REVIEW

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Whole-Body EMS to Fight Sarcopenic Obesity – a Review with Emphasis on Body Fat

Ganzkörper-EMS und Sarcopenic Obesity – mögliche Mechanismen der Körperfettreduktion

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Summary

- **Sarcopenia and sarcopenic-obesity (SO)** are key risk factors for disability, loss of independence and morbidity in older people. Although most studies confirm the positive impact of resistance training on muscle mass and functional capacity, the majority of older people fall far short of the exercise doses recommended to positively impact muscle mass or disabling conditions. For these persons, whole-body-electromyostimulation (WB-EMS) may be a time-efficient, physically less exhausting and joint-friendly option to increase lean-body-mass (LBM) and to reduce fat-mass.
- **In this narrative review,** we summarize the effects of WB-EMS on body composition with special regard to sarcopenia and SO. Further, possible mechanisms of WB-EMS-induced increases of energy expenditure are discussed.
- **The majority of** WB-EMS studies reported significant positive effects on lean-body and fat-mass in older adults. The few studies that focus on sarcopenia consistently determined improvements in morphometric and functional dimensions (i.e. gait-speed and /or handgrip-strength). The corresponding effect on (sarcopenic) obesity was less consistent. However, studies that applied WB-EMS at higher intensities reported predominantly significant acute-, short- and long-term increments of energy expenditure. Low doses of protein supplements (0.33g/kg/d; total intake: >1.2-<1.5g/kg/d) were unable to enhance the WB-EMS-induced effect on sarcopenia parameters.
- **In summary,** WB-EMS can be seen as an effective method for fighting sarcopenia and sarcopenic obesity in older people who are unable to perform intense exercise protocols. The role of additional protein supplements needs to be addressed in subsequent studies.

Zusammenfassung

- **Sarkopenie und Sarcopenic-Obesity (SO)** tragen ganz erheblich zu Gebrechlichkeit, Abhängigkeit und Mortalität des älteren Menschen bei. Die überwiegende Mehrheit derzeitiger Untersuchungen belegt den positiven Effekt eines Krafttrainings auf Muskelmasse und funktionelle Kapazität. Leider folgt nur die Minderheit der älteren Menschen den sportwissenschaftlichen Empfehlungen, die zur Generierung dieser positiven Effekte nötig wäre. Aufgrund seiner hohen Zeiteffektivität und Gelenkfreundlichkeit könnte Ganzkörper-Elektromyostimulation (WB-EMS) hier eine Interventionsoption darstellen.
- **In dieser narrativen Übersichtsarbeit** werden die derzeitigen Daten im Spannungsfeld „WB-EMS und Körperzusammensetzung“ unter Berücksichtigung von Sarkopenie und SO zusammengefasst und mögliche Mechanismen der WB-EMS-induzierten Erhöhung des Energieaufwandes diskutiert.
- **Die absolute Mehrzahl** der Untersuchungen berichtet signifikant positive Veränderungen von Muskelmasse und Körperfett nach WB-EMS-Applikation. Die wenigen Untersuchungen, die dezidiert die Sarkopenie des älteren Menschen evaluieren, zeigen übereinstimmend signifikante Verbesserungen von morphometrischen und funktionellen Sarkopeniegrößen (Gehgeschwindigkeit und/oder Handkraft). Weniger einheitlich ist der korrespondierende Effekt auf die (Sarcopenic)Obesity, wobei Untersuchungen, die reizintensive WB-EMS-Protokolle applizieren, signifikante Erhöhungen des akuten, kurz- und langfristigen Energieaufwandes erfassen. Geringe Proteindosen (0.33g/kg/d; Gesamteinnahme: >1.2-<1.5g/kg/d) zeigen keinen additiven Effekt auf die Verbesserung von Sarkopeniegrößen eines moderat-intensiven WB-EMS-Protokolls.
- **Zusammenfassend** stellt WB-EMS eine sinnvolle Interventionsoption zur Prävention und Rehabilitation von Sarkopenie und SO dar. Besonders interessant erscheint diese „alternative Trainingstechnologie“ für Menschen, die intensive (Kraft-)Trainingsprotokolle nicht mehr durchführen können (oder möchten). Aufgrund der hohen Relevanz einer zusätzlichen Proteingabe für die Sarkopenie und SO sollten künftige (WB-EMS) Untersuchungen dieses Forschungsziel verstärkt adressieren.

KEY WORDS:
Sarcopenia, Obesity, Electromyostimulation, Lean Body Mass, Body Fat, Older People

SCHLÜSSELWÖRTER:
Sarkopenie, Adipositas, Elektromyostimulation, Muskelmasse, Körperfett, älterer Mensch

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Introduction

The relevance of sarcopenia and sarcopenic obesity (SO), i.e. the unfavorable alteration of body composition at higher age, is becoming progressively significant for our quickly aging societies. Undeniably, the synergistic negative effect of loss of muscle mass and function combined with an increased fat mass are the most prominent components of disability, loss of independence and morbidity in older people (10, 50). Although the sarcopenia prevalence rate according to recent sarcopenia definitions (13, 16, 52) was (slightly) under 5%, at least for community dwelling (cdw) German men and women 70 years and older (34, 36), the high level of obesity among these people (64% (34, 36): cut-off points of >28% (men) and >35% (women) (55)) demonstrated the close interaction of muscle loss and fat accumulation at older age. With respect to body composition, exercise and nutrition are the key components of successful interventional strategies. Intense resistance exercise increases Lean Body Mass (LBM)and muscle-strength in older people (42, 43). Protein rich nutritional supplementation may also augment lean body and muscle mass in people with sarcopenia (20, 39). Combined strategies may lead to additive effects (18), although this topic has to be further addressed in older people (20). With respect to the obesity aspect of SO, energy restriction programs and endurance exercise were most effective for reducing fat mass in older adults (44). However, isolated energy restriction diets are inadvisable in SO since they provoke a significant loss of lean body mass (LBM) (20). In parallel, some studies reported significant LBM reductions after endurance type exercise (e.g. (28, 54)).

