)	69.4±8.99	74.10±7.40	68.90±6.90	69.30±5.30	1.13
SBP (mm Hg)	121±7.73	128±8.83	125±5.75	122±7.80	1.63
DBP (mm Hg)	80.60±5.89	83.70±4.85	82.80±6.87	81.00±7.37	0.54
RESPIRATORY RATE (per minute	18.30±3.46	20.70±3.80	19.50±2.70	18.60±2.75	1.1
ORAL TEMPERATURE (degree Celsius)	97.96 ± .604	98.43 ± .305	97.67 ± .955	97.84 ± .587	2.48
BLOODGLUCOSE (mg/dl)	99.00 ±17.15	81.80±15.74	89.10±17.56	93.90 ± 18.15	2.91*
BLOOD LACTATE (mmol/dl)	2.83± .80	6.19± 3.61	4.60±1.60	3.97±1.75	4.05**

minute of post stimulation and remain so after 20 minutes of stimulation (figure4). Effect size for blood glucose was 0.46 with Cohen d 1.04. The corresponding figures for blood lactate were 0.54 and 1.28 respectively.

4. Discussion:

The main finding of this study is that simultaneous electrical stimulation of 8 large muscles for 30 minutes using Russian currents brings about a drop in blood glucose level along with elevation of blood lactate without significantly affecting heart rate, blood pressure and oral temperature in healthy young adults. The program was well tolerated and no adverse effects were observed during 30 minute of stimulation and after. This observation has important clinical and academic implications. 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 (Selkowitz DM, 1989). The stimulator producing this current are routinely used in fitness centers and health clubs as inch loss weight loss machine. We could not locate any study that examined the effect of this specific current type on the blood glucose level of normal healthy adults. However, in individuals with type II DM significant reduction in blood glucose following electrical stimulation of single (Sharma et al, 2010) and multiple muscles (Kawaguchi et al, 2011; Miyamoto et al, 2012; Crowe and Caulfield, 2012) using low frequency current has been reported. The role of skeletal muscles in glucose metabolism is well known. Skeletal muscles are directly involved in the maintenance of whole-body glucose metabolism and contribute to about 70% of glucose disposable (DeFronzo, 1988). An acute bout of physical exercise increases glucose disposal into the contracting muscles leading to clinically significant decreases in blood glucose concentrations (Hamada et al, 2004). Barring few differences in the order of recruitment of muscle fibers, the effects of voluntary muscle contraction and electrical stimulation induced muscle contraction are same (Astrand et al, 2003). Thus, theoretically electrical stimulation induced contraction of muscle have potential to bring about blood glucose reduction. We hypothesized that a session of 30 minute of electrical stimulation would bring about reduction in the blood glucose level and that effect would last for some

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time after the cessation of stimulation. The data of this pilot study lend support to this assumption. Activated glucose uptake response in rat skeletal muscle following electrical stimulation (ES) has been reported in several studies (Ploug et al, 1984; Wallberg and Holloszy, 1984; Goodyear et al, 1990; Lund et al, 1995). Human research also demonstrated that ES induced muscle contraction enhanced blood glucose uptake (Miyamoto et al, 2012; Griffin et al, 2009; Kawaguchi et al, 2011; Hamada et al, 2003; 2004). Our observation is in agreement with these studies. Studies of Hamada et al (2003) were probably the first that suggested the possibility of using Low-frequency ES to activate energy and glucose metabolism in humans. They reported significantly enhanced glucose disposal rate (GDR) during euglycemic clamp following low-frequency surface Electrical stimulation of quadriceps femoris for 20 minutes. In subsequent study they (Hamada et al, 2004) compared the acute metabolic effects of ES to lower extremities with voluntary cycle exercise at identical intensity and reported a significant increase in whole body glucose uptake during and after the cessation of ES for at least 90 min. In the present study immediate post stimulation blood glucose level was significantly different from the pre stimulation level. The trend indicates lower blood glucose level even after 20-minute post stimulation though statistically significant differences were not observed across other point of time, which may be attributed to the small sample size. With regards to blood lactate our observation is in agreement with the previous studies that reported increase in blood lactate after electrical stimulation in resting condition (Hultman and Sjoholm, 1983; Ren et al, 1990). Hultman and Sjoholm (1983) reported that during stimulation of Quadriceps femoris in human, for 50 seconds, glycolysis began within 5 seconds of the initiation of contraction and lactate concentration within muscle increased with time throughout the entire contraction period of 50 seconds. Similar observation has also been made by Ren et al, 1990. The increase in blood lactate after of electrical stimulation has been attributed to the recruitment of large diameter type II fibers during electrical stimulation (Sinacore et al, 1990). It is well known that recruitment of fast twitch fibers leads to formation of lactate independent of tissue oxygenation (Essen et al, 1975). There exist differences between voluntary contraction and electrical stimulation induced muscle contraction in the order of muscle fiber recruitment. Unlike asynchronous voluntary contraction, where type I oxidative fibers are recruited first, the electrical stimulation results in synchronous contraction of all the fibers with preferential recruitment of type II Glycolytic fibers (Low and Reed, 1999) due to larger axonal diameter of type II motor units, which have lower electrical resistance against external electrical stimulation (Henning and Lomo, 1985).

The limitations of this study include a small sample size. Using the pre-stimulation and 20-minute post stimulation data of blood glucose a sample of 175 subjects would be required to detect a treatment difference at a one-sided 0.05 significance level at the probability level of 80%. There is a need to cross validate the finding of this study on a larger sample size. Further research is required to explore the feasibility of using this mode of muscle activation as a tool to activate energy and glucose metabolism in sedentary population. In conclusion the study suggests that 30-minute multi muscle stimulation using Russian current is safe and may be used as a supplementary tool for exercise training of sedentary healthy individual without any side effects.

5. Conclusion:

It can be concluded that simultaneous electrical stimulation of 8 large muscles for 30 minutes using Russian currents brings about a drop in blood glucose level along with elevation of blood lactate without significantly affecting heart rate, blood pressure and oral temperature in healthy young adults. This hints at the possibility of using this modality as tool to achieve glycemic control.

6. Competing Interest / Conflict of Interest:

The authors have no Competing interest among themselves to declare in this study. The manuscript has been seen and mutually agreed by all the co-authors. Furthermore, there is no financial interest to report by any author. We also would like to certify that the submission is original work and is not under review at any other publication

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