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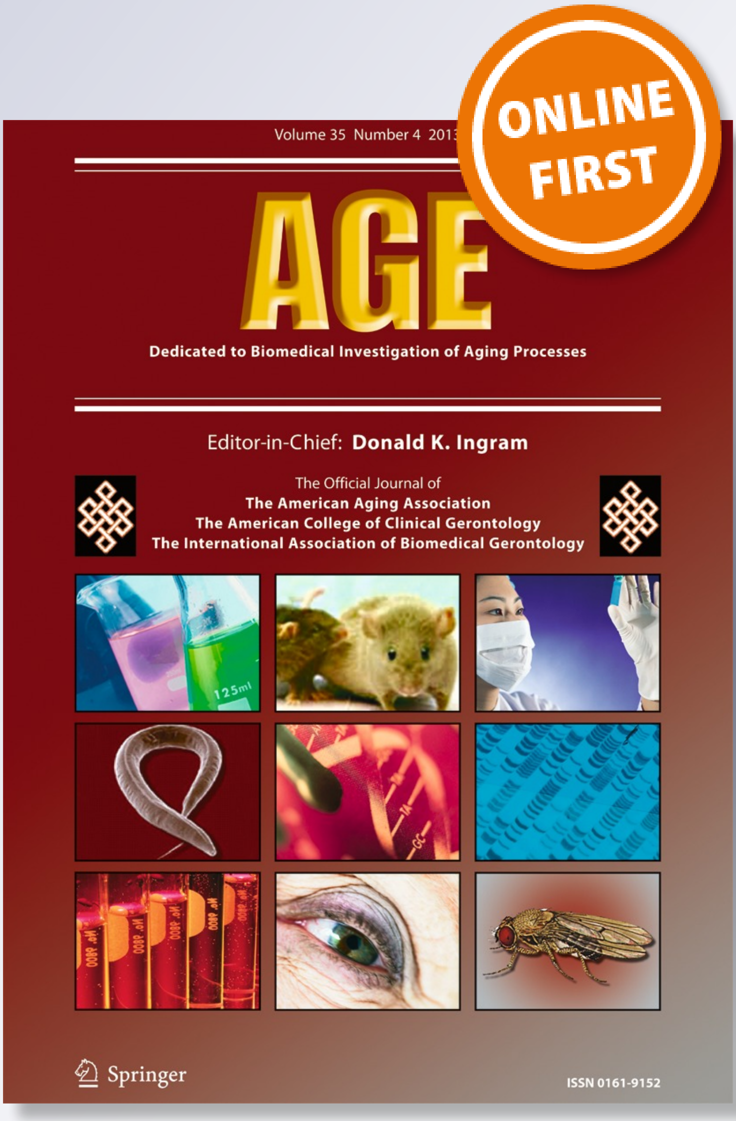

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Impact of whole-body electromyostimulation on body composition in elderly women at risk for sarcopenia: the Training and ElectroStimulation Trial (TEST-III)

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Abstract Most studies have confirmed the positive impact of resistance training on muscle mass and functional capacity in aging adults. However, due to physical limitation or a simple aversion against regular exercise, the majority of elderly subjects do not reach the exercise doses recommended for impacting strength or muscle mass. This led us to evaluate the effect of whole-body electromyostimulation (WB-EMS), a novel, time-efficient and smooth training technology, on body composition with special regard to sarcopenia. Seventy-six lean, non-sportive women (75±4 years) were randomly assigned to either a WB-EMS group (WB-EMS, n=38) that performed 18 min of WB-EMS (bipolar, 85 Hz) 3 sessions in 14 days (1.5 sessions/week) or a semi-active control group (aCG, n=38). Body composition was assessed by dual-energy X-ray absorptiometry and maximum strength was evaluated using isometric techniques for trunk and legs. After 54 weeks of intervention, significant inter-group differences were determined for appendicular skeletal muscle mass (WB-EMS, 0.4±2.2 % vs. aCG, −1.5±3.1 %; p=0.009), lean body mass (WB-EMS, 0.8±1.8 % vs. aCG, −0.8±2.7 %; p=0.008) and maximum isometric strength (leg extensors, 9.8±12.9 % vs. 0.2±10.4 %; p=0.003; trunk extensors, 10.1±12.7 vs. −1.6±8.6 %; p=0.001). Although borderline significant for abdominal fat mass (WB-EMS, −2.9±8.3 vs. aCG, 1.5±10.7 %; p=0.069), differences did not reach statistically significant levels for body fat parameters. Considering the clinical effectiveness for impacting sarcopenia and the good acceptance of this technology by this non-sportive cohort of elderly women, we conclude that for elderly subjects unable or unwilling to perform dynamic strength exercises, electromyostimulation may be a less off-putting alternative to maintain lean body mass and strength.