However, when applied in combination with dietary protocols (44), reductions were attenuated compared with isolated energy restriction programs (44). In summary, exercise seems to be the cornerstone in the treatment of sarcopenia, obesity and SO, however, most older people in Germany fall far short of the exercise doses recommended for positively affecting muscle mass, obesity or disabling conditions (12, 49). For these people, whole-body Electromyostimulation (WB-EMS) may be a time-efficient, physically less exhausting and joint-friendly option to increase LBM and to reduce fat mass. The aim of this narrative review is to provide a summary of WB-EMS interventions with and without dietary components that focused on sarcopenia, obesity and sarcopenic obesity in older adults with special emphasis placed on mechanism of WB-induced fat reductions.

Definition and Prevalence of Sarcopenia and Sarcopenic Obesity

Although sarcopenia now has their own International Classification of Diseases (ICD-10, M62.84), there is still no mandatory sarcopenia definition with respect to criteria and/or cut-off points. However, all recent definitions (11, 13, 16) coincide in including morphometric (skeletal muscle mass index: SMI) and functional parameters (i.e. handgrip-strength (52), gait velocity (16) or both (11, 13)). With respect to the calculation of the SMI two different approaches exist. While the Asian Working Group for sarcopenia (AWGS; (11)), the European Working Group on sarcopenia in Older People, (EWGSOP; (13)), and the International Working Group on Sarcopenia; (IWGS (16)) divided appendicular skeletal muscle mass (ASMM) by body height^2 (kg/m^2), the most recent sarcopenia Definition (Foundation of National Institute of Health, FNIH; (52)) include Body Mass Index as the factor (ASMM/BMI). Table 1 gives the criteria and cut-off points of the most common sarcopenia definition.

Applying the definitions (EWGSOP, IWGS, FNIH) to community-dwelling Bavarians 70+ resulted in a roughly comparable sarcopenia prevalence of 3.3-4.5% for women (36) and 3.7-4.8% for men (34); however, the diagnostic overlap between the definitions in identifying people with sarcopenia is low-moderate (≤50%) at best (34). As if this were not complicated enough, the evident inappropriateness of the BMI-based approach to identify obesity in the area of sarcopenic obesity further aggravates a mandatory definition of SO. Using body-fat as a more valid obesity criteria, there is no clear consensus with respect to obesity cut-off points. While most studies used the >35% total body fat threshold for female populations, approaches for (older) men vary between 25-30% (3, 10). Using a threshold of 28% and 35% for cdw Bavarian men and women 70+, we recently determined a SO prevalence of 1.8-2.3% (women) and 2.1-4.1% in men (34, 36).

Thus, although the prevalence rate for sarcopenia and sarcopenic obesity in cdw older people might be low-moderate only (at least compared to osteopenia or osteoporosis (15)), there is a need to identify and evaluate non pharmacologic therapeutic options for cohorts which demonstrate low enthusiasm for frequent exercise participation (47).

Whole-Body Electromyostimulation (WB-EMS)

Although WB-EMS is a well-known exercise technology in Germany and its neighboring countries, a brief introduction will be given for readers less familiar with this technology. Most innovative and different to local EMS, current WB-EMS equipment enables the simultaneous activation of up to 10 regions or 14 muscle groups. Summing up the stimulated area, up to 2,800cm^2 of area can be simultaneously activated, however, with selectable intensity for each region.

Generally two WB-EMS strategies exists. The more common and commercially used strategy relies on relatively high amperage without or with low intensity/low amplitude movements, while the more athletic approach focuses on the correct sport-specific movement with superimposed (WB-)EMS (e.g. (56)). At present, there are several WB-EMS concepts and devices, but the most common and scientifically validated concepts rely on bipolar, low frequency (50-100Hz) EMS with moderate impulse width (300-400µs). Further, most applicants use an intermitted schedule with 4-6s of impulse and 4s of impulse break with a direct impulse boost and a dynamic mode in a standing position. With a validated standard protocol of (1)-1.5 sessions of 20min/week (i.e. each Monday or Tuesday and every second Thursday or Friday) WB-EMS is also a very time-efficient method that focuses on body composition and strength (33) but might also positively impact cardiometabolic health parameters (27).

Due to body region and individual disparities in current sensitivity EMS intensity, the generation of a sufficient but tolerable intensity (mA) is subjectively prescribed by the rate of perceived exertion (RPE). To date, commercial WB-EMS is primarily applied as personal training with an instructor and one or two users. Figure 1 shows WB-EMS equipment with electrode vests and cuffs.

WB-EMS-Effects on Sarcopenia Parameters in Older People

As mentioned above, recent sarcopenia definitions include morphometric and functional criteria (11, 13, 16, 52). Basically, the positive effect of EMS on dimensions of muscle strength and power was validated by the majority of studies (17). Reviewing the literature, WB-EMS induced gains in strength and power were on average slightly lower compared with local application (17), but still ranged in the clinically relevant area of 10-25% after 8-14 weeks (e.g. (6, 7, 24, 25, 29, 30, 32, 33, 40)). However, two trials that compared WB-EMS versus resistance exercise observed widely comparable strength gains in students (40) or untrained, middle-aged men (33).

Addressing muscle mass, early studies reported cross-sectional area increases of the locally EMS-stimulated muscle that averaged around 10% (e.g. (5, 22)). With respect to lean body

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Table 1

Sarcopenia criteria, cut-off points and diagnostic prodecure of the sarcopenia definitions of the AWGS, EWGSOP, IWGS, FNIH. ^{1}=SMI cut-points were prescribed by the AWGS, FNIH and IWGS, while the EWGSOP suggested a T-Score based approach; here the corresponding data (-2 SD T-Score of young references) for Germany were given (34, 36).

