



EFFECTS OF HIGH INTENSITY RESISTANCE TRAINING VERSUS WHOLE-BODY ELECTROMYOSTIMULATION ON CARDIO-METABOLIC RISK FACTORS IN UNTRAINED MIDDLE AGED MALES. A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Background: Time-efficient exercise protocols may encourage subjects to exercise more frequently and could thus be excellent tools for health promotion. The aim of this study was to compare the effectiveness of the time-efficient methods HIT and/versus WB-EMS on cardio-metabolic risk factors in untrained middle-aged males. *Methods:* Untrained, healthy males (30-50 years) were randomly allocated either to 16-weeks of WB-EMS with 3 applications of 20 min/2 weeks, or 16 weeks of high intensity (resistance) training (HIT) performing 2 sessions/week. Both methods addressed all the main muscle groups. Metabolic-Syndrome Z-Score (MetS-Z-Score), abdominal body fat and total cholesterol/HDL-cholesterol (TC/HDL-C) were defined as the study endpoints. *Results:* HIT and WB-EMS were similar ($p \leq 0.096$) effective to improve the MetS-Z-Score (HIT: $p = 0.031$ vs. WB-EMS: $p = 0.001$) and abdominal body fat (HIT: $-4.5 \pm 8.1\%$, $p = 0.014$ vs. WB-EMS $-4.0 \pm 5.2\%$, $p = 0.002$) in this cohort. No significant changes (HIT: -2.7 ± 7.4 , $p = 0.216$ vs. WB-EMS: -2.2 ± 10.2 $p = 0.441$) or group-differences ($p = 0.931$) within and between the groups were determined for TC/HDL-C. *Conclusion:* WB-EMS and HIT-RT is equally effective, attractive, feasible and time-efficient methods for combatting cardio-metabolic risk factors in untrained middle-aged males. WB-EMS can be considered as an effective option, particularly for subjects with low time resources unwilling or unable to conduct exhausting HIT protocols.

Keywords: Resistance exercise, Electrical stimulation, Cardio-metabolic risk, Metabolic syndrome, Abdominal fat.

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Contribution/ Originality

The paper's primary contribution is finding that both exercise methods, high intensity resistance training (HIT) as defined as "single-set-to-failure protocol with intensifying strategies" and whole-body electromyostimulation (WB-EMS) are equally effective, attractive and feasible approaches for tackling cardio-metabolic risk factors in untrained middle-aged males with limited time resources.

1. INTRODUCTION

Time-efficient exercise protocols may be the best choice for promoting the health of subjects with limited time resources. In the area of resistance exercise (RT), whose general relevance for cardio-metabolic prevention is now undisputed (Williams *et al.*, 2007; Strasser *et al.*, 2012; Strasser and Pesta, 2013) two methods, namely high intensity training (HIT) and whole-body electromyostimulation (WB-EMS), were identified as candidates that satisfy the time-effectiveness requirement. However, the effect of both methods on dedicated cardio-metabolic parameters has yet to be proved. This is especially the case for WB-EMS, a novel exercise technology that simultaneously innervates up to 12 main muscle groups with dedicated intensity. Although a recent study demonstrated the

positive effect of WB-EMS on body composition in older men with the Metabolic Syndrome (Kemmler *et al.*, 2010) the general effect on cardio-metabolic indices has not been evaluated yet. Thus, the purpose of this study was to determine the effectiveness of WB-EMS, compared with a similar time-efficient but more “conventional” resistance exercise protocol (HIT), concerning cardio-metabolic risk factors in the highly relevant cohort of untrained middle-aged males.

Our primary hypothesis were that both methods significantly improve the MetS-Z-Score (H1), but the effects of HIT were significantly more pronounced compared with WB-EMS (H2).

2. MATERIALS AND METHODS

We conducted a 16-week single-blinded, randomized controlled trial, using a parallel group design (Fig. 1). The study was conducted by the Institute of Medical Physics, University of Erlangen (FAU), Germany. The study was approved by the ethics committee of the FAU (Ethikantrag 245_13b), and the Federal Bureau of Radiation Protection (Z5-22462/2-2013-090). All the study participants gave written informed consent prior to study participation.

The study was fully registered under www.clinicaltrials.gov. (NCT02078986). No changes were made to the trial protocol after commencement. We strictly adhered to the Consolidated Standards of Reporting Trial (CONSORT) for reporting (randomized) clinical trials (Moher *et al.*, 2010).