Keywords EMS · Exercise · Sarcopenia · Body fat · Muscle · Elderly

Introduction

In the USA, about 10 % of adults 75 years and older lose the ability to independently perform the basic activities of daily living due to disability each year (Gill et al. 1995). Exercise positively impacts a large variety of risk factors and diseases of advanced age (Börjesson et al. 2010; Pedersen and Saltin 2006) and may thus be a key factor for independent life. With respect to sarcopenia and its related functional consequences, most studies confirmed the positive impact of resistance training on muscle mass (Peterson et al. 2011) and functional capacity (Latham et al. 2003) in aging adults. However, the majority of elderly subjects in Germany (Statistisches-Bundesamt 2006) or the USA (Clark 1999) fall far short of the exercise doses recommended for positively impacting muscle mass or disabling conditions (AHHS 2008; Chodzko-Zajko

W. Kemmler (✉) · M. Bebenek · K. Engelke · S. von Stengel
Institute of Medical Physics, Friedrich-Alexander University of Erlangen-Nürnberg, Henkestrasse 91, 91052 Erlangen, Germany
e-mail: wolfgang.kemmler@imp.uni-erlangen.de

et al. 2009). Thus, a large number of elderly subjects seem to be either unable or unwilling to perform conventional exercise programmes. Novel, innovative training concepts that overcome some limitations of conventional exercise programmes can be an option for these sedentary subjects. In this context, whole-body electromyostimulation (WB-EMS) may be an acceptable (Weineck 2009), time-saving option to affect muscle mass by its directly stimulating effect on skeletal muscle protein synthesis rate (Wall et al. 2012) at least in less active elderly persons with functional limitations and/or low sport affinity. WB-EMS is a technology that enables the simultaneous activation of the muscles of up to 16 regions with a total size of electrodes of 2.650 cm^2 and with different dedicated intensities per region. The first pilot trials with elderly subjects that focused on body composition (Kemmler et al. 2010b), metabolic syndrome (MetSyn) parameters (Kemmler et al. 2010a), energy expenditure (Kemmler et al. 2010b, 2012) and functional capacity (Kemmler et al. 2010a, 2010b) generally resulted in positive outcomes. Also of importance, the acceptance of this technology by the participants was rather high (Kemmler et al. 2010a, 2010b). However, definite evidence that WB-EMS positively impacts body composition in elderly subjects with low sport affinity and higher risk for sarcopenia, i.e. the cohort for which WB-EMS seems to be an ideal solution, was yet not provided. Thus, the purpose of this article is to determine the effect of 12 months of WB-EMS exercise on total and regional muscle and fat mass in lean, non-sportive, osteopenic women 70 years and older.

Our primary hypothesis was that WB-EMS training significantly impacts total and regional muscle mass compared with a semi-active control. Our secondary hypothesis was that WB-EMS training significantly impacts both abdominal fat mass and (to a lesser degree) total body fat compared with a semi-active control.

Material and methods

The Training and ElectroStimulation Trial III (TEST-III) was a randomized, controlled 12-month study with lean, non-sportive, osteopenic women 70 years and older that focused on sarcopenia and osteoporosis.[1] The study protocol was approved by the Ethical Committee of the Friedrich-Alexander University Erlangen-Nuremberg, Germany (Ethik Antrag 4184) and the German radiation safety agency (Z 5 – 22462/2 – 2010–027). After detailed information, written informed consent was obtained from all the subjects prior to the study entry. The study was conducted from November 2010 through July 2012 at the Institute of Medical Physics, Friedrich-Alexander University Erlangen-Nuremberg. The study is fully registered under www.clinicaltrials.gov (NCT 12296776).

The primary endpoints are the following:

- Appendicular skeletal muscle mass (ASMM)
- Lean body mass (LBM)

The secondary endpoints are as follows:

- Abdominal fat mass (AFM)
- Total fat mass (TFM)
- Maximum isometric leg (MIS-leg) and trunk strength (MIS-trunk)

Subjects

Figure 1 shows the participant flow during the different phases of the study. Using citizen registration records, the complete population of 9,256 female subjects 70 years and older, living in the area of Erlangen, were contacted by personal mail with detailed study information including eligibility criteria for the study. Altogether, 451 women responded (5 %) and were further assessed for eligibility by phone calls. In order to generate a homogeneous cohort with high relevance for WB-EMS Application in older subjects with high risk of sarcopenia, exclusion criteria focus on “leanness” and “physical inactivity”, factors that prevent proper WB-EMS application or parameters that may confound study results. Thus, 272 subjects had to be excluded after phone interviews because they (a) did not meet our criteria for “leanness” as determined by body weight (in kilogram) > body height (in centimetre)−100 (Broca Index; Liebermeister 1995), (b) exercised more than 60 min/week during the last decade, (c) reported injuries (i.e. hip TEPs, abdomen/groin hernia) or diseases (i.e. epilepsy, cardiac arrhythmia) that prevent WB-EMS intervention, (d) used medication and/or suffered from diseases affecting our primary endpoints or (e) said that they would be absent

