Effect of Combined Electrical Stimulation as a Recovery Modality on Selected Physiological Transients in Adolescent Judo Players

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Abstract

The study was conducted on 14 Haryana state level junior judo players to find out the effectiveness of Russian current stimulation as a recovery modality following exhaustive exercise on heart rate, temperature, blood lactate and blood pressure. Each subject was asked to do 20-m shuttle run test until exhaustion for three times with one week gap in between. After shuttle test, each subject underwent the following three recovery interventions, between 3-33 min, in a systematic random order. Recovery I: passive recovery where the subject was asked to sit for 33 minutes. Recovery II: active recovery where the subject was asked to walk/run at 60% maximal heart rate (MHR) between 3-33 minutes. Recovery III: electrical stimulation where the subject received Russian current (50 hz, 10 sec on: 50 sec off) for 5 min i.e. 3rd to 8th min and 18th to 23rd min of recovery with interspersed 10 min rest in between. Heart rate, temperature, blood lactate, systolic blood pressure, diastolic blood pressure was recorded before the shuttle test and 3rd, 8th, 18th, 23rd and 33rd minutes of recovery period. ANOVA repeated measures (with- in subjects) was used to see the effect of electrical stimulation on physiological parameters in different timings and ANOVA (between subjects) to compare the electrical stimulation with active and passive recovery. Significant level was set at ‘0.05’ ($p<0.05$). Results showed electrical stimulation produced increased heart rate but not significantly, when compared to passive recovery but significantly less when compared to active recovery. Russian current also significantly increased the blood lactate level when it compared to both active and passive recovery values at regular intervals. Active recovery produced significantly lesser body temperature and lactate as well as significantly higher systolic blood pressure when compared to both passive and electrical stimulation modalities. It is concluded that electrical stimulation results in increased blood lactate production without much changes in other physiological parameters.

Keywords: Russian Current, Blood Lactate, Heart Rate, Blood Pressure, Shuttle Run

Introduction

Surface neuromuscular electrical stimulation (NMES) is a useful treatment tool in sports medicine apart from treating other clinical conditions such as stroke, cerebral palsy, and spinal cord injury.

NMES protocols consist of a combination of pulse parameters and time modulations to induce muscle contractions that aim to simulate both endurance and resistance training *(Binder-Macleod and Synder-Mackler, 1993; Dudley et al, 1999; Bax et al, 2005; Delay et al, 2005).*

In humans, transcutaneous chronic electrical stimulation sessions can increase muscle oxidative capacity, capillarisation of fast twitch fibers, or induce some fiber type transitions among type II fiber sub types *(Cabric et al, 1987; Gauthier et al, 1992; Thériault et al, 1996; Perez et al, 2002).* Traditionally Russian current has been used to strengthen individual muscles; however *Perez et al (2003)* reported in their study that low intensity current does improve the delta efficiency of muscle at high sub-maximal work load without improving endurance performance in normal healthy individuals. Further *Kesar et al (2008)* reported in their study that frequency modulation is better than pulse duration modulation in torque production during the functional electrical stimulation. So Russian current, a medium frequency current that produce a low frequency current through frequency modulation, could be the best choice to improve the endurance performance than the low frequency current used by *Perez et al (2003)*.

Accumulation of blood lactate has been considered to be a cause for the fatigue in athletic population that may lead to various injuries during training and competition, however till date no study has reported the effect of electrical stimulation on blood lactate or whether it could be used as a recovery modality after exhaustive training.

The purpose of the present study is to examine the effect of Russian current stimulation as a recovery intervention in the clearance of blood lactate and restoration of other physiological parameters and compare it with traditional active and passive recovery.

Material and Methods

Fourteen male judo players aged between 15 to 19 yrs, who were actively participating in at least state level competitions and were training at SAI, Regional center, Hisar, Haryana were recruited for the present study. After getting their informed consent, they were fully apprised of possible risks or discomfort associated with the electrical stimulation protocol. Each subject was asked to do a 20-m shuttle run test until exhaustion for three times with one week gap in between. After shuttle test, each subject underwent the following three recovery interventions, between 3-33 min, in a systematic random order.