2.1. Subjects

Sixty-seven males responded to our personalized letters and were assessed for eligibility (Fig. 1). A total of 57 subjects remained eligible after applying the inclusion criteria of (a) male subjects, 30-50 years old; (b) “untrained status” defined as no regular resistance exercise training (RT: <1 session/week) and less than 90 min of total exercise/week; and the exclusion criteria of: (c) pathological changes of the muscle and heart or inflammatory diseases; (d) medication/diseases affecting muscle metabolism; (e) conditions that prevent WB-EMS (e.g. epilepsy, cardiac pacemaker), and (f) absence of >2 weeks during the interventional period. Nine subjects withdrew after informative meetings presenting the specific study design, interventions and measurements (most of these due to unwillingness to join the randomization procedure (n=5) and/or to conduct the DXA assessment (n=2)). The remaining 48 subjects were then given the opportunity to draw lots to randomly allocate themselves one of the two study arms “High Intensity Training (HIT)” and “Whole-Body Elektromyostimulation (WB-EMS)”, with neither the participants nor the researchers knowing the next allocation. However, since two subjects allocated to the HIT study arm immediately withdrew after randomization, the randomization sequence was adjusted by replacing a WB-EMS assignment by a HIT one to generate similar sample sizes per group. Consequently, 23 subjects of the HIT and 23 subjects of the WB-EMS group started the exercise program (Fig. 1). All the study participants were strongly urged to maintain their physical activity and exercise habits during the study period.

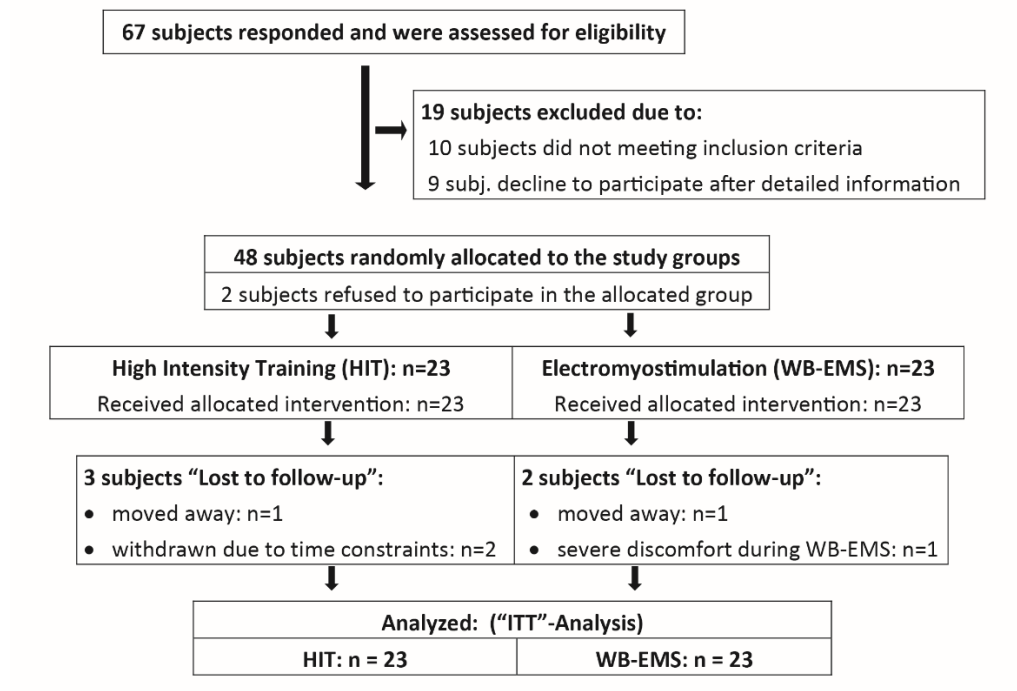


Fig-1. Flow diagram through the phases of the present study
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Table 1 gives baseline characteristics of the subjects. Baseline characteristics and parameters that may have confounded our results did not vary significantly between the groups.

