Burgos-Postigo S[1]*, Recarey A*[1,2]*, Fernández-Elías VE*[1]

Acute Effects of WB-EMS on 20-min Rowing Time Trial Performance: Randomized Crossover Study

Akute Auswirkungen von WB-EMS auf die Leistung beim 20-minütigen Rudern im Zeitfahren: Randomisierte Crossover-Studie

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1. UNIVERSIDAD EUROPEA DE MADRID, *Faculty of Sport Sciences, Madrid, Spain*
2. UNIVERSIDAD ISABEL I DE CASTILLA, *Faculty of Health Sciences, Burgos, Spain*

Summary

- **Whole-body electromyostimulation (WB-EMS) training** is effective in improving training adaptations and recovery. However, WB-EMS is associated with potential side effects and contraindications that can lead to excessive muscle damage and physiological impairment. This randomized crossover study aimed to analyze the acute effects of WB-EMS on muscle damage, autonomic modulation, and performance fatigability during a single high-intensity cardiovascular training rowing session.
- **Nineteen healthy and physically active participants,** 10 men and 9 women (with a mean 26±4.07 and 25±5.90 years; 75.4±12.43 and 62.0±5.58 kilograms; and 174±7.33 and 164±4.50 centimeters, respectively), randomly performed two rowing sessions, each lasting twenty minutes, with and without WB-EMS (performing a mean of 4069.8±351.7 and 4091.1±498.8 meters (p=0.88); 112.2±28.0 and 116.6±40.2 watts (p=0.70), respectively). Data showed no significant differences between trials for muscle damage (blood creatine kinase levels), lactate blood levels and performance after exercise, except for squat jump's height which increased in the WB-EMS trial. Likewise, heart rate, blood oxygen saturation and the rate of perceived exertion were similar between trials.
- **The heart rate variability** analysis also showed a similar autonomic response among the trials. WB-EMS resulted to be safe by not negatively affecting the health and performance parameters, while offering a stimulus like regular training in physically active participants, regardless of the delivery of the electrical stimuli. More studies are needed to assess the effectiveness of WB-EMS in improving exercise adaptations during training programs.

Zusammenfassung

- **Ganzkörper-Elektromyostimulationstraining (WB-EMS)** ist wirksam bei der Verbesserung von Trainingsanpassungen und Erholung. Allerdings ist WB-EMS mit potenziellen Nebenwirkungen und Kontraindikationen verbunden, die zu übermäßigen Muskelschäden und physiologischen Beeinträchtigungen führen können. Ziel dieser randomisierten Crossover-Studie war es, die akuten Auswirkungen von WB-EMS auf Muskelschäden, autonome Modulation und Leistungsermüdung während einer einzelnen hochintensiven Herz-Kreislauf-Trainings-Rudersitzung zu analysieren.
- **Neunzehn gesunde und körperlich aktive Teilnehmer,** 10 Männer und 9 Frauen (mit einem Durchschnittsalter von 26±4.07 und 25±5.90 Jahren; 75.4±12.43 und 62.0±5.58 Kilogramm; 174±7.33 und 164±4.50 Zentimetern, jeweils), führten zufällig zwei durch Rudersitzungen, die jeweils zwanzig Minuten dauerten, mit und ohne WB-EMS (mit einem Mittelwert von 4069.8±351.7 und 4091.1±498.8 Metern (p=0.88); 112.2±28.0 und 116.6±40.2 Watt (p=0.70), jeweils). Die Daten zeigten keine signifikanten Unterschiede zwischen den Versuchen in Bezug auf Muskelschäden (Kreatinkinase-Spiegel im Blut), Laktatspiegel im Blut und Leistung nach dem Training, mit Ausnahme der Höhe des Squat-Jumps, die in der WB-EMS-Studie zunahm. Ebenso waren die Herzfrequenz, die Blutsauerstoffsättigung und die wahrgenommene Anstrengungsrate zwischen den Versuchen ähnlich.
- **Die Analyse der Herzfrequenzvariabilität** zeigte auch eine ähnliche autonome Reaktion in den Versuchen. WB-EMS erwies sich als sicher, da es dies Gesundheits- und Leistungsparameter nicht negativ beeinflusste und körperlich aktiven Teilnehmern unabhängig von der Abgabe der elektrischen Reize einen Reiz wie regelmäßiges Training bot. Weitere Studien sind erforderlich, um die Wirksamkeit von WB-EMS bei der Verbesserung der Übungsanpassungen während Trainingsprogrammen zu bewerten.