Recovery Intervention I: Passive recovery where the subject was asked to sit for 33 minutes. *Recovery Intervention II:* Active recovery where the subject was asked to walk/run at 60-65% of MHR (120-130 beats/min) during 3rd to 33rd of minute of recovery period. *Recovery Intervention III:* Electrical stimulation through TORC Plus TR-841 (Johari digital Healthcare Ltd, Jodhpur, India an ISO Certified unit) in which the subject received Russian current stimulation (frequency 2500Hz, sweep 50 Hz). Subject's bilateral quadriceps and hamstrings (total 4) were used as stimulation sites. In order to maintain the consistency in electrode placement the distance between ASIS and base of patella was divided into three parts with two elastic bands fitted in the junction areas (total 4). Each stimulation site, two superiorly and two inferiorly located, as well as elastic band, two anteriorly and two posteriorly, received four medium sized circular electrodes (total 16). In each stimulation site the electrodes of channel 1 and 2 were placed criss-cross (X) manner. Seventy two mA intensity current (i.e. 60% of maximal) with 10 sec on and 50 sec off duration was used to stimulate the four sites for 5 min with 10 min rest in between (i.e. Quadriceps and Hamstrings stimulations were done during 3rd to 8th min and 18th to 23rd min periods of recovery).

The minute heart rate (beats/min), temperature (ºF), blood lactate (mmol/L), systolic and diastolic blood pressures (mmHg) were recorded before the shuttle test and at 3rd, 8th, 18th, 23rd and 33rd minutes of recovery period. Heart rate was monitored using Polar telemeter (F6 model, Polar Electro Oy, Finland). Oral temperature was measured using Digital Clinical Thermometer an ISO approved model with accuracy ±0.1ºF (Geon Corporation, Taiwan).

A hand-held portable lactate analyzer (Lactate Plus, Nova Biomedical, Waltham, MA, USA) along with non reusable strip was used to determine blood lactate level.

Blood pressure was measured using Sphygmomanometer (Pagoda an ISI approved model, Elite Surgical Industries, New Delhi) and Stethoscope (Micro-Tone model, Malhotra Surgical Industries, Delhi). All the measurements were recorded as per manufacturer's user manual.

Data is presented by mean, standard deviation. It was further analyzed by ANOVA repeated measures (within subjects) to see the effect of electrical stimulation on physiological parameters in different timings and ANOVA (between subjects) to compare the electrical stimulation with active and passive recovery. Significant level was set at '0.05' ($p<0.05$).

Results and Discussion

Results showed there was no significant difference during rest (pre-exercise) as well as at 3rd minute post exercise recovery period in all the physiological parameters among the three recovery groups.

Table 1: Changes in physiological transients at different intervals during electrical stimulation recovery (n=14).

	HEART RATE (BEATS/MIN)		ORAL TEMPERATURE (ºF)		BLOOD LACTATE (MMOL/L)		SYSTOLIC BP (MMHG)		DIASTOLIC BP (MMHG)	
	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
Pre-exercise	78.64	9.45	97.15	1.36	3.41	1.18	131.43	10.77	84.00	7.69
3rd min	118.43	9.61^{c}	95.91	2.04^{b}	11.80	4.15^{c}	156.21	17.29^{c}	73.93	8.55^{b}
8th min	113.28	12.34^{c,d}	97.56	0.98^{e}	13.84	4.04^{c,d}	138.86	13.81^{a,f}	85.29	9.40^{e}
18th min	105.78	8.67^{c,f,h}	98.36	0.66^{b,f,i}	10.59	3.68^{c,g}	127.86	12.66^{f,i}	86.43	10.32^{e}
23rd min	107.14	10.93^{c,f,h}	98.21	0.65^{b,e,g}	11.44	5.07^{c}	128.29	10.64^{f,h}	87.57	9.09^{a,e}
33rd min	98.21	8.45^{c,f,i,m}	98.16	0.64^{b,e,g}	7.78	2.79^{c,e,i,m}	122.86	11.99^{a,f,i}	86.00	8.39^{d}