Tab-1. Baseline characteristics of the HIT and WB-EMS participants; ¹ 4-day dietary protocol, analyzed by the Freiburger Ernährungs-Protokoll (Freiburger nutrition protocol, Nutri-Science, Freiburg, Germany); ² as assessed by chi-square test

Variable	HIT n=23	WB-EMS n=23	Difference (p)
Age [years]	41.9 ± 6.4	43.7 ± 6.1	.429
BMI [kg/m ²]	26.9 ± 3.3	28.5 ± 4.1	.151
Total body fat (DXA) [%]	24.7 ± 4.8	26.5 ± 5.2	.220
Exercise volume [min/week]	45.9 ± 37.8	50.2 ± 35.2	.689
Energy Intake [kcal/d] ¹	2346 ± 463	2387 ± 712	.828
Protein/KH/Fat/Alcohol [% of energy intake] ¹	16/46/35/3	17/41/38/4	----
Overweight (BMI>25 kg/m ²) [%]	65	74	.375 ²
Hypertension (>90 or >140 mmHG) [%]	22	43	.074 ²
Hypercholesterolemia (>200 mg/dl) [%]	78	78	.639 ²
Smoker [%]	30	26	.743 ²
Weekly working time [%]	43.2 ± 3.8	43.2 ± 4.0	.970

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2.2. Procedures

2.2.1. Primary Study Endpoints

- Metabolic Syndrome (MetS) Z-Score according to the MetS definition of the International Diabetes Federation (IDF) (Alberti *et al.*, 2006).

2.2.2 Secondary Study Endpoints

- Abdominal body fat (%) as assessed by Dual Energy x-ray Absorptiometry
- Rate of Total Cholesterol to High Density Lipid Cholesterol (TC/HDL-C)

2.2.3. Explanatory Study Endpoints

- Parameters constituting the MetS according to IDF (Alberti *et al.*, 2006).

2.3. Measurements

The subjects were tested at the same time of the day (± 1 h) at baseline and follow-up participants within 60 min by the same researcher. All assessments and analysis were determined in a blinded mode.

2.3.1. Anthropometry

Body height, weight and waist circumference were measured using calibrated devices. Waist circumference was determined as the minimum circumference between the distal end of the rib cage and the top of the iliac crest along the midaxillary line.

Body composition was determined by Dual Energy X-ray Absorptiometry (QDR 4500a, discovery upgrade; Hologic, USA) using the manufacturer's standard protocols. Abdominal body fat was segmented between the lower end of the 12th thoracic vertebra and the upper end of the iliac crest. Follow-up segmentation was conducted using the "compare mode", which retained the area of the initial segmentation.

2.3.2. Blood Parameters

After an overnight fast, blood was sampled in the morning (7:00 to 9:00) in a sitting position from an antecubital vein. Serum samples were centrifuged at 3000 RPM for 20 minutes and analyzed by the "Zentrallabor" of the Medical Department, University of Erlangen-Nürnberg. Glucose, total cholesterol, HDL- and LDL cholesterol and triglycerides (Olympus Diagnostica GmbH, Hamburg, Germany) were determined.

Blood pressure was determined in a sitting position after 5 minutes' rest with an automatic oscillometric device (Bosco, Bosch, Jungingen, Germany). All measurements were taken in a non-fasting condition. Subjects were asked to avoid relevant physical activity 12 hours before the tests and to refrain from coffee or tea for at least two hours prior to testing.

2.3.3. Metabolic Syndrome

The MetS-Z-Score was calculated according to the calculation proposed by Johnson *et al.* (2007) albeit based on the more recent MetS definition presented by the IDF (Alberti *et al.*, 2006) instead of the NCEP-ATP-III definition (Expert-Panel, 2001). Under the IDF definition, MetS is prevalent if waist circumference is increased (≥ 94 cm for Caucasian males) and two of the four following factors are also present: (1) raised triglyceride (TriGly) levels (≥ 150 mg/dl) (2) reduced HDL-C (< 40 mg/dl for males; or specific treatment for previously detected hypertriglyceridaemia / reduced HDL-C) (3) raised blood pressure (≥ 85 or ≥ 135 mmHG, or specific treatment) (4) raised fasting plasma glucose (≥ 100 mg/dl, or previously diagnosed type 2 diabetes). Based on these cut-off points, the individual data and the corresponding baseline standard deviation (SD) of the entire cohort the Z-Score was calculated as follows: $\left[\frac{(40 - \text{HDL-C})}{\text{SD HDL-C}} \right] + \left[\frac{(\text{TriGly} - 180)}{\text{SD TriGly}} \right] + \left[\frac{(\text{Glucose} - 100)}{\text{SD Glucose}} \right] + \left[\frac{(\text{waist circumference (WC)} - 94)}{\text{SD WC}} \right] + \left[\frac{(\text{Mean arterial (blood) pressure (MAP)} - 107.5)}{\text{SD MAP}} \right]$.