KEY WORDS:
Heart Rate Variability, Lactate, Oxygen Saturation, Whole-Body Electromyostimulation, Creatine Kinase

SCHLÜSSELWÖRTER:
Herzfrequenzvariabilität, Laktat, Sauerstoffsättigung, Ganzkörper-Elektromyostimulation, Kreatinkinase,

CORRESPONDING ADDRESS:
Anel Recarey, PhD
Faculty of Health Sciences
Universidad Isabel I de Castilla
Calle Fernán González 76,
Burgos 09003, Spain
✉: aneleduardo.recarey@ui1.es

Introduction

Electrostimulation (EMS) is an established technology used primarily to treat athletes undergoing rehabilitation for muscle injuries or surgical procedures (10). The rationale behind EMS is that it stimulates the muscles by transmitting electrical impulses via electrodes attached to the skin. The impulses induce involuntary contractions in muscle tissue, consequently facilitating the activation of fast-twitch muscle fibers (18). EMS has been employed to prevent muscle atrophy, enhance muscle strength, and mitigate the loss of muscle mass (17). The effectiveness of electrostimulation has been the subject of academic research for the past several decades (21)

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Table 2

Statistical analysis of Heart rate and Oxygen saturation. Within group differences were calculated by repeated measures ANOVA with Bonferroni-adjusted post hoc test ^{A} or Friedman Test with Conover's post hoc tests ^{F}. Effect size was determined by Eta squared (η^2) ^{E} or Kendall's W ^{W}. ^{a}=Significant difference versus basal ($p<0.05$). ^{b}=Significant difference versus immediately post warm-up ($p<0.05$). Between group differences were calculated by Independent Student's T-Test ^{T} or Mann-Whitney U Test ^{U}. Effect size was determined by Cohen's d ^{D} or rank-biserial correlation ^{R}. Group x Time interaction effects were calculated by Two-Way Repeated measures ANOVA 2A or Two-Way Repeated measures ANOVA with Greenhouse-Geisser correction ^{2AG}. Effect size was determined by Partial eta squared (η_p^2) ^{PE}. *=Significant differences ($p<0.05$). POST WU=immediately post warm-up of 10 minutes, POST WO=immediately post-workout based on 20 minutes rowing session, BPM=beats per minute, %=percent, N=number of subjects, M=mean, SD=standard deviation, WB-EMS=continuous whole-body electromyostimulation, CON=control or without whole-body electromyostimulation.

VARIABLE	GROUP	BASAL	POST WU	POST WO	EFFECT SIZE	P-VALUE (INTRAGROUP × TIME)	EFFECT SIZE	P-VALUE (INTERACTION GROUP × TIME)
Heart Rate (BPM) (N=19)	WB-EMS	71.7±16.6	121.4±22.8 ^{a}	166.5±22.5 $^{a\,b}$	0.935 ^{W}	<0.001 ^{F} *	0.031 ^{PE}	0.319 ^{2A}
(M±SD)	CON	69.2±15.7	127.3±26.7 ^{a}	161.3±17.7 $^{a\,b}$	0.920 ^{E}	<0.001 ^{A} *		
EFFECT SIZE		0.160 D	-0.238 ^{D}	0.249 ^{R}				
p-Value		0.63 T	0.47 T	0.19 ^{U}				
Oxygen Saturation (%) (N=19)	WB-EMS	97.4±1.2	96.9±1.1	95.3±2.0 ^{a}	0.271 ^{W}	0.008 ^{F} *	0.059 ^{PE}	0.133 ^{2AG}
(M±SD)	CON	97.7±1.2	97.1±1.0 ^{a}	96.5±1.2 ^{a}	0.399 ^{W}	<0.001 ^{F} *		
EFFECT SIZE		-0.291 ^{D}	-0.047 ^{R}	-0.332 ^{R}				
p-Value		0.38 ^{T}	0.81 ^{U}	0.08 ^{U}				

Table 3

Statistical analysis of Lactate level. Within group differences were calculated by Paired Samples T-Test ^{PT}. Effect size was determined by Cohen's d ^{D}. Between group differences were calculated by Independent Student's T-Test ^{T} or Mann-Whitney U Test ^{U}. Effect size was determined by Cohen's d ^{D} or rank-biserial correlation ^{R}. Group x Time interaction effect was calculated by Two-Way Repeated measures ANOVA ^{2A}. Effect size was determined by Partial eta squared (η_p^2) ^{PE}. *=Significant differences ($p<0.05$). Pre=baseline, POST=immediately post-exercise, mmol/L=millimole per liter, N=number of subjects, M=mean, SD=standard deviation, WB-EMS=continuous whole-body electromyostimulation, CON=control or without whole-body electromyostimulation.