DEFINITION/CRITERIA	SMI^1	GAIT VELOCITY	HANDGRIP STRENGTH
AWGS (9)	<5.4/<7.0kg/m^2 and	<0.8m/s or	<16/26kg
EWGSOP (11)	<5.67/<7.18kg/m^2 and	<0.8 m/s or	(when ≥0,8m/s) <20/30kg
FINH (47)	<0.512/0.789 and	-	<16/26kg
IWGS (13)	≤5.67/≤7.23kg/m^2; 3 and	<1.0m/s	-

or muscle mass, all recent trials consistently reported significant increases after WB-EMS applications of 12-54 weeks (8, 19, 31, 32). A direct comparison with a HIT-resistance exercise protocol resulted in similar positive changes in LBM (33).

Due to its effectiveness, time-efficiency, joint-friendliness and less exhausting application, WB-EMS may be thus particularly attractive for tackling sarcopenia in older people who are unable or unwilling to conduct (intensive) resistance exercise programs. However, only a few studies focus on the application of WB-EMS in older cohorts with low muscle mass or sarcopenia (23, 32). The Training and Electromyostimulation Trial III (TEST III) (23) determined the effect of WB-EMS on sarcopenia in 76 untrained cdw women 70+ with low SMI (5.98±0.41kg/m^2) as assessed by DXA. The WB-EMS protocol scheduled 1.5x20min/week (bipolar, 85Hz, 350µs, rectangular, 6s impulse – 4s impulse break, dynamic mode in a standing position with slight movements; intensity: RPE: 6 (i.e. "hard+") on a Borg CR10-scale) while the control group conducted two blocks of 10 weeks with 1x60min/w. of easy calisthenics. After 12 months of intervention, SMI increased significantly in the WB-EMS group (1.5±2.1%) and decreased slightly (-0.6±2.0%) in the semi-active control group (Effect Size (ES), d': 1.02, p=.001).

In parallel handgrip strength, another sarcopenia criterion was more favorably affected by WB-EMS (11.6±9.7, p=.001) compared with control (1.5±8.2%) (ES, d': 1.1, p=001). Quite recently, the FORMoSA study (32) provided definite evidence for the favorable effect of WB-EMS on sarcopenia in 75 cdw women 70+ with sarcopenic obesity. In this study the effect of 1x20min/week of WB-EMS (bipolar, 85Hz, 350µs, rectangular, 4-6s impulse – 4 s impulse break, with slight movements of the upper and lower limbs; intensity RPE 5-6 (i.e. hard-hard+) on a Borg CR10 Scale) in a supine sitting/lying position with (EMS&P) and without (EMS) low-dose protein supplements (0.33±0.16g/kg/d body weight) was validated against an inactive control group (CG). Protein Supplements consisted of whey protein with a high leucine/L-leucine component in order to realize an individual protein intake >1.20 to <1.50g/kg/d body weight. After six months of intervention, significant increases of SMI in both WB-EMS groups (EMS: 2.5±2.7% and EMS&P: 2.0±2.7%) and a decrease in the control group (-1.3±3.3%, p=.050) (ES, d': 1.1-1.2, p≤.002) were validated using DXA.

Functional sarcopenia parameters were also favorably affected in both WB-EMS groups compared with control; however, the differences in gait speed (EMS: 7.4±12.2% and EMS&P: 6.2±14.2% vs. CG: -2.6±10.8%; p≤.044; d': 0.85 and 0.70) and grip strength (EMS: -0,6±7.4% and EMS&P: 1.4±8.7% vs. CG: -6.2±9.3%; p≤.045; d': 0.67; 0.84) did not reach the dimensions determined for morphometric parameters.

In contrast however, the effects on leg extensor strength as assessed by an isokinetic leg press were significant (EMS: 21±8% and EMS&P: 23±8% vs. CG: 2±5%; p<.001; d': 2.86; 2.97). Further, based on a comparable baseline protein uptake of about 1.05±0.17g/kg/d among the study groups, additional protein supplementation did not enhance the WB-EMS induced effect on sarcopenia or related functional parameters (i.e. leg extensor strength).

In summary, the increase in skeletal muscle mass index corresponded to a net effect (WB-EMS vs. control) on LBM of 0.9-1.2kg or 0.7-1.0kg for ASMM. The clinical significance of these changes is debatable, changes of LBM were, however, in the range of data listed for conventional resistance exercise protocols applied in older people (9, 43). In contrast, effects on functional parameters after conventional resistance exercise training were slightly more favorable compared with WB-EMS, even when the WB-EMS application was realized in an active setting (i.e. with slight movements and combined with slight voluntary contractions). Apart from functional aspects, increased muscle mass plays a vital role in thermoregulation and especially resting metabolic rate (51). The latter mechanisms however will be addressed in the following chapter.

WB-EMS-Effects on Body Fat in Older People

Total and/or abdominal body fat reductions after WB-EMS interventions were frequently reported for normal- and overweight male and female populations (e.g. (19, 31, 33, 53)). With respect to obesity or sarcopenic obesity, three WB-EMS trials focus on this issue in older people (≥65 years) (24, 32, 35).

The TRIAL II study determined the effect of 1.5x30 min/week of WB-EMS versus a vibration control group (Vib-CG) with a corresponding "time under tension" in 24 predominately overweight-obese men 65+ with the Metabolic Syndrome according to the International Diabetes Federation (2, 24). WB-EMS consisted of 15min of endurance exercise on a cross-trainer at 70-85% HR_{max} with a continuous 85Hz bipolar application and 15min of intermitted application (4s impulse – 4s impulse break, 85Hz, 350µs, rectangular) in a standing position conducting slight movements. After 14 weeks of intervention, both groups lost abdominal (WB-EMS: -6.8±5.4% vs. Vib-CG): -0.9±5.4%; d´: 1.09; p=.005) and total body fat (-6.3±5.3% vs. -1.4±3.9%; d´: 1.05; p=009) as assessed by DXA technique; however, the reduction was significant in the EMS group only (p=.001). In contrast (d´: 0.97; p=.024) to the Vib-CG (-1.1±2.3%; p=.173), the WB-EMS group slightly (0.8±1.6%, p=.066) increased its SMI. Of importance, no changes in dietary habits were recorded by the dietary protocol, conducted by all participants immediately before and after the intervention.