Values are mean ± standard deviation, BP. ^{a,b,c} are 'p' value 0.05,0.01,0.001 respectively when compared to pre exercise value. ^{d,e,f} are 'p' value 0.05,0.01,0.001 respectively when compared to 3rd min value. ^{g,h,i} are 'p' value 0.05,0.01,0.001 respectively when compared to 8th min value. ^{j,k,m} are 'p' value 0.05,0.01,0.001 respectively when compared to 18th min value

Table 1 shows the changes in physiological parameters during electrical stimulation recovery. Minute heart rate remains significantly ($p< 0.001$) increased than the pre-exercise level throughout recovery period. However, it does show a trend of decrease gradually from 3rd min to 33rd min except at 23rd min, the period which coincides with the second electrical stimulation phase, where it increased slightly from 105.78 ± 8.67 to 107.14 ± 10.93 beats/min. All heart rate reduction values are significantly lower ($p < 0.001$) than 3rd min value of 118.43 ± 9.61

beats/min except at 8th min, of recovery i.e. the phase of first electrical stimulation, where the value of 113.28 beats/min reduced the significant level to 0.05. Pre-exercise oral temperature value of 97.15 ± 1.36ºF reduced significantly ($p < 0.01$) to 95.91 ± 2.04ºF after exhaustive work, which returned to near normal, 97.56 ± 0.98ºF, at 8th min. Thereafter, oral temperature increased significantly ($p<0.01$) at 18th min, 23rd min, 33rd minute intervals of post recovery period. In contrast to the first electrical stimulation period, during second electrical stimulation period the temperature decreased from 98.36 ± 0.66ºF to 98.21 ± 0.65ºF without any significant difference.

All the measured blood lactate values after exhaustive work are observed to remain significantly higher ($p<0.001$) than the pre-exercise value of 3.41 ± 1.18 mmol/L. After the first electrical stimulation period, blood lactate level significantly increased from 11.80 ± 4.15 to 13.84 ± 4.04 mmol/L ($p < 0.05$) at 8th min, then it reduced significantly to 10.59 ± 3.68 mmol/L ($p<0.05$) at 18th min post-recovery. After second electrical stimulation period, blood lactate level increased marginally to 11.44 ± 5.07 mmol/L without any significant difference at 23rd min, followed by significant reduction observed at 33rd min with the value of 7.78 ± 2.79 mmol/L ($p<0.001$).

Pre-exercise systolic blood pressure of 131.43 ± 10.77 mm Hg increased significantly to 156.21 ± 17.29 mmHg at the 3rd min after exhaustive work ($p<0.001$), followed by first electrical stimulation this significant level reduced to '0.05' ($p < 0.05$) with the value of 138.86 ± 13.81 mm Hg recorded at 8th min post-recovery. In comparison to 8th min, systolic BP of 18th min reduced significantly below the pre-exercise level with mean value of 127.86 ± 12.66 mm Hg ($p<0.001$), following second electrical stimulation mean value increased slightly, 128.29 ± 10.64 mm Hg, with slight reduction in significance ($p < 0.01$) at 23rd min.

Mean diastolic blood pressure was observed to decrease from pre-exercise value of 84.00 to 73.93 mm Hg at the 3rd minute of recovery. Thereafter a slight increase in diastolic blood pressure after first electrical stimulation was observed from 73.93 ± 8.55 mm Hg to 85.29 ± 9.40 mm Hg, as well as after second electrical stimulation, from 86.43 ± 10.32 mm Hg to 87.57 ± 9.09 mm Hg, without any significance.

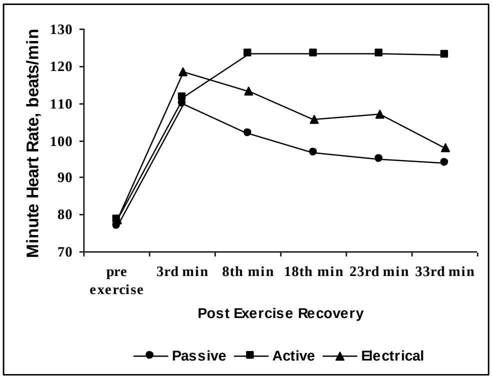

Fig.1: Mean minute heart rate values at rest and recovery heart rates during different interventions, following exhaustive shuttle run test (N=42).