VARIABLE	GROUP	PRE	POST	EFFECT SIZE	P-VALUE (INTRAGROUP × TIME)	EFFECT SIZE	P-VALUE (INTERACTION GROUP × TIME)
Lactate (mmol/L)	WB-EMS	2.0±0.8	9.2±3.7	-1.870 ^{D}	<0.001 PT *	<0.001 ^{PE}	0.954 ^{2A}
(N = 19) (M ± SD)	CON	2.0±1.2	9.2±5.1	-1.448 ^{D}	<0.001 PT *		
Effect size		0.139 ^{R}	0.019 ^{D}				
p-Value		0.47 ^{U}	0.95 ^{T}				

Whole-body electromyostimulation (WB-EMS) is a developed form of EMS that has become popular among trainers because it allows to activate different muscle groups in a synchronized way.

Importantly, WB-EMS is linked to muscle damage and acute muscle soreness following strenuous exercise (9). Further negative side effects of this technique stem from increases in levels of creatine kinase (CK) that can reach high level and lead to rhabdomyolysis (9,12). To mitigate WB-EMS-related side effects, a standardized set of instructions and safety norms were introduced to provide guidance on the participant health (13).

WB-EMS has showed positive effect on the parameter related to sarcopenia and regional fat accumulation on subject unwilling or unable to exercise conventionally (14) and the technology had a good acceptance by non-sportive elderly people.

In the same way, significant effect due to the WB-EMS intervention was found in obese elderly women, concerning body composition (decreased fatness, increased skeletal muscle mass and basal metabolic rate) and biomarkers (decreased tendencies in some cytokines such as tumor necrosis factor-a, C-reactive protein, resistin, and carcinoembryonic antigen), positive changes were represented in lipoprotein-cholesterols (15). The use of WB-EMS showed improvement in cardiovascular endurance, dynamic leg strength and agility in a group of 34 post-menopausal women (22).

The benefit of WB-EMS seems smaller with young and trained people. This technology induced improvement in lower extremity strength in adult males of all ages (27) however the general effectiveness of WB-EMS to significantly increase strength is during the adult lifespan. However, the number of research conducted in young and healthy populations is limited compared to those conducted in elder and unhealthy populations.

This technique may have additional advantages over other active recovery methods (24). The increased local blood flow induced by WB-EMS while training may contribute to removal lactate from active muscles. In this line, aerobic exercise such a running or rowing may benefit from the addition of WB-EMS. Therefore, the aim of this study was to determine the effects of WB-EMS on muscle damage, heart rate variability, and performance fatigability, during a single rowing session in physically active young people.

Material and Methods

Participants

Nineteen participants, ten men and nine women participated in the study. All were healthy and physically active. Participants age, height and body weight are described in table 1. Despite sex differences in participants characteristics, the variables studied were not different between males and females at any time point during the experiment, and thus, results were pooled, analyzed, and reported with all participants grouped.

All participants were students enrolled in the Universidad Europea de Madrid. Inclusion criteria were being in good health, being physically active and practiced strength or aerobic training 3 times per week over the last 12 months. Exclusion criteria were having a medical condition, taking a prescription drug or a supplement which could affect the results of the research or suffering from an injury that prevented doing the exercises properly.

A detailed explanation of the nature of the study and its risks, benefits, and reliability were provided to every participant. Informed consent was obtained from each subject before participating. The experimental protocols in this study were approved by the Ethical Review Board of the Community of Madrid (#HUFA 19/52).

Experimental Design

We carried out a randomized trials with a crossover design in which each participant was subjected to two separate experimental tests consisting of two rowing sessions, each lasting 20 minutes.

A different protocol was used in each session: the first consisted of a session of WB-EMS using continuous whole-body electromyostimulation with a pulse current of 85 Hz frequency and a pulse width of 250/350 µs (WB-EMS) and the second consisted of a session without WB-EMS and served as the control group (CON).

Experimental Protocol

The WB-EMS or CON rowing sessions were performed randomly with breaks of 4 days between sessions. Subjects were asked not to exercise one day prior to the test and one day afterwards. They were also asked not to drink alcohol or caffeine one day before the test to avoid distorting the results of the experiment.

Pre, during, and post-effort data was collected. Prior to training, the following was measured: heart rate variability (HRV), cardiac frequency, oxygen saturation levels, lactate levels, and creatine kinase (CK) levels. Following this data collection, a 5-minute pre-warm-up session was performed, then a series of physical performance tests was measured: squat jump, countermovement jump, Abalakov jump, isometric handgrip strength and explosive push up.