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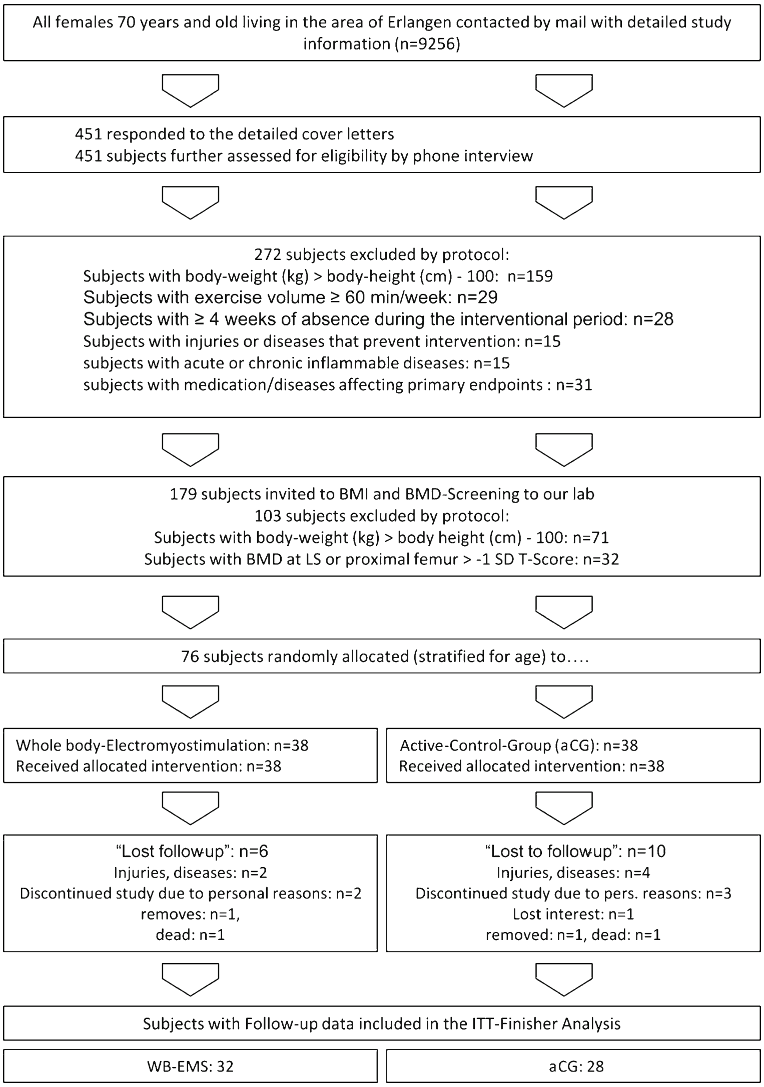
[1] In this article, we focus on sarcopenia and body composition, however.

Fig. 1 Flow chart of the "TEST" study



for more than 4 weeks during the interventional period. The remaining 179 women were invited to our lab. After measuring weight and height using calibrated devices, 71 women then had to be excluded. A further 32 women were excluded because they did not meet our criteria of osteopenia at lumbar spine or proximal femur (< −1 SD T score).

Finally, 76 eligible subjects were stratified by age (strata: 70–75, 76–80, 81–85) and randomly assigned to two intervention groups: WB-EMS (n=38) or semi-active control (aCG, n=38). Table 1 shows the baseline characteristics of the WB-EMS and aCG group. No differences were observed for these parameters.

Intervention

Based on the previous results of our working group (Kemmler et al. 2010a, 2010b, 2012), the WB-EMS protocol scheduled 18 min of supervised whole body electromyostimulation training three times in 2 weeks (every Monday or Tuesday and every second Thursday or Friday) for 54 weeks (total number of sessions, 80; total volume of the sessions, 24 h). In order to validate the isolated effect of WB-EMS and to blind participants, we implemented an active control group (aCG). The aCG performed two blocks of a supervised slight exercise programme over 10 weeks (1 session of 60 min/week) with intermitted rest periods of 10 weeks

Table 1 Baseline characteristics of the WB-EMS and control group

Variable	WB-EMS (n=38)	aCG (n=38)
Age [years][a]	74.7 ± 3.7	74.7 ± 4.4
Age at menopause [years][a]	50.5 ± 5.8	49.7 ± 5.6
BMI [kg/m^2]	22.1 ± 1.5	22.1 ± 1.2
Total body fat DXA [%]	31.6 ± 4.6	32.1 ± 3.7
Waist circumference [cm]	83.1 ± 7.4	84.8 ± 6.4
Total energy uptake [kcal/day][b]	1,583 ± 432	1,611 ± 398
Exercise volume [min/week][a]	34.1 ± 21.6	31.3 ± 19.3
Grip strength [kg]	23.7 ± 4.0	23.5 ± 4.1
Walking speed [m/s]	1.42 ± 0.38	1.48 ± 0.44
"Sarcopenia score"[c] [kg/m^2]	5.97 ± 0.42	6.04 ± 0.51
Sarcopenia according to Baumgartner et al.[d] [n]	3 (8 %)	3 (8 %)
Sarcopenia according to EWGSOP[e] [n]	0	0
Multimorbidity[f] [n]	22 (58 %)	25 (66 %)

WB-EMS whole-body electromyostimulation

[a] As assessed by detailed questionnaires (Kemmler et al. 2004a, 2004b)

[b] As assessed by 4-day dietary protocols

[c] "Skeletal Muscle Mass Index" (ASMM/body height^2) (Baumgartner et al. 1998)

[d] Skeletal Muscle Mass Index <5.45 kg/m^2 (Baumgartner et al. 1998)

[e] European Working Group on Sarcopenia in Older People (Cruz-Jentoft et al. 2010)

[f] Prevalence of two and more diseases (CHD, 71 %; DM type II, 17 %; osteoporosis, 41 %; chronic LBP, 34 %; arthritis, 51 %; hypo-/hyperthyroidism, 21 %; with no relevant differences between groups)

(total number of sessions, 20; total volume of the sessions, 20 h), while performing the identical slight movements as the WB-EMS group. The WB-EMS sessions and aCG sessions were consistently run and supervised by the same two instructors who also recorded subject attendance and compliance.