Table 2 & Fig 1 compare heart rate recovery with electrical stimulation, active and passive recovery interventions.

Compared to passive recovery, there is a highly significant increased heart rate values in active recovery at 8th min, 18th min, 23rd min, and 33rd min post exercise intervals ($p<0.001$), first as well as second electrical stimulations produced significant increase in heart rate (101.93 ± 10.79 vs. 113.28 ± 12.34, $p < 0.05$ at 8th min and 94.93 ± 12.05 vs. 107.14 ± 10.93, $p<0.01$). In comparison to the active recovery, electrical stimulation produced significant decrease in heart rate at the 18th min, 23rd min and 33rd min intervals ($p< 0.001$); however this significant level was reduced after the first electrical stimulation at 8th min (123.50 ± 3.06 vs. 113.28 ± 12.34 beats/min, $p<0.05$).

Table 2: Comparison of minute heart rate (beats/min) recovery at different time intervals during the three recovery modes.

		PASSIVE	ACTIVE	ELECTRICAL
Pre-exercise	Mean	76.86	78.71	78.64
	±SD	9.25	7.77	9.45
3rd minute	Mean	110.00	111.64	118.43
	±SD	11.86	13.12	9.61
8th minute	Mean	101.93	123.50	113.28
	±SD	10.79	3.06^{c}	12.34^{a,d}
18th minute	Mean	96.57	123.57	105.78
	±SD	10.92	2.06^{c}	8.67^{a,f}
23rd minute	Mean	94.93	123.50	107.14
	±SD	12.05	2.77^{c}	10.93^{b,f}
33rd minute	Mean	94.00	123.14	98.21
	±SD	13.16	2.48^{c}	8.45^{f}

Values are mean ± SD in beats/min. ^{a,b,c} are ‘p’ value 0.05,0.01,0.001 respectively when compared to passive recovery value (i.e.) passive vs. active and passive vs. electrical. ^{d,e,f} are ‘p’ value 0.05, 0.01, 0.001 respectively in active vs. electrical

Table 3 & Fig 2 compare electrical stimulation temperature recovery with active and passive recovery. There is no significant difference between passive and electrical stimulation recovery through out the recovery period, however electrical stimulation shows a significant higher temperature compared to active recovery at 18th min (98.36 ± 0.66ºF vs. 97.19 ± 0.92ºF, $P<0.001$). This significant level reduced to ‘0.01’ after a second electrical stimulation at the 23rd min (98.21 ± 0.65ºF vs. 97.31 ± 0.87ºF, $p<0.01$), again the significant level increased to ‘0.001’ at 33min (98.16 ± 0.64ºF vs. 97.08 ± 0.82ºF, $p<0.001$).

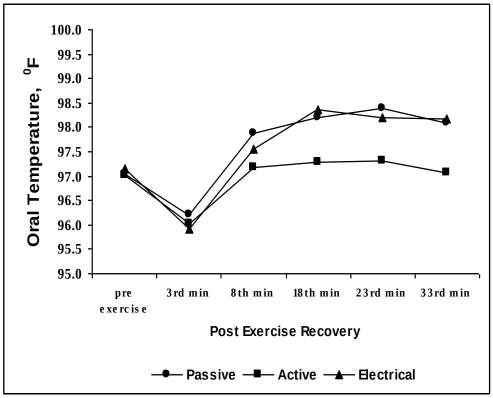

Fig.2: Mean oral temperature values at rest and recovery oral temperature values during different interventions, following exhaustive shuttle run test (N=42).

Table 3: Comparison of oral temperature (ºF) recovery at different intervals during the three recovery modes.