2.3.4. Baseline Characteristics, Confounding Factors

Lifestyle, diseases and medication, pain intensity and frequency at different sites were assessed at baseline and follow-up by standardized questionnaires. Changes in physical activity and exercise were also determined by follow-up questionnaires (Kemmler *et al.*, 2004) and personal interviews.

Dietary intake of the participants was assessed pre- and post-trial by a 4-day dietary protocol. The consumed food was analyzed using the *Freiburger Ernährungs-Protokoll* [Freiburger Nutrition Protocol] (nutri-science, Hausach, Germany).

2.4. Study Procedure

Participants of both groups conducted a 16-week HIT or WB-EMS intervention from November 2014 until March 2015 or from January 2015 until May 2015 in a local gym (Benefital, Herzogenaurach, Germany). All the exercise sessions were supervised; further individual 4-week training logs, prescribing intensity, volume and frequency of the exercise given to the participants were regularly checked and recorded by research assistants. Participants were urged not to vary their medication, dietary habits, physical activity and exercise throughout the study course.

2.4.1. Hit Protocol

HIT-resistance exercise was defined as “*single-set-to-failure protocol with intensifying strategies*”. The exercise protocol scheduled two, rarely three (9th, 13th, 16th week) exercise sessions per week on non-consecutive days. All the main muscle groups were addressed by 10-13 exercises/session taken from a pool of 17 exercises conducted on RT devices (Technogym Gambettola, Italy). Tab. 2 gives the composition of the HIT protocol.

After 4 weeks of conditioning the periodized 12-week HIT-training sequence started with the specification to work to momentary muscular failure (MMF). Following a maximum effort approach (MMF), the number of repetitions was decreased linearly over 3 weeks with each 4th week planned as a “recreational week” with lower effort (maximum effort – 1 rep). In detail, participants were requested to choose a load such that they were just able to perform the prescribed repetitions. Sets were always conducted to MMF, even when subjects failed to achieve the given number of repetitions. Superset variations conducted either as agonist supersets using related muscle groups (i.e. back lat pulleys, seated rowing, front chins) as or antagonistic supersets (i.e. leg extension, leg curl, leg press) were introduced during the third 4-week phase. Lastly, and additionally, during the last 4-week phase, “drop sets” were prescribed. Under this concept, after “initial” MMF, subjects were requested to reduce the load once (week 13, 14) or twice (week 15, 16) and work again up to MMF (Tab. 2).

Tab-2. Details of the HIT exercise protocol.

Time	Number of Reps (Break)	Work to failure strategy	TUT (s)
Phase 1: 1-2 week 3-4 week	conditioning phase: 2 x 15 Reps (break: 90 s) 1 x 8-10 Reps (break 90 s)	MMF – 2-3 Reps MMF – 1 Rep	2 - 1 - 2
Phase 2: 5-8 week	8-10 Reps (break 2 min) 5-7 Reps (break 2 min) 3-5 Reps (break 2 min) RegW: 10-12 Reps (break 2 min)	MMF MMF MMF MMF – 1-2 Reps	expl - 1 - 2 expl - 1 - 2 3 - 1 - 4 2 - 1 - 2
Phase 3: 9-12 week	see phase 2, however, break between SuS-exercises: <20 s; between SuS-“blocks“: 2 min week 4: RegW (s. Phase 2)	see phase 2 + Supersets: 1. session/w. agonists SuS ¹ 2. session/w antagonists SuS ² 2-4 exercises per SuS-„block“	see phase 2
Phase 4: 13-16 week	see phase 3	see phase 3 and one or two Drop-sets: week 13, 14: 1 Drop-set (-10 to 25% load) week 15, 16: 2 Drop-sets (-10-20% und -20% load)	2 - 1 - 2 to 3 - 1 - 3

Reps: repetitions, TUT: Time under Tension (s concentric - s isometric - s excentric range), MMF: work to momentary muscular failure; RegW: regeneration week; expl: explosive movement; SuS: supersets; DropSets: immediate exercise with slightly reduced weight. ¹subsequent training of identical muscle groups; ²intermittent training for agonist/antagonist.

2.4.2. Whole Body Electromyostimulation (WB-EMS)

In contrast to the classical local application, the WB-EMS technology vests and cuffs electrodes (Miha bodytec, Gersthofen, Germany) used in our studies allow simultaneous but dedicated control and innervation of 8-10 muscle groups with a total electrode area of up to 2800 cm².