All the sessions were performed at the Institute of Medical Physics, which is centrally located and can be easily reached by public transport. In order to generate an optimum calcium and vit D supplementation, all the subjects (WB-EMS and aCG groups) were provided with a maximum of 1,200 mg/day Ca and 800 IE/day of cholecalciferol (Rottapharm/Madaus, Cologne, Germany) dependent on their dietary uptake. All the subjects were requested to maintain their physical activity habits and dietary intake beyond the study intervention.

WB-EMS intervention

Because WB-EMS technology is a rather novel technology, a brief introduction will be given. Most innovative and different to the well-established local EMS, the current WB-EMS equipment enables the simultaneous activation of up to 14–18 regions or 8–12 muscle groups (upper legs, upper arms, bottom, abdomen, chest, lower back, upper back, latissimus dorsi and four free options) with different selectable intensities. Adding the stimulated area, up to 2.800 cm^2 of area can be simultaneously activated. Strain or current intensity can be individually selected and modified during the EMS session. Our WB-EMS protocol scheduled the intermitted low intensity/low amplitude movement protocol specifically evaluated for elderly subjects and carefully described in our recent pilot studies (Kemmler et al. 2010a, 2010b, 2012). Briefly, three subjects underwent video-guided exercise at three EMS stations under the supervision of a certified instructor. Bipolar electric current was applied with a frequency of 85 Hz, and an impulse breadth of 350 μs intermittently with 6 s of EMS simulation using a direct impulse boost to perform the movement and 4 s of rest (Table 2) using WB-EMS devices (Fig. 2) from miha bodytec (Augsburg, Germany). We are unable to prescribe the exact stimulation intensity (in milliampere) due to differences with respect to regional and individual

Table 2 "Core exercise" performed under WB-EMS Application. Core exercise was also combined and/or slightly modified (i.e. twisted crunch) to generate 20 exercises that were used alternately during WB-EMS and aCG

Exercises
1. Deadlift (6 sdown) with arm extension/deadlift (6 s up) with arm flexion
2. Squat (6 s down) with trunk flexion (crunches)
3. Squat (6 s down) with lat pulleys/squat (6 s up) with military press
4. Squat (6 s down), crunch with butterfly/squat (6 s up) and reverse fly
5. Squat (6 s down) and vertical chest press/squat (6 s up) und vertical rowing

disparities of current sensitivity. Thus, to realize an adequate intensity of the EMS application, participants were requested to exercise at a rate of perceived exertion (RPE) between "somewhat hard" and "hard". To accurately determine and record the level of RPE during the EMS application, we used the RPE scale (Borg scale 14–16 of 20; Borg 1970).

Basic movements ("core exercises") given in Table 2 were combined and slightly modified (e.g. twisted crunch). Thus, all in all, a TEST-III WB-EMS session consisted of 10–14 dynamic exercises performed without any additional weights in a standing position. Exercises were structured in one to two sets of eight repetitions.

Amplitude, velocity and corresponding intensity generated by the movement were set low (i.e. squat, leg flexion, <35°) to prevent effects from the exercise per se.[2] Further, no progressive increment of intensity with respect to the exercises was conducted during the interventional period.

During the first session, current intensity was individually adapted in accordance with the participants. This baseline current intensity was saved for each region on chip cards to generate a fast, reliable and valid setting during the subsequent sessions. After this initial setting and a current conditioning period of 3–5 min, instructors slightly increased current intensity every 3–5 min in close cooperation with the participants in order to generate the rate of perceived exertion between somewhat hard and hard. Comparable to conventional exercise programmes, (current) intensity can be considered a key factor for positive effects; thus, strong emphasis was placed on the subjects' adequate appraisal of this parameter.

Semi-active control group

Primarily in order to validate that WB-EMS and not exercises per se was effective for impacting the study endpoints but also to generate a "placebo condition", we installed a semi-active control group that exercised in another setting/framework, however. Subjects of the aCG intermittently exercised for 10 weeks (1 session/week with 60 min) with 10 weeks of rest. Two 10-week blocks were realized during the 54-week interventional period. After a gentle warm-up (5 min of walking), emphasis was placed on the identical dynamic exercises (Table 2) as performed during the EMS sessions. In parallel to the WB-EMS protocol, 8–10 exercises with two sets of eight repetitions were carried out. Further, the sessions focused on flexibility, coordination and relaxation exercises with no or minor impact on our study endpoints.

Testing procedures

Baseline and follow-up tests were performed by the same assistants at the same time of the day (±1 h). All measurements were carried out by (blinded) research assistants who were not informed about the status of the participant (EG or CG) and who were strictly requested not to ask for this information.