		PASSIVE	ACTIVE	ELECTRICAL
Pre-exercise	Mean	97.04	97.02	97.15
	±SD	1.18	1.28	1.36
3rd minute	Mean	96.20	96.02	95.91
	±SD	1.38	1.87	2.04
8th minute	Mean	97.88	97.19	97.56
	±SD	0.64	0.95	0.98
18th minute	Mean	98.20	97.28	98.36
	±SD	0.49	0.92^{b}	0.66^{f}
23rd minute	Mean	98.40	97.31	98.21
	±SD	0.53	0.87^{c}	0.65^{e}
33rd minute	Mean	98.08	97.08	98.16
	±SD	0.34	0.82^{c}	0.64^{f}

Values are mean ± SD in ºF. ^{a,b,c} are ‘p’ value 0.05,0.01,0.001 respectively when compared to passive recovery value (i.e.) passive vs. active and passive vs. electrical. ^{d,e,f} are ‘p’ value 0.05,0.01,0.001 respectively in active vs. electrical

Table 4 & Fig 3 compare electrical stimulation recovery with both active and passive recovery. After first electrical stimulation, the mean value of 13.84 ± 4.04 mmol/L is observed to be significantly higher than both active (8.78 ± 3.21 mmol/L, $p<0.01$) and passive (10.21 ± 4.17 mmol/L, $p<0.05$) recovery. However after the second electrical stimulation, significant level reduced to '0.05' when compared to the active (active 6.41 ± 3.09; electrical 11.44 ± 5.07 $p<0.05$) recovery. After the 8th min of recovery even though blood lactate levels of active recovery is lesser than passive recovery but the differences were not observed to be significant in statistical terms.

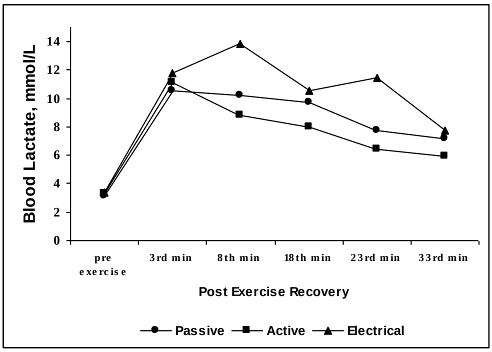

Fig.3: Mean blood lactate value at rest and recovery blood lactate during different interventions, following exhaustive shuttle run test (N=42).

Table 4: Comparison of blood lactate recovery at different time intervals during three recovery modes

		PASSIVE	ACTIVE	ELECTRICAL
pre exercise	**Mean**	**3.16**	**3.29**	**3.41**
	±SD	**1.15**	**1.04**	**1.18**
3rd minute	**Mean**	**10.54**	**11.16**	**11.80**
	±SD	**3.12**	**3.11**	**4.15**
8th minute	**Mean**	**10.21**	**8.78**	**13.84**
	±SD	**4.17**	**3.21**	**4.04**[a,e]
18th minute	**Mean**	**9.75**	**8.03**	**10.59**
	±SD	**3.75**	**4.70**	**3.68**
23rd minute	**Mean**	**7.72**	**6.41**	**11.44**
	±SD	**4.35**	**3.09**	**5.07**[d]
33rd minute	**Mean**	**7.16**	**5.91**	**7.78**
	±SD	**3.26**	**3.26**	**2.79**

Values are mean ± SD in mmol/L. [a,b,c] are 'p' value 0.05,0.01,0.001 respectively when compared to passive recovery value (i.e.) passive vs. active and passive vs. electrical. [d,e,f] are 'p' value 0.05,0.01,0.001 respectively in active vs. electrical

Unlike voluntary contractions, during electrically elicited contractions, smaller and more fatigue-resistant motor units are not always recruited prior to larger and more fatigable ones *(Binder-Macleod et al., 1995; Feiereisen et al., 1997; Heyters et al., 1994; Knaflitz et al., 1990; Trimble and Enoka, 1991)*; therefore, rapid lactate accumulation was thought to result in part due to the difference in recruitment order between electrical stimulation and voluntary activation of motor units.

Conclusion

The results of the present study show that electrical stimulation causes increment in heart rate, blood lactate and blood pressure, decrement in oral temperature when compared to the active and passive modes of recovery as well as with in different intervals. Since electrical stimulation stresses cardio-vascular system with out reducing the lactate, it can be concluded that electrical stimulation may not be a useful tool in recovery after exhausted exercise.

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