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Short-time effect of a single session of intense whole-body electromyostimulation on energy expenditure. A contribution to fat reduction?

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1 **Short-time effect of a single session of intense whole-body**
2 **electromyostimulation on energy expenditure. A contribution to fat**
3 **reduction?**

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21 **Running Title:** Energy expenditure and WB-EMS

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24 ABSTRACT

25 To determine the underlying mechanisms after one session of (intense) whole-body
26 electromyostimulation (WB-EMS) on total energy expenditure (TEE) and resting metabolic rate
27 (RMR), 16 subjects followed a standardized protocol of indirect calorimetry for up to 72h in 12h
28 intervals. The single session significantly increased RMR about $25\pm 10\%$ ($p<0.001$) and TEE for about
29 $9.5\pm 1\%$, a net effect of $\sim 460\pm 50$ kcal (WB-EMS vs. CG).

30 KEY WORDS

31 whole-body electromyostimulation; WB-EMS; total energy expenditure; resting metabolic rate; RMR;
32 fat reduction; body composition

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33 INTRODUCTION

34 Whole-body electromyostimulation (WB-EMS) might be an alternative to conventional resistance
35 training (RT) for improving body composition. With respect to body-fat parameters, a similar 14-
36 week randomized controlled trial reported similar significant and clinically relevant reductions after
37 high-intensity RT (HIT) and WB-EMS (Kemmler et al. 2016a) that even (slightly) exceed the increases
38 of muscle mass. Addressing acute exercise effects, a single session of 20 min WB-EMS increases EE by
39 up to 470 kcal/h (Boccia et al. 2016; Kemmler et al. 2012), thus WB-EMS can be considered as a high-
40 intensity training setting (Haskell et al. 2007). Further, WB-EMS significantly affects Resting Metabolic
41 Rate (RMR) through its significant impact on muscle mass (Kemmler et al. 2016a). However, neither
42 the acute nor chronic mechanisms (via RMR) of WB-EMS-induced increases of EE (Kemmler et al.
43 2010; Kemmler et al. 2012) can fully explain the significant and clinically relevant body-fat reduction
44 during WB-EMS applications, so it is important to further determine the “missing link”, which might
45 be the immediate post-exercise effects of WB-EMS on EE. Therefore, it was the aim of this study to
46 determine the short-/medium-term effects of one single session of an intense but otherwise
47 conventional WB-EMS application on EE.

48 Our hypotheses are (1) that a single session of WB-EMS induces significant short-term effects on EE
49 and (2) that these significant effects on EE last up to 60 hours post-exercise.

50 MATERIALS and METHODS

51 The project was realized in a randomized parallel group, crossover design with each participant (n=
52 16) undergoing all the RMR assessments (pre, 1, 12, 24, 36, 48, 60, 72h post) twice, thus acting as
53 their own control. The project was conducted between February and June 2016 by the Institute of
54 Medical Physics (IMP), University of Erlangen-Nürnberg (FAU) Germany. The study complied with the
55 Helsinki Declaration “Ethical Principles for Medical Research Involving Human Subjects” and was
56 approved by the ethical committee of the FAU (No. 183_14B). All participants gave their written
57 informed consent.

58 *Primary study outcome:*

- 59 ▪ Total energy expenditure (TEE) with and without previous WB-EMS application determined
60 via indirect calorimetry.

61 *Secondary study outcomes:*

- 62 ▪ Changes of RMR and EE with and without previous WB-EMS application determined via
63 indirect calorimetry.

64 There were no changes in the outcomes after trial commencement.

65 **Participants**

66 16 eligible participants (13 men, 3 women; age: 33.5 ± 9.6 years, weight: 79.5 ± 12.4 kg, height:
67 180.2 ± 8.2 cm, SMM: 37.4 ± 6.4 kg, training volume: 327 ± 128 min/week) were included if they (a)
68 were healthy, 20-50 years old, (b) frequently conducted RT (≥ 2 sessions/week) and (c) were
69 experienced in WB-EMS. Subjects were excluded under the following criteria: (a)
70 medication/diseases affecting muscle metabolism or renal function, or (b) conditions that prevent
71 WB-EMS (e.g. cardiac arrhythmia) and (c) inability to attend all the RMR assessments within a variance
72 of ± 1 h.

73 **Assessment**

74 Height was determined with a stadiometer (Holtain Ltd. Crymmych, Wales), weight, muscle mass and
75 body fat were assessed via multi-frequent bioelectrical impedance analysis (DSM-BIA, InBody770,
76 BioSpace, Seoul, Korea).

77 Indirect calorimetry was used to determine RMR and EE (Oxycon Mobil, Viasys, Conshohocken, PA,
78 U.S.). VO_2 , VCO_2 , VE were continuously determined breath by breath. The HR was continuously
79 evaluated using a Polar tester (Polar RS 800, Kempele, Finland). Tests were performed pre- and
80 immediately post-intervention and further in 12h cycles for 72 h (supplementary figure S1). After
81 resting for 10 min in a supine position in a semi-dark room (23°C), data of the subsequent 20 min was

82 included in the analysis. Participants were asked to rest and do not move or talk during the test.
83 Participants were required to avoid intense physical activity, drugs and unusual nutrition 24h prior to
84 the tests. Equipment was calibrated according to the manufacturer's recommendations before each
85 test.