Body weight was measured to the nearest 0.1 kg on digital scales. Height was determined barefoot to the nearest 0.1 cm with a stadiometer. Waist circumference was measured as the minimum circumference between the distal end of the rib cage and the top of the iliac crest along the midaxillary line. BMI was calculated by weight (kilogram)/height (square metre).

Body composition (LBM, TFM) was assessed with dual-energy X-ray absorptiometry (DXA, QDR 4500a, Discovery upgrade; Hologic Inc., Bedford, USA) using standard protocols. Region of interest for AFM was segmented between the lower edge of the 12th rib and the upper edge of the iliac crest. ASMM index (fat- and

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[2] Indeed, as assessed (Kemmler et al. 2010b), these slight movements as performed without WB-EMS application did not affect strength or power in a cohort of post-menopausal women 65 years old.

Fig. 2 Whole-body electromyostimulations equipment

bone-free proportion of the legs and arms (in kilogram) as assessed by DXA/height (in square metre)) was segmented and calculated according to the method proposed by Baumgartner et al. (1998). Following Baumgartner et al. (1998), sarcopenia was defined as ASSM of more than 2 standard deviations below the values of a “normal” healthy cohort about 30 years old (i.e. ASMM <5.45 kg/m^2). In order to calculate the more recent sarcopenia scores of the “European Working Group on Sarcopenia in Older People” (Cruz-Jentoft et al. 2010) and the “International working group on Sarcopenia” (Fielding et al. 2011), we also determined the functional abilities (walking speed, grip strength) described above.

Walking speed was tested according to the 10-m walk test validated by Perera et al. (2006). The coefficient of variation for our walking test was 4.5 %.

Grip strength of the dominant hand was determined using a Jamar dynamometer (Jamar, Bolingbrook, IL) according to the method suggested by Mathiowetz et al. (1984). MIS of the trunk was measured with a Schnell M3 isometric tester using the test protocol suggested by Tusker (1994). Maximum isometric strength during a leg press (knee flexion, 85°) was determined with a force plate (MTD-Systems, Neuburg v. W., Germany). The exact positioning and procedures have been described elsewhere (Kemmler et al. 2009). The coefficients of variation of our testing scheme were 3.5 % for grip strength, 3.1 % for trunk extension and 3.9 % for leg extension.

A detailed questionnaire was used to assess the subjects' status (i.e. age, years postmenopausal, diseases, medication, lifestyle) as well as their well-being, pain frequency and intensity at different skeletal sites, pre-study exercise levels and normal daily activity levels (Kemmler et al. 2004a, Kemmler et al. 2004b). The follow-up questionnaires also contained sections to monitor lifestyle changes, disease incidences, changes in disease severity or sport activities outside the TEST-III training programme.

The individual dietary intake was assessed by a 5-day protocol completed by each study participant. The consumed food was weighted precisely. The protocols were analysed using Prodi-4,5/03 Expert software (Wissenschaftlicher Verlag, Freiburg, Germany).

Statistical analyses

The sample size calculation was based on the study endpoint “Bone Mineral Density changes at the lumbar spine” in the light of on our experience that bone mass was less sensitive compared to muscle or fat mass at least with respect to conventional exercise programmes. A “Finisher” analysis that included all the subjects with 12-month follow-up data was performed. Baseline values are reported as means and standard deviations. Within-group changes between baseline and follow-up were reported as absolute (tables) and percentage changes (text). In order to obtain the normally distributed data required for the dependent (paired) t test and the analysis of variance with repeated measurements, all the primary (ASMM, LBM) and secondary endpoints (AFM, TFM, MIS) were log-transformed. Normal distribution before and after log-transformation was tested graphically as well by using the Shapiro–Wilks test. Differences within groups were analysed by paired t tests. Analyses of variance with repeated measurements were performed to check time–group interactions. All tests were two-tailed and statistical significance was accepted at $p<0.05$. Effect sizes (ES) based on the absolute difference (±standard deviation) between baseline and follow-up in the WB-EMS versus the CG were calculated using Cohen's d (Cohen 1988). SPSS 19.0 (SPSS Inc, Chicago, IL) was used for all statistical procedures.

Results

Of the 38 subjects of the WB-EMS group and aCG, respectively, altogether 16 subjects (WB-EMS, 6 vs. aCG, 10) were lost to follow-up (Fig. 1). Six women had to quit the study due to serious injuries (fractures, n=2), surgery (n=1) or diseases (cancer, CHD, n=3) unrelated to the study. Five subjects listed personal reasons for their withdrawal (lack of time, n=2; problems getting to classes, n=2; discomfort performing the WB-EMS application, n=1). One subject of the CG lost interest, two women moved and one participant of the aCG died during the study period. Thus, 32 subjects of the WB-EMS group (84 %) and 28 subjects of the aCG (74 %) were included in the analysis. Attendance rate in the WB-EMS group was 79±18 % (61.0 of 78 sessions) compared with a rate of 74±18 % (14.8 of 20 sessions) in the aCG. Net exercise volume averaged 24 min/week in the WB-EMS group and 18 min in the aCG. Average exercise intensity of the WB-EMS session as assessed biweekly was reported as high (Borg RPE scale, 14.4±1.3) and did not relevantly vary after the 8th week of WB-EMS exercise training. As intended, average exercise intensity was significantly lower in the aCG (RPE-scale, 10.1±1.6).