During the session that included electrostimulation (WB-EMS) the participants wore a custom-made electrostimulation suit. The electrical impulses were administered via the attachment of suit's electrodes to the abdominal, lumbar, dorsal, and thigh muscles. The impulse intensity was set at the maximum intensity tolerated by each individual and muscle, considering the individual capacities to persevere with the rowing action.

The warm-up of each session consisted of a 10-minute rowing warm-up with an effort of 5 on the modified Borg scale (2). Following the warm-up session, heart rate and oxygen saturation were assessed.

During the session, the participants rowed for 20 minutes under conditions of WB-EMS or CON. The intensity of the electrical impulse was determinate based on individual tolerance level of each one and according to the expected limits of each muscle. When the subjects started rowing, the display blocked from view so that the distance covered during the session could not be seen. Listening to music was prohibited as this extra stimulus could have speeded up the rowing action.

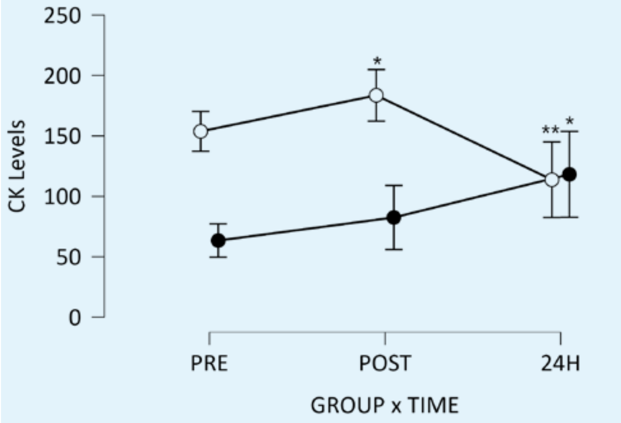

Figure 1

CK levels at baseline (PRE), immediately after exercise (POST) and 24 hours after (24H) the row exercise session with continuous stimulus whole-body electromyostimulation (WB-EMS) and without whole-body electromyostimulation (CON). *=Significant differences with WB-EMS PRE ($p<0.05$). **=Significant differences with CON POST ($p<0.05$). White=CON; black=WB-EMS

Table 1

Participants characteristics. All values show the mean ± standard deviation. a=significantly different than male ($p<0.05$) by Independent Student's T-Test; b= significantly different than male ($p<0.05$) by Mann-Whitney U-Test. kg=kilograms, cm=centimeters.

	AGE	BODY WEIGHT (KG)	BODY HEIGHT (CM)
Male	26.1±4.07	75.4±12.43	174±7.33
Female	25.1±5.90	62.0±5.58 [a]	164±4.50 [b]

After the rowing session, participants completed the physical performance tests and measurements were taken for heart rate, oxygen saturation levels, lactate levels, and CK levels. Perception of effort was determined by asking the participants to estimate it according to modified Borg scale (1-10). Rowing distances were noted, as were number of Watts generated. CK levels were also measured 24 hours after the session. Participants were asked not to engage in physical activity during the 24 hours intermission in the study.

Measurements

Squat jump (SJ), countermovement jump (CMJ), Abalakov jump (ABK) and explosive push up were performed before and after experimental trials. Best jump high out of three attempts was determined using an inertial measurement unit (FreeSense, Sensorize Ltd, Italy) attached to the participant waist using a specific belt.

Isometric handgrip strength (IHS) was measured using a calibrated handgrip dynamometer (Takei 5101, Tokyo, Japan). Participants sat with 0 degrees of shoulder flexion, 0 degrees of elbow flexion, and the forearm and hand in a neutral position. The highest value out of two attempts was recorded as the maximum voluntary handgrip strength.

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Table 4

Statistical analysis of autonomic stress response assessed by Heart Rate Variability. Within group differences were calculated by Paired Samples T-Test $^{PT.}$ Effect size was determined by Cohen's d ^{D}. Between group differences were calculated by Independent Student's T-Test ^{T}. Effect size was determined by Cohen's d ^{D}. Group x Time interaction effect was calculated by Two-Way Repeated measures ANOVA ^{2A}. Effect size was determined by Partial eta squared (η_p^2) ^{PE}. Pre=baseline, POST=immediately post-exercise, ms=milliseconds, N=number of subjects, M=mean, SD=standard deviation, WB-EMS=continuous whole-body electromyostimulation, CON=control or without whole-body electromyostimulation, LF=low frequency, HF=high frequency, N.U=normalized unit.

