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Influence of WB-EMS on strength endurance parameters and subjectively perceived back pain: A multicentre study

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ABSTRACT

Whole-body electromyostimulation (WB-EMS) has become a time-efficient train-ing method with positive effects on maximum strength, back pain and strength endurance of the lower extremities. Therefore, the aim of the present study was to analyze the influence of a WB-EMS intervention on strength endurance parameters and subjectively perceived back pain in a multicentric implementation. 148 participants (35.2 ± 12.5years, 173.3 ± 9.4cm, 76.6 ± 15.9kg, BMI 25.4 ± 4.6) were divided into an intervention group with a 6-week WB-EMS in-tervention (EMS, n = 81) and an inactive control group (CON, n = 67). Primary outcome measure was strength endurance of the trunk, secondary outcome measures were subjectively perceived back pain and strength endurance of the plan. A two-way analysis of variance (ANOVA) with repeated measures (2 groups x 2 times) was applied for all var-iables. Statistical analysis revealed a significant main effect of time ($p < .001$, $\eta p^2 = .490$) and time x group ($p < .001$, $\eta p^2 = .614$). Furthermore, significant time effects were detected for VAS24 ($p < .001$), VAS7 ($p < .001$), lateral flexion of the right side ($p < .001$), left side ($p < .001$), trunk flexion ($p < .001$), -extension ($p < .001$) and plank position ($p < .001$) with significant group differences. WB-EMS leads to significant changes in parameters of strength endurance and subjectively perceived backpain after a 6-week intervention in commercial WB-EMS facilities.

Keywords: Performance analysis, Whole-body electromyostimulation, Electrical muscle stimulation, Performance diagnostics, Back pain, Strength training, Sports health.

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INTRODUCTION

Whole-body electromyostimulation (WB-EMS) has established itself over the last few decades in various settings and for different target groups as a new and time-efficient training method that can be used both commercially as well as in a therapeutic setting as medical WB-EMS (Berger et al., 2022; Kemmler et al., 2024). Electrodes attached to the skin provide an impulse to the muscles underneath, stimulating them to contract involuntarily. In contrast to local EMS, which is primarily known from therapy and rehabilitation of injuries, WB-EMS is applied via at least six current channels with the involvement of all large muscle groups and a training-effective stimulus that induces adaptations (Kemmler et al., 2020). All main muscle groups, including the deeper muscles, can be stimulated to their individual maximum with an electrode area of up to 2.8 m^2. This results in a shorter training time of approximately 20 minutes and a lower training frequency with a simultaneous intensive training impulse. This makes WB-EMS training interesting for commercial use with patients and recreational athletes as well as in a competitive sports context (Stengel et al., 2015). In addition to this stimulation, active movements can be carried out, which according to the training level of the trainee can be individually adapted to their physical constitution (Kemmler et al., 2018). However, it is also possible to perform WB-EMS in a static or lying position, which extends the range of applications and for example has even had a positive effect on gait speed and the sarcopenia Z-score of older women who partly performed the training in a lying position (Kemmler, Teschler, et al., 2016). One of the main advantages of this involuntary stimulation of the muscles is the low joint load, as weights do not have to be moved via one or more muscle-joint systems to create a training stimulus, as is the case with conventional resistance training.

Previous research has extensively explored the benefits of WB-EMS across various populations, including athletes, recreational exercisers, and clinical populations as well as different age groups. Studies have demonstrated improvements in muscle strength, functional performance, and pain reduction, highlighting the versatility and effectiveness of WB-EMS as a training method (Filipovic et al., 2016; Kemmler et al., 2017; Ludwig et al., 2020; Weissenfels et al., 2019). One of the most frequently investigated parameters is the influence of WB-EMS on maximum strength of different muscle groups. In a study with adult footballers, significant improvements of 8.5% in leg flexors and 15.1% in the leg press were observed after seven weeks of WB-EMS training (Filipovic et al., 2019). After a 10-week WB-EMS training intervention, increases in the maximum strength of the knee flexors (20.68 ± 21.55 %), knee extensors (31.43 ± 37.02%), hip adductors (21.70 ± 12.86%) and trunk flexors (33.72 ± 27.43%) were measured in adolescent soccer players, leading, according to the authors, to both injury prevention and improved performance in the sport performed (Ludwig et al., 2020). Independently of the athletic subject characterization, significant improvements in the maximum strength of trunk flexion and extension could also be measured in untrained subjects through a 10-week WB-EMS training course 1.5 times a week, furthermore a significant increase in jump height measured by the Counter Movement Jump and Squat Jump was observed (Berger, Ludwig, Becker, Backfisch, et al., 2020). A study by von Stengel and Kemmler (2018) confirmed the general effectiveness of WB-EMS to increase the maximum hip and leg strength during the adult lifespan, which is in line with the results of Berger et al. (2023) who conducted a WB-EMS training intervention over a 6-month period with people aged between 20 and 80 years. In this study, all age decades were able to improve the maximum strength capabilities of the muscle groups tested, whereby the older decades benefiting the most from the intervention (Berger et al., 2023). The general influence of WB-EMS on maximum strength in non-athletic cohorts was also confirmed by a review of Kemmler et al. (Kemmler et al., 2021). Furthermore, patients with different clinical patterns such as sarcopenia, metabolic syndrome, diabetes, Parkinson's disease or cancer can benefit from the WB-EMS application with regard to different parameters, which emphasizes the universal application possibilities for different groups of people, gender and ages (Berger et al., 2023; Di Cagno et al., 2023; Houdijk et al., 2022; Kemmler et al., 2014; Kemmler, Kohl, & S, 2016; Schink et al., 2018). However, most if not all studies addressed outcomes of WB-EMS in a scientific framework, that might overestimate the effect of commercially applied WB-EMS due to higher adherence and compliance in scientific settings. Additionally, these studies often involve controlled environments and specific protocols that may not be replicated in everyday fitness centres. Consequently, the real-world effectiveness of WB-EMS could be lower than what is reported in research, highlighting the need for further investigation in typical user settings.