We applied a WB-EMS protocol involving a bipolar impulse. Based on the available literature (Lam and Qin, 2008; Filipovic *et al.*, 2011) and our past experience (Kemmler *et al.*, 2010; Kemmler *et al.*, 2010; Kemmler *et al.*, 2011; Kemmler *et al.*, 2014) the stimulation frequency was selected at 85 Hz, the impulse width at 350 microseconds and the impulse rise as direct (rectangular application). Impulse duration was 6 sec with a 4-sec break between the impulses. Groups of three participants guided by a certified instructor conducted 20 min WB-EMS-sessions 3 times in 2 weeks (each Monday or Tuesday and each second Thursday or Friday or Saturday), always on two non-consecutive days. In order to generate an effect throughout the range of motion, slight movements were performed in a standing position during the impulse phase as per the instructions in videos that exactly mimic the 6 s movement and 4 s rest rhythm of the WB-EMS protocol.

To generate an adequate intensity of the WB-EMS application, subjects were requested to exercise at a rate of perceived exertion (RPE) of between “somewhat hard” and “hard” (Borg CR-10 Scale “6” of “10” (impossible) (Borg and Kaijser, 2006). Initially, the impulse intensity was individually adapted in close cooperation with the participant. The corresponding impulse intensity per muscle group was saved on smart cards to ensure a fast, reliable and valid application during the subsequent WB-EMS sessions. Then this setting was successively increased every 3-5 min during the WB-EMS session to achieve the objective of RPE “hard” to “very hard”.

2.5. Statistical Analysis

We calculated an a priori sample size estimation that focused on “Lean Body Mass”. Based on a Type 1 Error of 5% and a statistical power (1- β) of 90% a sample size of 21 subjects per group was sufficient to detect a 10% (SD: 10%) LBM difference between the groups. Anticipating a dropout rate of \approx 15-20%, we aimed to recruit \approx 25 subjects per group.

An Intention to Treat (ITT) analysis was conducted that included all participants with baseline data. The ITT analysis was performed using the statistics software R (R Development Core Team Vienna, Austria) in combination with multiple imputation by Amelia II. The full data set was used for multiple imputation, with imputation being repeated 50 times. In addition, the approach of Barnard and Rubin (1999) was used to compute mean, SD (combination of within- and between-imputation variance) and p values (t-distribution with adjusted degrees of freedom). In all cases, the results obtained were in very good agreement with the respective results determined with the approach of Steele *et al.* (2010).

Baseline and follow-up data were reported as mean values (MV) and standard deviations (SD). Changes between baseline and follow-up within the HIT and WB-EMS group were described as absolute (tables) and percentage changes (text). With respect to the comparison of the groups, mean differences (with 95% confidence intervals) between HIT and WB-EMS based on absolute changes were reported in the tables. Welch T-Tests were consistently applied to check for differences between the groups (Ruxton, 2006). All tests were 2-tailed, statistical significance was accepted at $p < .05$. Effect sizes (ES) were calculated using Cohen’s d' . SPSS 21.0 (SPSS Inc, Chicago, IL) was used for all statistical procedures apart from multiple imputation.

3. RESULTS

Baseline characteristics did not vary significantly between the groups (Tab 1). The majority of participants were overweight or demonstrated central obesity (HIT: 70% vs. WB-EMS: 78%) according to IDF (Alberti *et al.*, 2006). With respect to relevant diseases, 4 subjects listed (treated) Diabetes Mellitus Type-II (HIT: $n=1$), 5 subjects reported slight allergic respiratory disorders (HIT: $n=1$), 2 participants suffer from depression (HIT: $n=1$), 3 males

indicate resection of the thyroid or hypothyroidism (HIT: n=1). Energy and macro-nutritional intake per se was inconspicuous and did not vary between groups. All participants were in full-time employment, 78% of the participants of both groups were white-collar workers in middle to upper positions.

Three participants of the HIT and two participant of the WB-EMS group were lost to follow-up. Further, as already mentioned, two subjects refused to join their allocated intervention (HIT) and quit the study immediately after randomization without any assessments. One subject gave the study intervention as the reason for withdrawing (“severe discomfort during the WB-EMS application”), four others stated job-related relocation (HIT: n=1, WB-EMS: n=1), or job-related time constraints (HIT: n=2) (Fig. 1).