Body weight changes after 12 months did not significantly vary between both groups (WB-EMS, 0.1±1.3 vs. KG, −0.3±2.6 kg; p=0.431). With respect to the primary study endpoints (Table 3), ASMM did not change significantly (0.4±2.2 %; p=0.322) in the WB-EMS group but decreased significantly by −1.5±3.1 % (p=0.015) in the semi-active CG. Similarly, LBM significantly increased in the WB-EMS group (0.8±1.8 %, p=0.014) and non-significantly decreased (p=0.121) in the aCG group (−0.8±2.7 %). Corresponding differences between the WB-EMS and aCG groups were significant for both parameters (ASMM, p=0.009, ES d=0.71; LBM, p=0.008, ES d=0.71).

Fat content of the abdominal ROI (AFM) decreased significantly by −2.9±8.3 (p=0.040) in the WB-EMS group and increased slightly by 1.5±10.7 % (p=0.431) in the aCG. Total body fat mass (TFM) decreased slightly by −0.8±8.1 % (WB-EMS: p=0.558) and by −0.4±9.8 % (aCG: p=0.992) in the two groups. Although borderline for AFM, differences between WB-EMS and aCG did not reach statistically significant levels for both fat parameters (AFM: p=0.069; TFM: p=0.865). Of interest, differences for waist circumference, defined as an experimental endpoint only, were significant (WB-EMS, −1.1±2.1 cm vs. aCG, 0.7±2.7 cm; p=0.006).

Maximum isometric strength of the leg (9.8±12.9 %) and trunk extensors (10.1±12.7) increased significantly in the WB-EMS group ($p<0.001$) and was maintained (leg extensors, 0.2±10.4 %; p=0.969) or decreased slightly (trunk extensors, −1.6±8.6; p=0.349) in the aCG (Table 4). Differences in intra-group changes between WB-EMS and aCG were significant for both parameters ($p\leq0.003$).

Discussion

The present study is the first clinical trial to evaluate the effect of WB-EMS on body composition in this highly relevant cohort of elderly females at risk for/or with prevalent (Table 1) sarcopenia and corresponding risk of independence (Bauer et al. 2008). With respect to muscle mass and function (maximum isometric strength), we clearly verify our primary hypothesis that WB-EMS training significantly impacts total and regional muscle mass compared with a semi-active control group performing similar slight movements during their classes. Despite positive results, the effect of WB-EMS was borderline non-significant (p=0.069) for abdominal body fat and almost completely absent for total body fat mass; thus, our secondary hypothesis was rejected. Although we did not primarily address the “sarcopenic obesity” phenomena (Stenholm et al. 2008; Zamboni et al. 2008), we did expect to significantly impact both muscle and (abdominal) fat in view of the positive findings of our pilot trials (Kemmler et al. 2010a, b) and a

Table 3 Baseline and follow-up data, absolute changes and statistical parameters of primary endpoints in the WB-EMS and control group

	WB-EMS (MV±SD)	aCG (MV±SD)	Difference MV (95 % CI)	p value	Effect size (d)
Appendicular skeletal muscle mass [g]					
Baseline	15,804±2,123	15,851±1,721	–	–	–
12 months	15,866±2,120	15,618±1,877	–	–	–
Difference	62±346 n.s.	−233±475*	294 (82 to 508)	0.009	0.71
Lean body mass [g]					
Baseline	35,151±4,320	35,419±3,520	–	–	–
12 months	35,424±4,403	35,124±3,595	–	–	–
Difference	273±589*	−296±977 n.s.	568 (157 to 979)	0.008	0.71

Exact significance values are listed in the "Results" section

n.s. non-significant

*p<0.05; **p<0.01; ***p<0.001 (significance (p) for within-group effects)

cross-sectional study that specifically focused on energy expenditure during WB-EMS (Kemmler et al. 2012). However, the fundamental difference between these pilot studies with elderly subjects either with osteopenia (women, 65±6 years) or the metabolic syndrome (men, 65±6 years) may be, that both cohorts were less lean (BMI, 25.9±4.1 and 27.8±3.5 kg/m^2) compared with the subjects of the present study. Nevertheless, the fact that we included "lean" elderly females only did not necessarily exclude the possibility of a high proportion of (abdominal) fat mass in these subjects. Indeed, although our cohort ranged in the lowest quartile of sex and age with respect to BMI (22.1±1.4) compared with German peers (Benecke et al. 2003; DESTATIS 2012), waist

Table 4 Changes of body fat and maximum isometric strength in the WB-EMS and control group