In a sub-analysis of the Test III study the effect of WB-EMS on body fat parameters as assessed by DXA was evaluated in 46 cdw women 70+ with sarcopenia and abdominal obesity according to the International Diabetes Federation (2, 35). After 54 weeks of intervention we determined significant differences for waist circumference (WB-EMS: -1.3±3.2% vs. CG: 1.0±2.7%; d´: 0.85; p=.007) and abdominal body fat mass (WB-EMS: -1.2±5.7% vs. 2.4±5.8%; d´: 0.63; p=.038) between the groups, while no significant effect was observed for total body fat mass. Again, dietary protocols did not indicate changes in dietary habits during the interventional period.

Similar results were reported by the FORMoSA study (32, 57) that focused on the effect of low-dosed WB-EMS application with and without additional protein supply vs. a non-training CG on sarcopenia and obesity in cdw women 70+ with sarcopenic obesity. As with TEST-III, no relevant effects were observed for total body fat mass, however waist circumference decreased

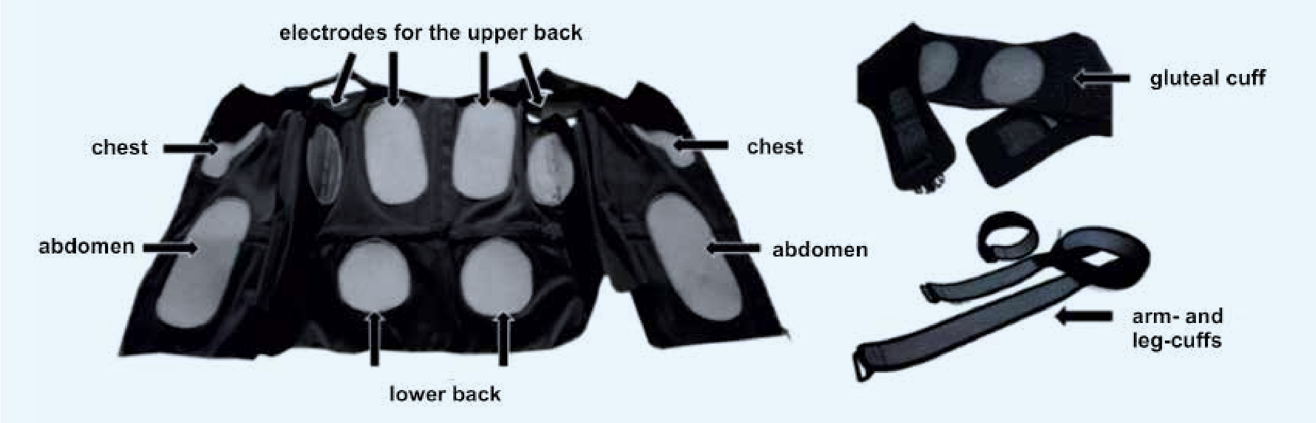

Figure 1

WB-EMS equipment with electrode vest and cuffs.

significantly in the WB-EMS groups (-1.2±1.9%, p=0.011) and was unchanged in the CG (0.0±2.5%, p=.963) (d': 54; p=0.046). Less favorable data were observed for abdominal body fat mass (EMS: -1.1±2.2%, p=0.038 vs. CG: -0.3±2.1%, p=.571)(d': 37; p=.088). Results were not affected by protein supplementation or changes in dietary habits during the interventional period.

Possible Mechanisms of WB-EMS Induced Fat Reductions

While the WB-EMS induced effect on muscle mass is comprehensible, the significant reductions of abdominal and/or total body fat may conflict with the low volume feature of WB-EMS application. Compared with a high intensity resistance training (HIT) protocol, WB-EMS generated comparable effects on abdominal (-5.2±6.4, p=.011) and total body fat (-4.3±5.0, p=.001) after 16 weeks. However, even the low volume (2-3x30min/week) of this "single set training to muscular failure with intensity strategies" (=HIT) exceeds the average weekly time expenditure of WB-EMS (30min/week) by far (33).

Even more surprisingly, a HIIT-endurance protocol with a weekly volume of 110±13min as applied to a similar cohort of men 30-50 years old with the same duration (16 weeks) did not relevantly exceed the WB-EMS induced total body fat reductions (-4.9±9.0%; p=.010) (28).

Whilst it is not the primary scope of this narrative review, we would nevertheless like to briefly address the mechanisms of WB-EMS induced effects on energy expenditure. Basically, three main mechanisms are involved in the exercise induced short and long-term increments of energy expenditure (EE): (a) the acute energy expenditure during exercise, (b) a post-exercise effect induced by energy restoration, repair and adaptive processes and (c) changes of resting metabolic rate.

Some studies that reported a slight increase in EE (≈300kJ/h) after local EMS of both thighs (e.g. (21, 48)) support the suggestion that WB-EMS which stimulates much more muscle area may generate a high EE. In a recent cross-over study, 20 participants 20-40 years old without WB-EMS experience performed (very) low intensity resistance exercises in a standing position with and without a WB-EMS standard protocol (bipolar, 85Hz, 350μs, 4s impulse – 4s break, 16min, RPE 7 (very hard)) (37). Using indirect calorimetry EE during the low intensity resistance exercise with adjuvant WB-EMS was significantly higher (p=.008) than during the control condition (1690±244 vs. 1443±285kJ/h; d`=.092, p=.008). Nevertheless, the total net effect (WB-EMS vs. control) of the 16min-WB-EMS session averaged only around 70kJ. Even when WB-EMS was not adjusted for control conditions, the total EE of 525kJ/session may hardly be a relevant contributor of fat reduction, at least when considering the low exercise frequency of this technology. However, comparable to resistance exercise, the real effect of WB-EMS on EE may be significantly underestimated by indirect calorimetry because of the correspondingly high extra-mitochondrial fraction of energy production that cannot be determined by this method (46). Of importance, Robergs et al. (46), who conducted a multiple regression analysis using VO_2, load and distance lifted to predict the EE of a moderately intense bench press and squatting protocol (70% 1RM), reported predicted EEs (≈65 kJ/min) 2-3 times higher compared with corresponding studies that focus on indirect calorimetry only.