The attendance rate of both methods was high (HIT: $93.3 \pm 7.0\%$ vs. WB-EMS: $89.5 \pm 10.7\%$) and did not vary relevantly between the groups ($p=.171$). With respect to time efficiency, the length of the HIT sequence averaged 30.3 ± 2.3 min/session; the corresponding duration of WB-EMS was 20 ± 0 min. However, taking into account that HIT participants exercised at least twice per week, while WB-EMS participants exercised on average 1.5 times per week, the total volume of exercise conducted in the HIT group was twice ($p<.001$) as high (847 ± 87 min) compared with the WB-EMS group (403 ± 87 min).

As described above, the perceived exercise intensity of the WB-EMS participants was consistently adjusted to maintain an RPE of at least 6 (5=“hard”, 7=“very hard”) during the session. Due to the progression of the HIT protocol (Tab. 2) participants reported an almost linear increase in their RPE starting with $4.75 \pm .28$ for the first 4-week period, 5.64 ± 4.4 for the second, $6.42 \pm .39$ for the third and finally $7.31 \pm .36$ for the last 4-week period.

No relevant negative side effects with respect to musculoskeletal lesions or diseases potentially related to the study intervention were recorded during the study period.

3.1. Study Endpoints

Table 3 lists baseline and follow-up data, corresponding changes and group differences for MetS-Z-Score, abdominal body fat rate and the proportion of total cholesterol to HDL-C. At baseline, no relevant group differences were observed for the given parameters. MetS-Z-Score significantly improved in both groups ($p \leq .031$) with no significant differences between the two groups ($p=.096$). Thus, we verify our hypothesis H1 “that both methods significantly improve the MetS-Z-Score”, but reject H2 “that the effects of HIT was significantly more pronounced compared with WB-EMS”.

Percent body fat rate decreased by $-4.5 \pm 8.1\%$ ($p=.014$) in the HIT and $4.0 \pm 5.2\%$ ($p=.002$) in the WB-EMS with no significant difference between the groups ($p=.895$). No significant changes (HIT: -2.7 ± 7.4 , $p=.216$ vs. WB-EMS: -2.2 ± 10.2 $p=.441$)¹ and no significant differences ($p=.931$) within and between the groups were determined for the rate of total cholesterol to HDL-cholesterol (Tab. 3).

Tab-3. Changes of primary study and secondary endpoints [6] in the HIT and WB-EMS group. ITT-analysis

	HIT (n=23)	WB-EMS (n=23)	Absolute difference MV (95% CI)	p	(d)
MetS-Z-Score [Index]¹					
Baseline	-0.74 ± 3.46	0.23 ± 3.19	----	.274	----
Difference	-0.52 ± 1.12 ($p=.031$)	-1.16 ± 1.43 ($p<.001$)	.63 (-.11 bis 1.38)	.096	.50
Abdominal body fat [%]					
Baseline	27.65 ± 6.52	29.30 ± 6.10	----	.395	----
Difference	-1.24 ± 2.27 ($p=.014$)	-1.17 ± 1.53 ($p=.002$)	0.07 (-1.06 bis 1.20)	.895	.04
Total Cholesterol /HDL-Cholesterol [rate]²					
Baseline	4.52 ± 1.03	$4.53 \pm .089$	----	.968	----
Difference	-0.12 ± 0.46 ($p=.216$)	-0.10 ± 0.63 ($p=.441$)	0.02 (0.32 to 0.35)	.931	.04

¹ negative Z-Score values were favorable, further a negative change of the MetS-Z-Score can be considered as an improvement.

² Negative changes of the TC/HDL-C rate can be considered as an improvement.

Table 4 show baseline and follow-up data, corresponding changes and group differences for parameters (except HDL-C) constituting the MetS according to IDF (Alberti *et al.*, 2006).

Tab-4. Changes of selected parameters constituting the Metabolic Syndrome in the HIT and WB-EMS group. ITT-analysis.