	WB-EMS (MV±SD)	aCG (MV±SD)	Difference MV (95 % CI)	p value	Effect size (d)
Abdominal fat mass [g]					
Baseline	1,662±713	1,899±558	–	–	–
12 months	1,612±705	1,929±625	–	–	–
Difference	−49±130*	29±195 n.s.	78 (−6 to 163)	0.069	0.47
Total body fat mass [g]					
Baseline	18,087±4,969	18,699±3,216	–	–	–
12 months	17,946±4,843	18,631±4,372	–	–	–
Difference	−141±1,349 n.s.	−67±1,739 n.s.	74 (−787 to 934)	0.865	0.05
Maximum isometric strength leg extensors (leg press) [N]					
Baseline	604±185	523±171	–	–	–
12 months	664±214	524±194	–	–	–
Difference	59.4±72.7***	0.8±69.7 n.s.	58.6 (20.7 to 97.2)	0.003	0.82
Maximum isometric strength trunk extensors [N]					
Baseline	74.1±26.6	72.1±22.9	–	–	–
12 months	81.6±27.7	70.9±22.5	–	–	–
Difference	7.5±9.3***	−1.2±6.2 n.s.	8.7 (4.4 to 23.0)	0.001	1.10

Exact significance values are listed in the "Results" section

n.s. non-significant

*p<0.05; **p<0.01; ***p<0.001 (significance (p) for within-group effects) circumference averaged 84±7 cm in this population of lean elderly females. In other words, the majority (73 %) of our subjects would fulfill the criteria of "abdominal adiposity" (WC>80 cm) specified for "europid" females according to the MetSyn-Definition of the IDF (Alberti et al. 2006) and 27 % exceeded the more generalized WHO (2000) criteria of abdominal adiposity (88 cm) for women. Thus, even in this cohort of elderly women in the lowest BMI quartile, the prevalence of abdominal adiposity and the corresponding relevance of abdominal fat reduction are far from trivial.

Although WB-EMS should be considered as an option for subjects who do not exercise conventionally anyway, it is of importance to estimate the significance of WB-induced muscle mass/LBM changes. Reviewing the literature for exercise-induced LBM changes in subjects 50 years and older (Peterson et al. 2011) as assessed by DXA shows that WB-EMS effects were well within the range of conventional exercise effects in elderly cohorts. Even with a focus on high-intensity exercise protocols (>70 % 1RM) (Ades 2001; Binder et al. 2005; Marques et al. 2011b; Nelson et al. 1996), no relevant differences can be noted. A direct comparison of the present WB-EMS results and data of our recent 18-month Senior Fitness and Prevention (SEFIP) trial (Kemmler et al. 2010c), which also applied an intense resistance protocol using identical methods and a comparable cohort of community living elderly women (69±4 years) who were however less lean (BMI, 26±4 kg/m^2), revealed comparable net effects (WB-EMS vs. CG) for ASMM (WB-EMS, 294 g vs. SEFIP, 299 g) and LBM (WB-EMS, 568 g vs. SEFIP, 509 g).

To underline our position with respect to WB-EMS application in the elderly, WB-EMS should not be regarded as an "alternative" to but as an "option" for replacing certain intensive exercise programmes for elderly subjects who are either unable or unwilling to exercise conventionally due to the more comprehensive impact of mixed exercise programmes (Börjesson et al. 2010) for the multi-morbid elderly (Tesch-Römer 2007). Thus, our pragmatic approach to recruiting a cohort for this WB-EMS training may be of specific interest. Besides opting to include non-sportive elderly women only, we focus on lean subjects with osteopenia to generate a study cohort with a high prevalence of sarcopenia. However, subjects who fulfill these criteria and are willing to participate in clinical trials are rare. We should point out that even though all the women 70 years and older living in the area of Erlangen (n=9,256) were contacted (Fig. 1), we just missed our calculated sample size of 40 subjects/group. With respect to different sarcopenia definitions (ASMM < 5.45 kg/m^2, (Baumgartner et al. 1998); ASMM < 5.67 kg/m^2 + gait speed < 1 m/sec (Fielding et al. 2011); ASMM < 5.45 kg/m^2 + gait speed < 0.8 m/sec (Cruz-Jentoft et al. 2010)) the prevalence of sarcopenia ranged between 8 % to 0 % only. Taking into account that the prevalence of sarcopenia (ASMM <5.45 kg/m^2) in the general US population was reported to be 5–13 % for subjects 60–70 years (Baumgartner et al. 1998; Morley 2008) and ≈30–50 % for subjects 80 years (Baumgartner et al. 1998; Morley 2012, Morley et al. 2001), our finding was unexpectedly low, at least after allowing for the age and status of the cohort. One main reason for our low prevalence may be that we included community-dwelling subjects only, while cut-off values of sarcopenia may severely conflict with independent living. This aspect seems consistent, although Arango-Lopera et al. (2012) still reported a prevalence of 33 % in their ambulatory cohort of Mexicans 70 years and older. However, with respect to a cohort closer to our study group of German females 70 years and older, a recent Finnish article (Patil et al. 2013) that addressed sarcopenia in 70–80-year-old home-dwelling women confirmed our rather low prevalence of sarcopenia. Applying the suggested EWGSOP (Cruz-Jentoft et al. 2010) algorithm for sarcopenia (gait speed (<0.8 m/s) and ASSM (DXA, <5.45 kg/m^2)), the authors (Patil et al. 2013) reported a prevalence of 0.9 % only. Of interest for the sarcopenia definition/classification issue, only 4 out of 57 subjects (7 %) with low gait speed showed a low muscle mass index (ASSM <5.45 kg/m^2) (Patil et al. 2013) while none of our subjects with low ASMM (<5.45 kg/m^2) demonstrated low gait speed (<0.8 m/s) (Table 1).