VARIABLE	GROUP	PRE	POST	EFFECT SIZE	P-VALUE (INTRAGROUP × TIME)	EFFECT SIZE	P-VALUE (INTERACTION GROUP × TIME)
RMSSD (ms)	WB-EMS	36.7±70.2	28.3±27.7	0.087 ^{D}	0.99 ^{PT}	0.002	0.451
(N=19) (M±SD)	CON	34.7±64.9	31.1±35.7	0.051 ^{D}	0.87 ^{PT}		
Effect size		0.125 ^{D}	0.186 ^{D}				
p-Value		0.36 ^{T}	0.25 ^{T}				
LF (n.u.)	WB-EMS	1136.7±929.5	637.8±381.2	0.101 ^{D}	0.14 ^{PT}	0.020	0.620
(N=19) (M±SD)	CON	1101.4±897.9	1251.4±653.4	0.060 ^{D}	1.00 ^{PT}		
Effect size		0.209 ^{D}	0.188 ^{D}				
p-Value		0.50 ^{T}	0.09 ^{T}				
HF (n.u.)	WB-EMS	2021.4±501	715.6±381.6	0.196 ^{D}	0.07 ^{PT}	0.035	0.585
(N=19) (M±SD)	CON	1525.8±689	789.2±345.7	0.191 ^{D}	0.08 ^{PT}		
Effect size		0.176 ^{D}	0.089 ^{D}				
p-Value		0.09 ^{T}	1.00 ^{T}				

Table 5

Statistical analysis of physical performance tests. Within group differences were calculated by Paired Samples T-Test ^{PT} or Wilcoxon signed-rank Test ^{WT}. Effect size was determined by Cohen's d ^{D} or matched rank biserial correlation ^{M}. Between group differences were calculated by Independent Student's T-Test ^{T} or Mann-Whitney U Test ^{U}. Effect size was determined by Cohen's d ^{D} or rank-biserial correlation ^{R}. Group x Time interaction effect was calculated by Two-Way Repeated measures ANOVA ^{2A}. Effect size was determined by Partial eta squared (η_p^2) ^{PE}. * Significant differences ($p<0.05$). Pre=baseline, POST=immediately post-exercise, SJ=Squat jump test, CMJ=Counter-movement jump test, ABK=Abalakov jump test, cm=centimeters, HIS=isometric handgrip strength test, kg=kilograms, PU=push-up test, s=seconds, N=number of subjects, M=mean, SD=standard deviation, WB-EMS=continuous whole-body electromyostimulation, CON=control or without whole-body electromyostimulation.

VARIABLE	GROUP	PRE	POST	EFFECT SIZE	P-VALUE (INTRAGROUP × TIME)	EFFECT SIZE	P-VALUE (INTERACTION GROUP × TIME)
SJ (cm)	WB-EMS	36±4.0	37±4.4	-0.569 ^{D}	0.02 ^{PT*}	<0.001 ^{PE}	0.917 ^{2A}
(N=19) (M±SD)	CON	35±4.3	36±4.6	-0.327 ^{D}	0.17 ^{PT}		
Effect size		0.215 ^{D}	0.221 ^{D}				
p-Value		0.51 ^{T}	0.50 ^{T}				
CMJ (cm)	WB-EMS	38±6.9	38±5.4	-0.144 ^{M}	0.62 ^{WT}	0.006 ^{PE}	0.639 ^{2A}
(N=19) (M±SD)	CON	38±4.7	38±5.1	-0.125 ^{D}	0.59 ^{PT}		
Effect size		0.014 ^{R}	0.000 ^{D}				
p-Value		0.95 ^{U}	1.00 ^{T}				
ABK (cm)	WB-EMS	42±6.5	43±6.4	-0.420 ^{D}	0.08 ^{PT}	0.013 ^{PE}	0.498 ^{2A}
(N=19) (M±SD)	CON	40±5.7	42±7.3	-0.448 ^{D}	0.07 ^{PT}		
Effect size		0.381 ^{D}	0.245 ^{D}				
p-Value		0.25 ^{T}	0.45 ^{T}				
Ihs (kg)	WB-EMS	36.7±10.2	35.8±8.6	0.198 ^{D}	0.40 ^{PT}	0.011 ^{PE}	0.538 ^{2A}
(N=19) (M±SD)	CON	35.3±10.2	35.2±9.4	0.034 ^{D}	0.88 ^{PT}		
Effect size		0.134 ^{D}	0.067 ^{D}				
p-Value		0.68 ^{T}	0.84 ^{T}				
PU (s)	WB-EMS	0.17±0.04	0.18±0.04	-0.398 ^{D}	0.099 ^{PT}	0.014 ^{PE}	0.475 ^{2A}
(N=19) (M±SD)	CON	0.18±0.08	0.19±0.08	-0.392 ^{M}	0.190 ^{WT}		
Effect size		-0.017 ^{R}	0.114 ^{R}				
p-Value		0.94 ^{U}	0.56 ^{U}				