Immediate and prolonged post-exercise energy demands induced by energy replenishment processes, repair mechanisms and adaptive responses regularly subsumed under "excess postexercise oxygen consumption" (EPOC) may be also a contributor to weight loss. In a just finished study, we determined the post-exercise effect of a WB-EMS session (bipolar, 85Hz, 350μs, 4s impulse – 4s break, 20min, RPE 7-8 on Borg CR 10 Scale) on Resting Metabolic Rate (RMR) using indirect calorimetry. In a cross-over design, 16 participants 25-50 years old with experience in WB-EMS were assessed either before, immediately after, and 12, 24, 36, 48, 60 and 72h post exercise or at corresponding points without WB-EMS-application. Compared with the control condition without WB-EMS, RMR after WB-EMS application was significantly increased for 60h and reached baseline values after 72h. Corresponding differences in total energy expenditure with and without WB-EMS averaged 2052±797kJ (d´: 0.91; p=.015) after 60h. These results confirmed data of de la O et al. that reported significantly increased EE up to 72h post WB-EMS (14). Even when assuming higher EE for acute WB-EMS application than determined by indirect calorimetry (37, 46), these results are much higher than the 6-15% of the energy cost during acute exercise summarized by LaForgia et al. (38). However, taking the low exercise frequency of WB-EMS (1.5 session/w.) into account, the corresponding average daily increase in EE is low-moderate only (≈400-450kJ/d).

Several studies (e.g. (1, 45)) reported higher levels of Resting Metabolic Rate (RMR) (4-7%) after resistance exercise training in older people. While the corresponding increase in fat-free mass may account for the main proportion of the RMR change (51), some studies reported significant RMR changes even in the absence of LBM changes (1, 45). However, considering the close physiological overlap of WB-EMS and resistance exercise, changes in RMR should also arise after WB-EMS interven-

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tions. Using indirect calorimetry, after 14 weeks of WB-EMS application (bipolar, 350 µs, 10 min 4s – 4s with 85Hz, and 10min continuously with 7Hz, RPE 6-7) in 15 women 55-70 years old, the TEST-I study determined a 4.9±6.9% increase in RMR compared with a control group (n=15), which parallels a net effect on RMR of 290±387kJ/d (d´: 0.62; p=0.095) (29, 31). Of interest, comparable to the results of some resistance exercise trials (1, 45), the net gain in LBM (WB-EMS vs. CG) averaged only 0.56±0.59kg (d´: 0.75; p=0.046), and thus did not fully explain the corresponding RMR increases.

Conclusion

In summary, WB-EMS has been recognized as an efficient exercise technology able to significantly affect muscle and fat mass and thus improve sarcopenia and (sarcopenic) obesity in older people. Further, recent studies reported high adherence rates (19, 31, 32, 33), consequently WB-EMS seems to be attractive, at least when conducted in this rather individual setting and free of charge.

However, some limitations and features of WB-EMS should be considered in order to ensure successful application. (a) The generation of an effective and adequate (impulse) intensity is an essential problem of WB-EMS, regardless of the WB-EMS-strategy used. This refers especially to people with low experience in exercise-induced pain sensation or (too) highly motivated subjects. Here, the close and confidential interaction of instructor and subject is very important for producing an effective exercise protocol and avoiding rhabdomyolysis-induced risks during the early sessions (26).

(b) Commercial settings focus on a once weekly WB-EMS-application. Data of the FORMoSA study, which focused on cdw SO-women 70+ and applied one WB-EMS session/week only, confirmed a correspondingly favourable effect on muscle mass, while contrary to all our other studies, the effect on body fat parameters were minor (32, 57). However, this result cannot be entirely referred to a "lower than usual" exercise frequency since other parameters (e.g. slightly lower RPE, application in a sitting/lying position) also differ from our common WB-EMS protocols (3). Although Filipovic et al. provide some corresponding insight by their excellent review(s) (17), there is a lack of studies that directly compared strain parameters (e.g. impulse frequency, chronaxie/impulse width, impulse intensity) with respect to body composition and functional parameters. This hinders the application of this very promising protocol, however.

Finally, revisiting the sarcopenia issue, the mode of additional (to exercise) protein application especially with respect to its dosage is still under debate. Recent recommendations of the PROT-AGE consortium of ≥1.20g/kg/d as applied in the FORMoSA study (≥1.20 to <1.50g/kg/d of whey protein) failed to generate an additional effect on muscle mass (4). Due to the anabolic resistance to dietary protein in the elderly and increased exercise-induced protein demands, higher doses (1.5-2.0g/kg/d) should be taken into consideration (41). This strategy (1.8-2.0g/kg/d), along with a slightly more intensive WB-EMS application that addressed cdw men with SO 70+, was applied in the recently finished, but yet not published, FRANSO-trial without any negative side effects (34). ■

Conflict of Interest

The authors have no conflict of interest.

References

(1) **ADES PA, SAVAGE PD, BROCHU M, TISCHLER MD, LEE NM, POEHLMAN ET.** Resistance training increases total daily energy expenditure in disabled older women with coronary heart disease. J Appl Physiol. 2005; 98: 1280-1285. doi:10.1152/japplphysiol.00360.2004

(2) **ALBERTI KG, ZIMMET P, SHAW J.** Metabolic syndrome-a new world-wide definition. A Consensus Statement from the International Diabetes Federation. Diabet Med. 2006; 23: 469-480. doi:10.1111/j.1464-5491.2006.01858.x

(3) **BATSIS JA, BARRE LK, MACKENZIE TA, PRATT SI, LOPEZ-JIMENEZ F, BARTELS SJ.** Variation in the prevalence of sarcopenia and sarcopenic obesity in older adults associated with different research definitions: dual-energy X-ray absorptiometry data from the National Health and Nutrition Examination Survey 1999-2004. J Am Geriatr Soc. 2013; 61: 974-980. doi:10.1111/jgs.12260