Besides clinical effectiveness, the feasibility and subjects' acceptance of the exercise method or technology are key factors for broad application. With respect to the latter aspect, the drop-out rate in the WB-EMS group was low and attendance was satisfying compared with exercise trials of comparable duration (Marques et al. 2011a). However, one has to bear in mind that our WB-EMS programme was performed under rather individualized conditions with one instructor and three participants. Thus, it may be the exclusiveness of the exercise programme rather than its mode that leads to this high commitment.

Although WB-EMS was a rather time-saving exercise technology, some features may nevertheless prevent its broad application. With respect to cost efficiency, the costs for WB-EMS training are higher compared with training on resistance machines. Although the initial costs may be comparable, WB-EMS can actually be regarded as quite an exclusive exercise technology due to rapid wear and tear of the WB-EMS equipment and personnel costs. However, whilst supervision by a trainer should not be dispensed with completely, improved handling and video guidance, feedback processes and easier positioning will no doubt help to lower the degree of supervision required and thus reduce personnel costs.

It should not be neglected that some limitations may decrease the meaningfulness of the present study. (1) We evaluated quite a dedicated cohort of non-sportive elderly females at risk for sarcopenia; thus, it may not be appropriate to generalize our results to the population of elderly subjects as a whole. (2) Although DXA is still the "golden standard" technology for assessing body composition, MRI of the abdominal region with its corresponding ability to discriminate between subcutaneous and intra-abdominal fat content may result in divergent results. Further, due to the inability to discriminate between muscle and other non-fat/non-osseous tissue (i.e. organs, viscera), LBM may not be the best choice for monitoring WB-EMS induced changes of muscle mass. Although it is not plausible that organs or viscera may be relevantly affected by our intervention, we cannot completely exclude a corresponding BIAS. (3) In order to generate a placebo effect, and to evaluate the proper effect of WB-EMS-application we decided to introduce a semi-active control group that performed the identical slight movements as applied during the WB-EMS protocol with comparable volume. However, due to the sedentary lifestyle of the participants, even the slight movements that did not affect strength or power in our recent study with postmenopausal women (Kemmler et al. 2010b)[3] may have generated positive effects on our primary or secondary endpoints. However, this factor may have in fact have led to an underestimation of the study effects. (4) In this context, the control group did not exactly copy the continuous exercise setting of the WB-EMS group but focused on blocks of 10 weeks (with 60-min sessions once per week). Although study results may slightly differ when applying more frequent but shorter sessions (even under the premise of comparable "total exercise volume"), we decided against requiring frequent CG visits to our lab to perform "sham exercises". This approach may account for the good adherence of the CG and thus the comparable total "time under load" for both study groups. (6) We just missed our estimated sample size of 40 subjects/group. From a statistical point of view, this failure is of minor relevance with respect to the "body composition issue" reported here, since the sample size calculation was based on the less responsive parameter "BMD at the lumbar spine". In the context of our apparently low recruitment results, one may argue that only few subjects are suitable for this sophisticated exercise technology, which may imply a limited relevance of WB-EMS as a strategy for combatting sarcopenia in the elderly. We do not share this inference for two key reasons: (a) our recruitment strategy focuses on subjects with at least normal (or lower) body weight (Liebermeister 1995) independent of their body composition. Thus, a considerable number of subjects (see Fig. 1) with high(er) body weight based on a high proportion of fat mass were excluded although their skeletal muscle mass may be decreased to a critical level. (b) We focus on the ambulatory elderly, even though the number of subjects at risk or with present sarcopenia and corresponding functional decline is obviously much higher among institutionalized persons. (7) Unlike "real" intention to treat (ITT) analysis, our "Finisher Analysis" did not apply sophisticated implementation strategies with respect to missing data. ITT per se, however, did not minimize the bias generated by missing data at study end (Kleist 2009). Further, with one exception, subjects who dropped out did not report that their withdrawal was related to the study procedures. Nevertheless, our approach of ignoring missing data may lead to a slight overestimation of our effects. (8) Although subjects reported RPE levels for WB-EMS intensity within our expectation and a great deal of effort was placed on corresponding briefing, conditioning and interaction, it is difficult to clearly decide whether subjects did achieve the requested exercise intensity during the WB-EMS training.

In summary, it is essential to create alternative or optional training technologies for the increasing number of elderly subjects unable or unwilling to exercise conventionally. Our findings clearly demonstrate that a whole-

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[3] …that were however slightly younger (Age, 65±5 years), less lean (BMI, 26±4 kg/m^2) and much more sportive

body EMS programme performed for 18 min/session, 3 sessions in 14 days, is effective for increasing muscle mass and is also safe and feasible, at least in an elderly cohort at risk for sarcopenia. Thus, we consider the application of this innovative exercise technology to be an appropriate option for elderly subjects looking to improve their body composition and muscular strength appropriately for independent and healthy aging. Taking into account that WB-EMS technology will become more feasible and cost effective over the next few years, the application of WB-EMS should be seriously considered as a means of exercise training that focuses primarily on body composition and strength parameters.

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