Capillary blood samples were collected to measure lactate and CK levels. The first blood sample was acquired before the exercise and was used to both for lactate and CK. The second sample was taken upon termination the exercise session. After the 24 hours intermission a third blood sample was taken, which was used to measure CK levels.

Lactate levels were analyzed using a Lactate Scout + device (Sens Lab GmbH, Leipzig, Germany). To collect a sample, the finger was first massaged to stimulate blood circulation and then disinfected with alcohol. A sterile single use lancet suitable for capillary blood sampling was then used to prick the fingertip. The first drop of blood was discarded. A minimum blood sample of 0.2 microliters (µl) was required. The detection strip was inserted into the analyzer and blood was placed onto the strip. Results were available within 10 seconds. CK levels were analyzed by using a Reflotron Plus blood analyzer (Hoffmann-La Roche, Basel, Switzerland). A blood sample size of 30 µL was required. The blood was collected on a strip. The strip was then inserted into the instrument, providing results within 2 minutes.

Heart rate and oxygen saturation levels were monitored using a pulse oxymeter (model MD300C15D, PRIM S.A, Madrid, Spain) which was placed on the finger of the participants. Measurements were taken at the beginning of the test, after the warm-up, and at the end of the session. Heart rate (HR) and oxygen saturation together can be used as measures of an athlete's level of fitness, fatigue, and performance, all factors used to determine individual responses to training regimes (25). HR it's also an important indicator of exercise intensity and training adaptability. It can be used to detect athlete overtraining (25).

Heart rate variability (HRV) shows the fluctuation between consecutives R waves on the electrocardiogram, and it is accepted as assured and non-invasive tool for analyzed the balance of sympathetic to parasympathetic nervous system activity. HRV was measured with a Suunto Ambit 3 Peak device, a smart sensor band was used. Participants was asked to lie down on a stretcher and remain still for 5 minutes while measurements were recorded. HRV measurements were taken both at the beginning and at the end of the test to assess changes in autonomic nervous system activity. The data was then analyzed using the Kubios software.

The total number of watts generated by each participant were recorded at the end of the 20-minute test during each session. The Concept-2 rower by Rogue was used for both warm-up and training.

The modified Borg scale was used to assess an individual's perceptions of exercise intensity (2), during both warm-up and training sessions.

Data Analysis

Data analyses were performed using SPSS Statistics (v 23.0, IBM, USA). Data are presented as mean (M)±standard deviation (SD). Shapiro Wilk test was used to confirm normal distribution of data. Homoscedasticity was assessed either by Levene's Test or Mauchly's Test of Sphericity. Participant's characteristics differences between genders were analyzed by an Independent Student's T-Test or Mann-Whitney U-Test. Differences within groups were assessed by repeated measures ANOVA with Bonferroni-adjusted post hoc test or Friedman Test with Conover's post hoc tests if there were more than two measurements; and Paired Samples T-Test or Wilcoxon signed-rank Test if there were only two measurements. Eta squared (η^2), Kendall's W, Cohen's d or matched rank biserial correlation was calculated to estimate the effect size, respectively. Differences between groups were assessed by Independent Student's T-Test, Welch's T-Test or Mann-Whitney U Test. Cohen's d, Hedge's g or Rank-biserial correlation was calculated to estimate the effect size, respectively. Group x Time interaction effects were calculated by Two-Way Repeated measures ANOVA or Two-Way Repeated measures ANOVA with Greenhouse-Geisser correction. If significant interaction was found, Bonferroni's post hoc test was carried out. Effect size was determined by Partial eta squared (η_p^2). Statistical significance was set at $p<0.05$.