(4) **BAUER J, BIOLO G, CEDERHOLM T, CESARI M, CRUZ-JENTOFT AJ, MORLEY JE, PHILLIPS S, SIEBER C, STEHLE P, TETA D, VISVANATHAN R, VOLPI E, BOIRIE Y.** Evidence-based recommendations for optimal dietary protein intake in older people: a position paper from the PROT-AGE Study Group. J Am Med Dir Assoc. 2013; 14: 542-559. doi:10.1016/j.jamda.2013.05.021

(5) **BEZERRA P, ZHOU S, CROWLEY Z, BROOKS L, HOOPER A.** Effects of unilateral electromyostimulation superimposed on voluntary training on strength and cross-sectional area. Muscle Nerve. 2009; 40: 430-437. doi:10.1002/mus.21329

(6) **BOECKH-BEHRENS W, BENGEL M.** Krafttraining durch Elektromyostimulation? Empirische Untersuchung zu den Krafteffekten bei einem Elektromyostimulationstraining am BodyTransformermit Variation der Belastungsdichte. (Report) Institut für Sportwissenschaften der Universität Bayreuth, Bayreuth 2005.

(7) **BOECKH-BEHRENS W, MAINKA D.** Krafttraining durch Elektromyostimulation? Empirische Untersuchung zu den Krafteffekten bei einem Elektromyostimulationstraining am Body Transformer mit Variation der Trainingsdauer. (Report) Institut für Sportwissenschaften der Universität Bayreuth Bayreuth 2006.

(8) **BOECKH-BEHRENS W, TREU S.** Vergleich der Trainingseffekte von Konventionellem Krafttraining, maxxF und EMS-Training in den Bereichen Körperzusammensetzung, Körperformung, Kraftentwicklung, Psyche und Befindlichkeit. (Report) Institut für Sportwissenschaften der Universität Bayreuth, Bayreuth, 2002.

(9) **BORDE R, HORTOBAGYI T, GRANACHER U.** Dose-Response Relationships of Resistance Training in Healthy Old Adults: A Systematic Review and Meta-Analysis. Sports Med. 2015; 45: 1693-1720. doi:10.1007/s40279-015-0385-9

(10) **CAULEY JA.** An Overview of Sarcopenic Obesity. J Clin Densitom. 2015; 18: 499-505. doi:10.1016/j.jocd.2015.04.013

(11) **CHEN LK, LIU LK, WOO J, ASSANTACHAI P, AUYEUNG TW, BAHYAH KS, CHOU MY, CHEN LY, HSU PS, KRAIRIT O, LEE JS, LEE WJ, LEE Y, LIANG CK, LIMPAWATTANA P, LIN CS, PENG LN, SATAKE S, SUZUKI T, WON CW, WU CH, WU SN, ZHANG T, ZENG P, AKISHITA M, ARAI H.** Sarcopenia in Asia: consensus report of the Asian Working Group for Sarcopenia. J Am Med Dir Assoc. 2014; 15: 95-101. doi:10.1016/j.jamda.2013.11.025

(12) **CHODZKO-ZAJKO WJ, PROCTOR DN, FIATARONE SINGH MA, MINSON CT, NIGG CR, SALEM GJ, SKINNER JS; AMERICAN COLLEGE OF SPORTS MEDICINE.** American College of Sports Medicine position stand. Exercise and physical activity for older adults. Med Sci Sports Exerc. 2009; 41: 1510-1530. doi:10.1249/MSS.0b013e3181a0c95c

(13) **CRUZ-JENTOFT AJ, BAEYENS JP, BAUER JM, BOIRIE Y, CEDERHOLM T, LANDI F, MARTIN FC, MICHEL JP, ROLLAND Y, SCHNEIDER SM, TOPINKOVÁ E, VANDEWOUDE M, ZAMBONI M; EUROPEAN WORKING GROUP ON SARCOPENIA IN OLDER PEOPLE.** Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. Age Ageing. 2010; 39: 412-423. doi:10.1093/ageing/afq034

(14) **DE LA O A, AMARO F, ROERO C, GUTIÉRREZ A.** Influencia de tres tipos diferentes de entrenamiento (Electroestimulación global, High Intensity Interval Training (HIIT) y Aerobio convencional) sobre el metabolismo basal post esfuerzo. Rev Andal Med Deporte. 2015; 8: 20-24.

(15) **DACHVERBAND OSTEOLOGIE E.V. (DVO).** DVO-Leitlinien 2009 zur Prophylaxe, Diagnostik und Therapie der Osteoporose bei Erwachsenen. Schattauer, Stuttgart, 2009.

(16) **FIELDING RA, VELLAS B, EVANS WJ, BHASIN S, MORLEY JE, NEWMAN AB, ABELLAN VAN KAN G, ANDRIEU S, BAUER J, BREUILLE D, CEDERHOLM T, CHANDLER J, DE MEYNARD C, DONINI L, HARRIS T, KANNT A, KEIME GUIBERT F, ONDER G, PAPANICOLAOU D, ROLLAND Y, ROOKS D, SIEBER C, SOUHAMI E, VERLAAN S, ZAMBONI M.** Sarcopenia: an undiagnosed condition in older adults. Current consensus definition: prevalence, etiology, and consequences. International working group on sarcopenia. J Am Med Dir Assoc. 2011; 12: 249-256. doi:10.1016/j.jamda.2011.01.003

(17) **FILIPOVIC A, KLEINODER H, DORMANN U, MESTER J.** Electromyostimulation - A Systematic Review of the Effects of Different EMS Methods on Selected Strength Parameters in Trained and Elite Athletes. J Strength Cond Res. 2012; 26: 2600-2614. doi:10.1519/JSC.0b013e31823f2cd1

(18) **FINGER D, GOLTZ FR, UMPIERRE D, MEYER E, ROSA LH, SCHNEIDER CD.** Effects of protein supplementation in older adults undergoing resistance training: a systematic review and meta-analysis. Sports Med. 2015; 45: 245-255. doi:10.1007/s40279-014-0269-4

(19) **FRITZSCHE D, FRUEND A, SCHENK S, MELLWIG KP, KLEINÖDER H, GUMMERT J, HORSTKOTTE D.** Elektromyostimulation (EMS) bei kardiologischen Patienten. Wird das EMS-Training bedeutsam für die Sekundärprävention? Herz. 2010; 35: 34-40. doi:10.1007/s00059-010-3268-8

(20) **GOISSER S, KEMMLER W, PORZEL S, VOLKERT D, SIEBER CC, BOLLHEIMER LC, FREIBERGER E.** Sarcopenic obesity and complex interventions with nutrition and exercise in community-dwelling older persons--a narrative review. Clin Interv Aging. 2015; 10: 1267-1282.