86 ***WB-EMS application***

87 The WB-EMS application was conducted with a miha bodytec® Type I device (Gersthofen, Germany)
88 consisting of a control panel and a set of electrodes. The system allows simultaneous stimulation of
89 up to 10 large muscle groups (Kemmler and von Stengel 2013) with regionally dedicated current
90 intensity.

91 We applied a bipolar WB-EMS protocol (20min, 85Hz, 350µs, 1s ramp, 6s impulse - 4s break)
92 (Filipovic et al. 2012) that stimulates 8 large muscle groups. During the impulse phase participants
93 performed (very) slight movement patterns (e.g. dynamic squatting with knee angle: $\geq 120^\circ$),
94 standardized by a synchronized video. Participants completed 1-2x 6-8 repetitions of 8 movements.
95 Certified instructors encouraged the participants to work with (very) high effort. Intensity was
96 increased every 3-5min to maintain the prescribed perceived exertion of "7"- "8" (very hard-very
97 hard+) on the Borg CR-10 scale (Borg and Kaijser 2006). Of importance, we did not apply the same
98 movements (without WB-EMS) during the control conditions.

99 ***Statistics***

100 In order to prove our hypothesis, quantified as a 10% higher TEE in the WB-EMS compared with the
101 CG, 14 subjects had to be included to generate a power of 95% ($\alpha=.05$) (Jamurtas et al. 2004).

102 The EE curves were approximated by linear interpolation of the six measurements taken at 12h
103 intervals. Then, the areas under curve (AUC) were determined by integration of the resulting
104 piecewise linear curves, i.e. $AUC = 12 * (1/2 * EE_{post} + EE_{12} + EE_{24} + EE_{36} + EE_{48} + EE_{60} +$
105 $1/2 * EE_{72})$.

Data are consistently reported as mean and standard deviations ($MV \pm SD$). Depending on the distribution of the data, we used student's t-tests or Wilcoxon rank-tests to analyze changes within groups. The differences between both conditions were evaluated using the Welch t-test. Significance was accepted at $p < .05$. Effect size (ES) was calculated by using Cohen d' and SPSS 22 (IBM, Chicago, USA) was used for all statistical procedure.

RESULTS

Table 1 listed the results for the total cumulated EE (TEE in total kcal) during the 72h assessment phase determined by the AUC. In summary, the difference for cumulated TEE between WB-EMS and control condition averaged 460 ± 51 kcal. Thus, hypothesis 1 that EMS induces significant short-term effects on EE can be confirmed.

Supplementary figure S2 shows the percentage changes of RMR (from baseline) for all time intervals during EMS and control condition along with the corresponding group differences. RMR after WB-EMS showed a highly significant 25% increase from pre- to immediately post-exercise (82.7 ± 6.9 to 103.5 ± 11.4 kcal/h; $p < .001$). RMR subsequently decreased almost linearly (supplementary figure S2), however we observed statistically significant group differences for all periods up to 48h: 1h: 103.5 ± 11.4 vs. 88.7 ± 8.9 kcal/h ($p < .001$); 12h: 100.1 ± 12.7 vs. 86.9 ± 10.3 kcal/h ($p < .001$); 24h: 97.3 ± 11.7 vs. 87.1 ± 10.4 kcal/h ($p < .001$); 36h: 93.7 ± 11.0 vs. 88.6 ± 9.9 kcal/h ($p < .001$); 48h: 90.5 ± 10.8 vs. 89.1 ± 10.1 kcal/h ($p = .014$). Nevertheless, differences after 60h were borderline non-significant ($p = .052$), so we have to reject hypothesis 2.

Of importance for the interpretation of the results, the respiratory exchange ratio (RER) increased significantly from pre- to post intervention ($.89 \pm .05$ to $.94 \pm .06$, $p = .001$), and further decreased significantly for 48h-60h with significant lower levels compared to pre-exercise ($.86 \pm .05$, $p = .034$; $.87 \pm .04$, $p = .078$). No corresponding variations were determined for the control condition.

DISCUSSION

WB-EMS is a promising exercise technology that favorably affects body composition (Kemmler et al. 2010; Kemmler et al. 2016a; Kemmler et al. 2016b; Kemmler and von Stengel 2013). However, the time efficiency of WB-EMS with 20min/session applied 1.5 times/week, hardly correlates with the significant fat reduction in cohorts of normal-weight, over-weight and obese people (Kemmler et al. 2016a; Kemmler and von Stengel 2013; Kemmler et al. 2017). Thus, it was the aim of this study to close the gap between acute and long-term EE effects after WB-EMS evaluated in earlier studies (Kemmler et al. 2010; Kemmler et al. 2012) .