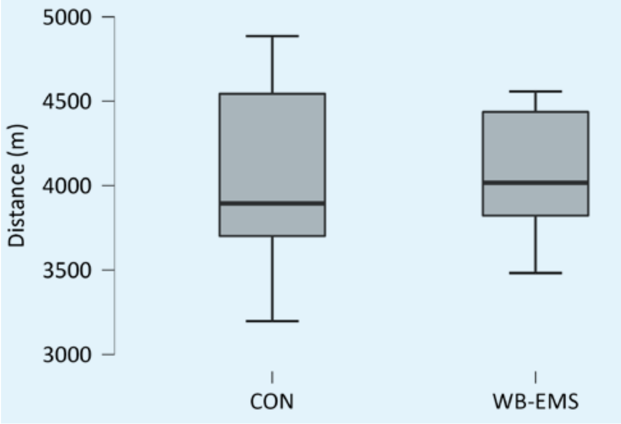

Figure 2

Distance covered during row exercise session with continuous stimulus whole-body electromyostimulation (WB-EM) and without whole-body electromyostimulation (CON).

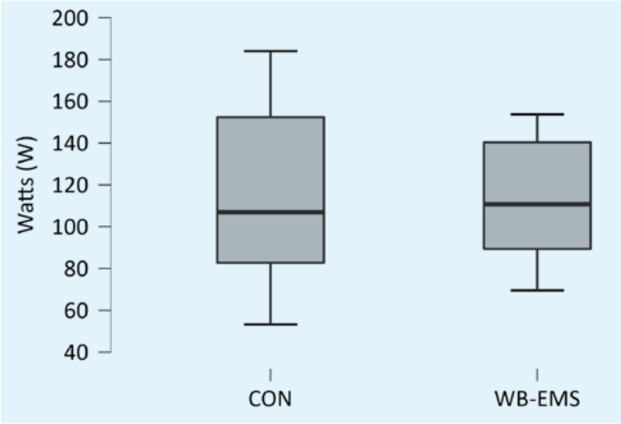

Figure 3

Watts generated during row exercise session continuous stimulus whole-body electromyostimulation (WB-EM) and without whole-body electromyostimulation (CON).

Results

During the study there were no negative side effects in relation to muscle damage, heart rate variability or performance fatigability. There were no significant differences observed between the results from the WB-EMS rowing session and the control session. At the end of the 10-minute warm-up, the modified Borg scale value was 5. At the end of the 20 minutes training session, the modified Borg scale values fell between 9 and 10.

When analyzing differences within groups, we observed statistically significant differences of the CK within the two groups. There was a significant difference between immediately and 24 hours post exercise CK levels with baseline in the WB-EMS group, observing a steady increment of CK levels within

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normal ranges. In the control group, there was a significant difference between immediately post exercise CK levels with baseline and 24 hours post exercise CK levels with immediately post exercise levels, observing a decline of CK levels at 24 hours post exercise but stabilizing with WB-EMS CK levels. When analyzing differences between groups, we only observed statistically significant difference in the baseline CK levels between control and WB-EMS groups. When analyzing interaction effects, we observed a significant Group x Time interaction effect ($F=11.562$; $p<0.001$; $\eta_p^2=0.243$) with a significant difference of CK levels between WB-EMS PRE with CON POST (mean differences=-120.1; effect size=-1.131; p=0.015) and WB-EMS 24H (mean differences=-54.7; effect size=-0.516; p=0.030); and of CON POST with CON 24H (mean differences=69.8; effect size=0.658; p=0.002). This suggests that WB-EMS did not cause dangerous increases in CK levels (figure 1, and supplementary table S1 online). In turn, differences within groups in the variables heart rate and oxygen saturation behaved in the same way, except for the post warm-up oxygen saturation of the CON group, observing a significant decline compared with basal oxygen saturation. In addition, no significant differences were observed in heart rate and oxygen saturation between groups, which fell within the normal range (table 2), both with and without electromyostimulation. There were no significant group x time interactions in neither variable.

There were no significant differences in lactate between groups, indicating that WB-EMS did not cause significant alterations of lactate levels (p>0.05) and differences within groups behaved the same way. Lactate levels increased within normal ranges whether or not electromyostimulation was applied (table 3). In the case of autonomic stress response, there were no significant differences in heart rate variability, low and high frequencies within or between groups (p>0.05), suggesting that WB-EMS did not cause a harmful autonomic stress response (table 4). There were no significant group x time interactions in Lactate or autonomic stress response variables.

There were no significant differences or group x time interactions in any of the performance test between groups, indicating that WB-EMS did not affect performance (p>0.05). We only observed differences within groups in the variable squat jump test, in the group with WB-EMS, observing an increase of the jump's height with a moderate effect size (table 5).

There were no significant differences in distance covered or Watts generated between groups (p>0.05), implying that WB-EMS didn't alter the physical capacity of the subjects (figure 2, figure 3, and supplementary table S2 online).