(21) **HAMADA T, HAYASHI T, KIMURA T, NAKAO K, MORITANI T.** Electrical stimulation of human lower extremities enhances energy consumption, carbohydrate oxidation, and whole body glucose uptake. J Appl Physiol. 2004; 96: 911-916. doi:10.1152/japplphysiol.00664.2003

(22) **HERRERO JA, IZQUIERDO M, MAFFIULETTI NA, GARCIA-LOPEZ J.** Electromyostimulation and plyometric training effects on jumping and sprint time. Int J Sports Med. 2006; 27: 533-539. doi:10.1055/s-2005-865845

(23) **KEMMLER W, BEBENEK M, ENGELKE K, VON STENGEL S.** Impact of whole-body electromyostimulation on body composition in elderly women at risk for sarcopenia: the Training and ElectroStimulation Trial (TEST-III). Age (Omaha). 2014; 36: 395-406. doi:10.1007/s11357-013-9575-2

(24) **KEMMLER W, BIRLAUF A, VON STENGEL S.** Einfluss von Ganzkörper-Elektromyostimulation auf das Metabolische Syndrom bei älteren Männern mit metabolischem Syndrom. Dtsch Z Sportmed. 2010; 61: 117-123.

(25) **KEMMLER W, ENGELKE K, VON STENGEL S.** Ganzkörper-Elektromyostimulation zur Prävention der Sarkopenie bei einem älteren Risikokollektiv. Die TEST-III Studie. Dtsch Z Sportmed. 2012; 63: 16-23.

(26) **KEMMLER W, FROEHLICH M, VON STENGEL S, KLEINÖDER H.** Whole-Body Electromyostimulation – The Need for Common Sense! Rationale and Guideline for a Safe and Effective Training. Dtsch Z Sportmed. 2016; 67: 218-221. doi:10.5960/dzsm.2016.246

(27) **KEMMLER W, KOHL M, VON STENGEL S.** Effects of High Intensity Resistance Training versus Whole-body Electromyostimulation on cardiometabolic risk factors in untrained middle aged males. A randomized controlled trial. J Sports Med. 2016; 3: 44-55.

(28) **KEMMLER W, LELL M, SCHARF M, FRAUNBERGER L, VON STENGEL S.** Hoch- versus moderat-intensive Laufbelastung – Einfluss auf kardiometabolische Risikogrößen bei untrainierten Männern. Die randomisierte, kontrollierte RUSH-Studie. DMW. 2015; 140: e7-e13. doi:10.1055/s-0040-100423

(29) **KEMMLER W, SCHLIFFKA R, MAYHEW JL, VON STENGEL S.** Effects of Whole-Body-Electromyostimulation on Resting Metabolic Rate, Anthropometric and Neuromuscular Parameters in the Elderly. The Training and ElectroStimulation Trial (TEST). J Strength Cond Res. 2010; 24: 1880-1887. doi:10.1519/JSC.0b013e3181ddaeee

(30) **KEMMLER W, TESCHLER M, BEBENEK M, VON STENGEL S.** Effekt von Ganzkörper-Elektromyostimulation auf die übergreifende sportmotorische Leistungsfähigkeit im Handball. Dtsch Z Sportmed. 2011; 62: 271.

(31) **KEMMLER W, TESCHLER M, VON STENGEL S.** Effekt von Ganzkörper-Elektromyostimulation – „A series of studies“. Osteologie. 2015; 23: 20-29.

(32) **KEMMLER W, TESCHLER M, WEISSENFELS A, BEBENEK M, VON STENGEL S, KOHL M, FREIBERGER E, GOISSER S, JAKOB F, SIEBER C, ENGELKE K.** Whole-body Electromyostimulation to Fight Sarcopenic Obesity in Community-Dwelling Older Women at Risk. Results of the Randomized Controlled FORMOsA-Sarcopenic Obesity Study. Osteo Int. 2016; 27: 3261-3270. doi:10.1007/s00198-016-3662-z

(33) **KEMMLER W, TESCHLER M, WEISSENFELS A, FRÖHLICH M, KOHL M, VON STENGEL S.** Ganzkörper-Elektromyostimulationst versus HIT-Krafttraining - Effekte auf Körperzusammensetzung und Muskelkraft. Dtsch Z Sportmed. 2015; 66: 321-327. doi:10.5960/dzsm.2015.209

(34) **KEMMLER W, TESCHLER M, WEISSENFELS A, SIEBER C, FREIBERGER E, VON STENGEL S.** Prevalence of Sarcopenia and Sarcopenic Obesity in community-dwelling German men 70+ using various established definitions. Osteo Int. 2017. [Epub ahead of print].