With respect of the short-term effect of WB-EMS, there is considerable evidence that intense WB-EMS needs prolonged periods of resynthesis, repair and adaptation (Teschler et al. 2016). Indeed, in the present study the EE value peaked 25% above baseline immediately post WB-EMS ($p<.001$) and remained significantly increased for up to 48h post exercise. In total, during the observational period of 72h the effect on EE (WB-EMS vs. control) averaged around 460 kcal. We further observed a significantly enhanced post-exercise lipid oxidation that remained for 48-60h, a result that confirmed data observed after conventional RT (e.g: Gillette et al. 1994; Melby et al. 1993; Paschalis et al. 2010).

Due to divergent interventions and EPOC observation length (60min (Haltom et al. 1999) up to 72h (Hackney et al. 2008)) it is difficult to compare our result with most of the recent studies. However, some studies applied intense RT with post-exercise observation periods comparable to this contribution.

After high-volume RT at 70% 1-repetition-maximum (1RM), significant increases in RMR ($\approx 5\%$) up to 15h (Gillette et al. 1994; Melby et al. 1993) were reported. In addition, ten upper and lower body exercises induced significant RMR elevation after 10h ($\approx 7.6\%$) that lasted up to 24h ($\approx 5.5\%$) (Jamurtas et al. 2004), whereas powerlifting training (four circuits of bench press, power cleans and

squatting) with $\approx$ 8-12 repetitions (70-80% 1RM; 2-min rest period) reported an increased RMR ($\approx$ 20%) for up to 39h (Schuenke et al. 2002).

RT with emphasis on the eccentric phase (leg-press, 8 sets at 6 RM, 1s concentric/4s eccentric) induced a RMR increase of 8-9% in trained and untrained subjects 48h post exercise (Dolezal et al. 2000). However, the trial most similar to our result applied a high volume, whole-body RT (4 upper and 4 lower exercises, 8 sets, 6 repetitions with 1s concentric/3s eccentric) and reported a significant 9.2% EE increase in untrained and 7.9% in trained subjects that remained up to 72h (Hackney et al. 2008). Also comparable to our results, isokinetic leg press exercises with emphasis on the eccentric phase (5 sets, 15 repetitions with MVC, 2min break) significantly raised RMR for up to 48h ($\approx$ 9%) in lean and for up to 72h in obese subjects ($\approx$ 25%) (Paschalis et al. 2010).

Thus, the scientific evidence so far suggests that strenuous RT-related exercise elevates post-exercise EE for a prolonged period. Additionally, the enhanced fat oxidation observed in this study and confirmed by RT-studies (Gillette et al. 1994; Melby et al. 1993; Paschalis et al. 2010) during the post-exercise period contributes to explaining the pronounced fat reduction after WB-EMS.

One study limitation may hinder the generality of our result. Subjects included were predominately infrequent WB-EMS applicants (1-2 sessions/month), who may be more responsive to the relatively unusual WB-EMS stimuli. Indeed, an earlier study (Teschler et al. 2016) with WB-EMS novices resulted in a very pronounced repeated bout effect, with a 20-fold reduction of initial CK peak values after 10-weeks of WB-EMS conditioning. Thus, familiarization might result in reduced WB-EMS-induced elevations of EE.

Not relevant for the present study, but a limitation of our general approach to determining acute, short- and long-term WB-EMS effects on EE might be that we do not consistently involve the same cohort. While the participants during the evaluation of acute and short time effects largely overlapped, long-term effects of WB-EMS on EE were determined with a postmenopausal cohort, potentially with an age-dependent lower potential for exercise induced-adaptation. However, the

comparison of two WB-EMS trials that applied the same exercise protocol, albeit with younger (Kemmler et al. 2010) or older men (Kemmler et al. 2016a), resulted in comparable changes of body composition (i.e. LBM and body fat).

In summary, the pronounced WB-EMS-induced reduction of body fat can be largely explained by acute, short- and long-term effects of regular (1.5 x 20min sessions/week) WB-EMS application on EE. Thus, a carefully supervised and guided WB-EMS application might be a safe, effective and very time-efficient option not only, but also to reduce body fat predominately for people unable or unwilling to exercise conventionally.

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The authors declare that there are no conflicts of interest.

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Tables

Table 1. Mean values (MV) and standard deviation (SD) of the cumulated TEE (kcal) structured for 12h-interval; significance (p)

	WB-EMS (n=16) (MV ± SD)	Non-WB-EMS (n=16) (MV ± SD)	p
Cumulated total energy expenditure [kcal]			
12 h	1,218 ± 147	1,052 ± 108	.001
24 h	2,402 ± 276	2,097 ± 222	.002
36 h	3,548 ± 389	3,150 ± 334	.004
48 h	4,666 ± 486	4,197 ± 430	.007
60 h	5,744 ± 572	5,244 ± 526	.015
72 h	6,778 ± 671	6,315 ± 610	.050