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

Ganzkörper-EMS und Sarcopenic Obesity – mögliche Mechanismen der Körperfettdreduction

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 fail to achieve the required 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 found 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


> **In dieser narrativen Übersichtsarbeiten** 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 Muskulatur und Körperfett nach WB-EMS-Applikation. Wenigen Untersuchungen, die dezidiert die Sarkopenie des älteren Menschen evaluieren, zeigen übereinstimmend signifikante Verbesserungen von morphometrischen und funktionellen Sarkopeniegrößen (Gehgeschwindigkeit und/oder Handkraft). Wenig 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.


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)
Definition and Prevalence of Sarcopenia and Sarcopenic Obesity

Although sarcopenia now has its 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 height² (kg/m²), the most recent sarcopenia definition (Foundation of National Institute of Health, FNHI; (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, FNHI) 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 2,800cm² of area can be simultaneously activated, however, with selectant intensity for each region.

Generally two WB-EMS strategies exist. 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.

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...
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 HIIT-resistance exercise protocol resulted in similar positive changes in LBM (33).

Due to its effectiveness, time-efficiency, joint-friendlyness 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/m²) 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 (1.1±0.7% vs. 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 1.0±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% HRmax 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±3.3% 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±8.5%; 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

### Table 1

<table>
<thead>
<tr>
<th>Definition/Criteria</th>
<th>SMI1</th>
<th>Gait Velocity</th>
<th>Handgrip Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWGS (9)</td>
<td>&lt;5.4/=-7.0kg/m² and &lt;0.8m/s or &lt;10/26kg</td>
<td></td>
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</tr>
<tr>
<td>EWGSOP (11)</td>
<td>&lt;5.67/=-7.18kg/m² and &lt;0.8m/s or &lt;20/30kg</td>
<td></td>
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<tr>
<td>FINH (47)</td>
<td>&lt;0.51/=-7.083 and -</td>
<td>&lt;=16/26kg</td>
<td></td>
</tr>
<tr>
<td>IWGS (13)</td>
<td>&lt;=5.33/=-7.23kg/m²; 3 and &lt;=1.0m/s</td>
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significantly in the WB-EMS groups (-1.2±1.9%, p=0.011) and was unchanged in the CG (0.0±2.5%, p=0.963) (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=0.571) (d’: 37; p=0.088). 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=0.011) and total body fat (-4.3±5.0, p=0.001) after 16 weeks. However, 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=0.010) (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 7-8 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=0.015) 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 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 VO₂ 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.
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._


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