	HIT (n=20)	WB-EMS (n=21)	Absolute Difference MV (95% CI)	p	(d)
Waist circumference [cm]					
Baseline	100.5 ± 9.6	102.6 ± 9.4	-----	.480	-----
Difference	-2.10 ± 4.13 (p=.021)	-3.41 ± 4.52 (p=.002)	1.31 (-1.25 bis 3.87)	.306	.30
Mean Arterial Blood Pressure [mmHG]					
Baseline	106.4 ± 9.6	110.8 ± 10.0	-----	.158	-----
Difference	-3.64 ± 5.63 (p=.005)	-4.86 ± 7.33 (p=.005)	1.22 (-2.69 bis 5.13)	.529	.19
Glucose [mg/dl]					
Baseline	94.3 ± 18.5	95.3 ± 14.6	-----	.837	-----
Difference	1.74 ± 8.53 (p=.320)	-4.27 ± 8.98 (p=.035)	6.01 (0.79 bis 11.24)	.025	.69
Triglycerides [mg/dl]					
Baseline	139.5 ± 61.0	161.2 ± 93.8	-----	.383	-----
Difference	-10.1 ± 47.9 (p=.307)	9.5 ± 55.5 (p=.423)	19.5 (-10.8 bis 49.9)	.200	.38

3.2. Confounding Parameters

In summary, no relevant changes of occupational, disease, or medication status was reported after the interventional period. Self-reported occupational and leisure time physical activity increased slightly and comparably (p=.793) in both groups (3-6%; p≥.650). Similarly, average exercise participation and weekly exercise volume did not change significantly in the HIT or WB-EMS. However, in response to a specific query two participants (HIT: n=1 vs. WB-EMS: n=1) with particular high weight loss admitted they had started endurance exercise training (2 and 2.5 h/week running) after the second and fourth week of the study intervention.

Dietary intake parameters changed considerably in both groups, but none of the subjects said they had changed their nutritional intake in order to reduce weight or body fat. Energy uptake comparably (p=.159) increased in both groups (HIT: 2.9±9.9%, p=.413 vs. WB-EMS 7.8±10.6%, p=.010). In parallel, relative protein-intake (g/kg/d) increased in the HIT (8.3±21.6%, p=.349) and WB-EMS group (11.0±17.5%, p=.030) similarly (p=.685), resulting in a protein uptake of 1.10±0.22 (HIT) and 1.20±0.27 g/kg body-weight (WB-EMS group) respectively (p=.247).

4. DISCUSSION

The primary finding of the study was that both interventions, HIT (“single-set-to-failure”) and WB-EMS were equally effective for significantly improving the MetS-Z-Score and abdominal body fat in untrained middle-aged males. However only slight, non-significant positive effects were determined for total Cholesterol/HDL-C rate, a parameter still considered as one of the most meaningful predictors of future cardiovascular events (Ridker *et al.*, 2005). Based on our previous findings (Kemmler *et al.*, 2010; Kemmler *et al.*, 2014) we hypothesized that HIT exercise was significantly more effective for combatting cardio-metabolic risk factors compared with WB-EMS, which was obviously not the case. With respect to time-effectiveness and feasibility both training methods were attractive, which was demonstrated by net exercise times around 30 min or less (WB-EMS), low dropout (Pahmeier, 1994) and high attendance rates (Peterson *et al.*, 2010). With one slight exception, we did not detect any changes in confounding parameters that may have limited the evidence of our finding. Most important, physical activity, diseases and medical treatment remained stable during the study period. Although energy intake rose by 3% (HIT) and 8% (WB-EMS) with a largely parallel development of macro-nutritional intake, these factors should not contribute to the improvement of central obesity or MetS-Z-Score. Thus, we conclude that HIT and WB-EMS were comparably effective and feasible methods to favorably address cardio-metabolic risk factors in untrained middle-aged males. This finding was not supported by a recent study of Bateman *et al.* (2011) which did not report

any positive RT-induced changes of the MetS-Z-Score (ATP-III definition (Expert-Panel, 2001) or its components in overweight dyslipidemic subjects 18-70 years old. However, apart from the chosen cohort, the progressive RT protocol of the authors considerably vary from the present HIT-program with respect to relative intensity, (no requirement to train to MMF), duration (8 months), volume (3 days/week, 3 sets/exercise, 11 exercises/session) and variation / periodization (consistently 8-12 reps/session over 8 months).