(35) **KEMMLER W, VON STENGEL S.** Whole-body electromyostimulation as a means to impact muscle mass and abdominal body fat in lean, sedentary, older female adults: subanalysis of the TEST-III trial. Clin Interv Aging. 2013; 8: 1353-1364. doi:10.2147/CIA.S52337

(36) **KEMMLER W, VON STENGEL S, ENGELKE K, SIEBER C, FREIBERGER E.** Prevalence of Sarcopenic Obesity in Germany using Established Definitions. Baseline data of the FORMOsA Study. Osteo Int. 2016; 27: 275-281. doi:10.1007/s00198-015-3303-y

(37) **KEMMLER W, VON STENGEL S, SCHWARZ J, MAYHEW JL.** Effect of whole-body electromyostimulation on energy expenditure during exercise. J Strength Cond Res. 2012; 26: 240-245. doi:10.1519/JSC.0b013e31821a3a11

(38) **LAFORGIA J, WITHERS RT, GORE CJ.** Effects of exercise intensity and duration on the excess post-exercise oxygen consumption. J Sports Sci. 2006; 24: 1247-1264. doi:10.1080/02640410600552064

(39) **MALAFARINA V, URIZ-OTANO F, INIESTA R, GIL-GUERRERO L.** Effectiveness of nutritional supplementation on muscle mass in treatment of sarcopenia in old age: a systematic review. J Am Med Dir Assoc. 2013; 14: 10-17. doi:10.1016/j.jamda.2012.08.001

(40) **MESTER J, NOWAK S, SCHMITHÜSEN S, KLEINÖDER H, SPEICHER U.** Kurz- und langfristige Trainingseffekte durch mechanische und elektrische Stimulation auf kraftdiagnostische Parameter, in: BISP (Hrsg.): BISP-Jahrbuch. Bundesinstitut für Sportwissenschaften, Bonn, 2009.

(41) **MURTON AJ.** Muscle protein turnover in the elderly and its potential contribution to the development of sarcopenia. Proc Nutr Soc. 2015; 74: 387-396. doi:10.1017/S0029665115000130

(42) **PETERSON MD, RHEA MR, SEN A, GORDON PM.** Resistance exercise for muscular strength in older adults: a meta-analysis. Ageing Res Rev. 2010; 9: 226-237. doi:10.1016/j.arr.2010.03.004

(43) **PETERSON MD, SEN A, GORDON PM.** Influence of resistance exercise on lean body mass in aging adults: a meta-analysis. Med Sci Sports Exerc. 2011; 43: 249-258. doi:10.1249/MSS.0b013e3181eb6265

(44) **POGGIOGALLE E, MIGLIACCIO S, LENZI A, DONINI LM.** Treatment of body composition changes in obese and overweight older adults: insight into the phenotype of sarcopenic obesity. Endocrine. 2014; 47: 699-716. doi:10.1007/s12020-014-0315-x

(45) **PRATLEY R, NICKLAS B, RUBIN M, MILLER J, SMITH A, SMITH M, HURLEY B, GOLDBERG A.** Strength training increases resting metabolic rate and norepinephrine levels in healthy 50- to 65-yr-old men. J Appl Physiol. 1994; 76: 133-137.

(46) **ROBERGS RA, GORDON T, REYNOLDS J, WALKER TB.** Energy expenditure during bench press and squat exercises. J Strength Cond Res. 2007; 21: 123-130. doi:10.1519/00124278-200702000-00023

(47) **RÜTTEN A, ABU-OMAR K, LAMPERT T, ZIESE T.** Körperliche Aktivität [Physical Activity]. (Report) Statistisches Bundesamt, Berlin, 2005.

(48) **SIMONEAU JA.** Energy expenditure of the human knee extenor muscle induced by neuromuscular low frequency electrical stimulation. Can J Sport Sci. 1989; 14: 136.

(49) **STATISTISCHES BUNDESAMT.** Gesundheit in Deutschland [Health in Germany]. Berlin, 2006.

(50) **STENHOLM S, HARRIS TB, RANTANEN T, VISSER M, KRITCHEVSKY SB, FERRUCCI L.** Sarcopenic obesity: definition, cause and consequences. Curr Opin Clin Nutr Metab Care. 2008; 11: 693-700. doi:10.1097/MCO.0b013e328312c37d

(51) **STIEGLER P, CUNLIFFE A.** The role of diet and exercise for the maintenance of fat-free mass and resting metabolic rate during weight loss. Sports Med. 2006; 36: 239-262. doi:10.2165/00007256-200636030-00005

(52) **STUDENSKI SA, PETERS KW, ALLEY DE, CAWTHON PM, MCLEAN RR, HARRIS TB, FERRUCCI L, GURALNIK JM, FRAGALA MS, KENNY AM, KIEL DP, KRITCHEVSKY SB, SHARDELL MD, DAM TT, VASSILEVA MT.** The FNIH sarcopenia project: rationale, study description, conference recommendations, and final estimates. J Gerontol A Biol Sci Med Sci. 2014; 69: 547-558. doi:10.1093/gerona/glu010

(53) **VATTER J.** Elektrische Muskelstimulation als Ganzkörpertraining - Multicenterstudie zum Einsatz von Ganzkörper-EMS im Fitness-Studio. AVM-Verlag München, 2010.

(54) **WEISS EP, RACETTE SB, VILLAREAL DT, FONTANA L, STEGER-MAY K, SCHECHTMAN KB, KLEIN S, EHSANI AA, HOLLOSZY JO; WASHINGTON UNIVERSITY SCHOOL OF MEDICINE CALERIE GROUP.** Lower extremity muscle size and strength and aerobic capacity decrease with caloric restriction but not with exercise-induced weight loss. J Appl Physiol. 2006; 102: 634-640. doi:10.1152/japplphysiol.00853.2006

(55) **WHO.** Physical status: the use and interpretation of anthropometry. Report of a WHO expert committee. Geneva, 1995.

(56) **WIRTZ N, ZINNER C, DOERMANN U, KLEINOEDER H, MESTER J.** Effects of Loaded Squat Exercise with and without Application of Superimposed EMS on Physical Performance. J Sports Sci Med. 2016; 15: 26-33.

(57) **WITTMANN K, SIEBER C, VON STENGEL S, KOHL M, FREIBERGER E, JAKOB F, LELL M, ENGELKE K, KEMMLER W.** Impact of whole body electromyostimulation on cardiometabolic risk factors in older women with sarcopenic obesity: the randomized controlled FORMOsA-sarcopenic obesity study. Clin Interv Aging. 2016; 11: 1697-1706. doi:10.2147/CIA.S116430