Discussion

Our study analyzed the effects of a single high-intensity cardiovascular training rowing session with whole-body electromyostimulation on muscle damage, heart rate variability and performance fatigability (6). The participants performed their exercise with protocols of whole body electromyostimulation with continuous stimulus (WB-EMS) and without stimulus (CON).

The main finding of our study was that a single rowing session with WB-EMS did not cause more muscle damage than the same session without WB-EMS in a period of 24 h. CK levels rose within a range of normal values after exercising. There is a breakpoint in CK release of 300 to 500 U/L after exercise and return to basal level occurs within 24 to 48 hours (4). CK blood levels extremely high (i.e., >10,000 U/L) are diagnosed as rhabdomyolysis, a pathological CK increased (23).

In addition, WB-EMS did not adversely affect lactate levels, oxygen saturation levels, heart rate and cardiac variability.

Our findings, contrary to some case reports (3,9,12), have showed that the proper use of WB-EMS does not increase muscle damage, as seen in this article results and in previous studies we have published (5,7).

Appropriate guidelines were followed when applying WB-EMS to prevent adverse effects. This included considering the participant, setting the electric impulses to proper levels, and providing relevant instruction to the trainer (13). The WB-EMS intervention protocol used was a standard one established previously, which consisted of a 250 nanosecond pulse at 85 Hertz for the torso and a 350 nanosecond pulse for the lower extremities (13).

Our sample was formed by healthy, young, and physically active people. In the same line, previous studies have found that cardiopulmonary and physiological factors were not adversely affected when WB-EMS was administered to healthy university students (10). In the study of Jee Y. (10), experimental group was trained 3 times per week (20 minutes) for 6 weeks. There were no abnormal changes in the cardiopulmonary variables (heart rate) and, similar to us, there were no significant difference between experimental and control groups. In addition, Kang and Hyong (11) evaluated the effects of EMS use during strength exercise on healthy subjects and found that HRV values increased slightly but not significantly, suggesting that strength training combined with EMS can be safely undertaken.

Our results do not show significant differences in the jump, dynamometry and push up tests; except for a significant improvement of the height reached in the squat jump test in the WB-EMS group. Previous studies on professional athletes have shown that complimentary training with WB-EMS can achieve efficient results in strength gains (8). The different findings of our study could be explained by the number of sessions involve in the experiment, since just one session might not have the effect of the 14 weeks used by Filipovic et al. (8).

As mentioned before, regarding jump performance, we only found significant differences in the squat jump test results in the WB-EMS group. Some studies have found that ten days after finishing the WB-EMS training session jump performance improved (8,20). The CMJ height did not improved after local EMS training in a group of elite basketball players. Nonetheless, after a four-week EMS break, a significant gain of 17 % was obtained (19). This means that a break can be important when applying EMS. On the other hand, studies have found improvements in jumping test after an EMS training of 14 weeks (17), and WB-EMS training of 6 weeks (1) with no break before the test. New studies are needed to establish more definitive conclusions.

To analyze whether the use of WB-EMS resulted in an increase in training stimulus or not, we controlled the training load during the exercise with internal load variables (heart rate and lactate) and external load variables (distance and/or watts and RPE). In this regard, we did not observe significant differences in any of the analyzed parameters between rowing with and without electrical stimulation.

Contrary to our findings, Schuhbeck et al. (26) confirm the improvement in performance of amateur hockey players after training with WB-EMS for 12 weeks. The final evaluation was done after a 4-week break. The researchers explain the improvement in jumping performance by the duration of training (12 weeks), as some authors (8) claim that complex movements require longer and more specific training before seeing the positive effects of EMS.

In this line, results found no significant differences in a group of participants with low back pain (28), in which the experimental group trained with WB-EMS (once a week, 20 minutes, for 12 weeks) versus the control group (once a week, 45 minutes, for 12 weeks). The authors concluded that WB-EMS training is a positive and effective alternative for people with limited time resources and other barriers to conventional training methods. Other studies show that WB-EMS is at least as effective as a multimodal treatment for low back pain (16). With only 20 minutes a week, may be a very-time efficient alternative. Our results points to the efficacy in terms of safety of WB-EMS.

Conlusion

The results show that applying WB-EMS did not cause excessive muscle damage in healthy people who had been physically active for at least one year. This is supported by the measurements of CK, which did not increase to levels outside normal range observed in training without WB-EMS. In addition, no other parameter was affected.

More studies are needed to assess what health effects WB-EMS may have when engaging in combination with physical activity.

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Conflict of Interest
The authors have no conflict of interest.

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