Looking behind the covariates of the MetS, MAP and waist circumference demonstrated the most pronounced reductions, with the latter result confirming our finding of significantly reduced abdominal fat as determined by DXA. While the positive effect of RT on blood pressure is generally accepted (Kelley and Kelley, 2000; Cornelissen and Fagard, 2005; Cornelissen and Smart, 2013) most researchers apply moderate intensity resistance exercise protocols. However, a recent meta analysis demonstrated similar effects of low, moderate or high ($\geq 70\%$ 1RM) intensity exercise programs on systolic and diastolic blood pressure (Cornelissen and Smart, 2013). Although there is some evidence that RT positively effects visceral obesity (Strasser *et al.*, 2012) it could not necessarily be expected that both programs reduce abdominal body fat, at least considering the low exercise volume and short duration of the intervention. Using indirect calorimetry we recently determined a rather low total energy expenditure (EE) of (140 ± 19 kcal) for a comparable 20 min WB-EMS protocol (Kemmler *et al.*, 2012). However, the high muscular tension of HIT-RT and particularly WB-EMS with its preferential activation of glycolytic type II fibers (Bossert *et al.*, 2006) required fast extra-mitochondrial energy production that prevents the valid assessment of EE by real-time methods such as indirect calorimetry (LaForgia *et al.*, 2006; Robergs *et al.*, 2007; Scott *et al.*, 2009). Robergs *et al.* (2007) used multiple regression analysis to predict the (real) metabolic costs of RT above steady state conditions (Scott *et al.*, 2009) (i.e. 65 and 70% 1RM; compared with $\geq 75\%$ 1RM in the present study) and calculated EEs 2-3 times higher (15.3 and 16.3 kcal/min⁻¹) than determined by indirect calorimetry. Additionally excessive post-exercise energy consumption (EPOC) is primarily related to exercise intensity (LaForgia *et al.*, 2006) thus the pronounced loading during HIT-RT and WB-EMS should result in very distinct raises of EPOC and correspondingly high post-exercise EE. Finally the significant raise of muscle mass generated by both programs (Lean Body Mass HIT: $1.25 \pm 1.44\%$, WB-EMS: $0.93 \pm 1.15\%$) (Kemmler *et al.*, 2015) also contribute to an increased EE (Stiegler and Cunliffe, 2006; Strasser *et al.*, 2012) although the relevance of this mechanism may be limited due to the short study duration. With one exception, (resting glucose in the WB-EMS group) blood parameters did not show significant favorable effects after the HIT- or WB-EMS intervention. With respect to HIT-RT, a largely identical 20-week "single set to failure protocol" (Kemmler *et al.*, 2014) in general created positive effects on HDL-C, LDL-C and triglycerides, although significance was reached for triglycerides only. On the other hand, a recent study with elderly males with MetS confirmed our finding of missing positive effects on lipids and lipoproteins after 20 min of WB-EMS application (Kemmler *et al.*, 2010).

In order to properly gauge the relevance, evidence and generalizability of our results, some particular features and limitations of the study must be addressed. (1) Our choice to use the MetS-Z-Score as the primary study endpoint offers strengths and limitations. Most critically, only a few exercise studies addressed this endpoint, thus preventing a sophisticated discussion of our study results. Compared with other cardio-metabolic indices (i.e. 10-year CHD risk-score (Wilson *et al.*, 1998) PROCAM (Assmann *et al.*, 2002) the MetS-Z-Score exclusively focused on modifiable risk factors and was thus more eligible for our interventional research question. (2) Furthermore, some statistical limitations may reduce the evidence generated by the study. Firstly, drawing lots may not be the most sophisticated randomization strategy. However, in the past (Kemmler *et al.*, 2011; Kemmler *et al.*, 2014) our approach of transferring the randomization process to the participants led to high participant adherence. This time, however, two subjects immediately quit the study after "they had allocated themselves" to the obviously undesired study arm, although initially all the subjects agreed to accept the decision by lots. Consequently, we slightly failed to reach our calculated sample size of ≈ 25 subjects/group; however due to the lower than expected dropout rate, the statistical power of the study ought to be sufficient to detect relevant effects. Finally, related to a lack of

corresponding literature, we are unable to generate a directional hypothesis, which was also a minor methodological limitation of the study. (3) We focused on a homogeneous cohort of untrained middle-aged males assuming that both WB-EMS and HIT-RT may be equally attractive and feasible for this cohort. We feel that the results would transferable to corresponding female cohorts, however from a pragmatic point of view a comparison of HIT and WB-EMS in female cohorts was of lesser relevance due to the muted enthusiasm for MMF-HIT-RF protocols in female cohorts. Nonetheless, the relevance of WB-EMS application may be particularly high for female cohorts.

5. CONCLUSION

In summary, WB-EMS and HIT-RT are equally attractive, feasible and time-efficient methods for tackling cardio-metabolic risk factors in untrained middle-aged males. Since this finding can be applied to muscle mass and strength (Kemmler *et al.*, 2015) WB-EMS can be considered as an effective but pricey option particularly for subjects with low time resources and who unwilling or unable to conduct exhausting HIT protocols.

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