The main parameters investigated in previous studies were the maximum strength of different muscle groups (e.g. trunk, lower extremities) or the influence of a WB-EMS intervention on non-specific back pain (Kemmler et al., 2021; Kemmler et al., 2018; Pano-Rodriguez et al., 2019). The reduction of back pain through WB-EMS is also one of the most frequently cited goals in commercial applications, however, specific diagnostics are rarely used and primarily implemented in scientific studies. In addition, aspects such as mobility diagnostics and strength endurance tests were only partially and primarily considered for the lower extremities (e.g. chair rise test) in older groups of people, although more comprehensive diagnostics (e.g. of the trunk) would be of great interest to a wide range of WB-EMS users of different ages (Fehr, 2011; Kemmler et al., 2021; Pano-Rodriguez et al., 2019). Different reviews have already summarized the effects of WB-EMS training, but despite many publications on fitness and health-orientated WB-EMS, the overall study situation does not yet appear to be sufficiently clear with regard to the parameters mentioned (Kemmler et al., 2021; Kemmler et al., 2018; Pano-Rodriguez et al., 2019; Teschler & Mooren, 2019). However, there are almost no results available that have been recorded in a multi-centre setting in the commercial sector and therefore enable direct transferability to the people training in the daily use of WB-EMS.

Therefore, the aim of the present study was to examine the influence of a WB-EMS intervention on strength endurance parameters and subjectively perceived back pain. It is hypothesized that 6-weeks of WB-EMS intervention in a commercial setting generate significant effects (a) on strength endurance of the trunk as measured by the Mc Gill strength test (primary outcome), (b) subjectively perceived back pain and (c) strength endurance as determined by the Plank Test, compared with a non-training control group.

MATERIAL AND METHODS

Participants and study design

The study was conducted using a non-randomized, parallel-group, multicentre study with a total of 159 participants included at study start. The lack of randomization is due to the multi-centre data collection in five different WB-EMS training centres, in which the individuals had to be assigned to the respective groups based on the time of implementation and further individual reasons. The WB-EMS group (WB-EMS) received a 6-week WB-EMS training, the control group (CON) was instructed not to engage in any exercise during the period. Strength endurance parameters and subjectively perceived back pain were measured in the week before and after the 6-week intervention. Therefore, the absolute duration of the study was 8 weeks for each participant.

All participants were recruited via e-mail distribution lists, flyers, and personal contact. In addition, online acquisition was expanded with the help of social media to generate the largest and most differentiated sample possible. Eligibility criteria for the study were (1) healthy adult males and females 18-60 years of age, (2) WB-EMS novices, (3) no other fitness training, (4) no competitive athletes and rehab patients (5) no medication that might affect the outcomes (pain medication, beta blockers etc.) and (6) no contraindications according to the current guidelines (Stengel et al., 2024). No specific search was conducted for people with basal back pain. Before the study began, the participants were informed about relative and absolute contraindications, and potential exclusion criteria were analysed. The participants gave their written consent to participate in the intervention. The study was approved by the ethics commission of the German University for Prevention and Health Management (ref. no. 02/17) and was conducted based on the Declaration of Helsinki (World Medical Association, 2013).

WB-EMS intervention

Due to the non-identical availability in the participating facilities, the WB-EMS application was carried out using the WB-EMS devices of miha bodytec (Augsburg, Germany) and XBody (Dorsten, Germany), as these two products are approved as medical devices and therefore guarantee safe and effective WB-EMS. Both systems used the same wired application method, number of electrodes and the identical stimulation parameters. Participants performed a familiarization session before the start of the intervention. This session lasted 12 minutes and involved getting used to the low-intensity electrical impulses in preparation for the upcoming training sessions. The 6-week training included a total of six WB-EMS sessions (one training session per week) which is in line with the guidelines for WB-EMS beginners (Kemmler et al., 2023). If a training session was cancelled due to illness or further reasons, it was caught up in the following week, leading to an extension of the intervention period to ensure the compliance of intended session numbers. All training sessions were personalized with one trainer for a maximum of two trainees, which guaranteed optimal support and direct supervision. The training sessions were carried out at the same time of day to avoid fluctuations in performance. Participants were instructed not to train on a completely empty stomach and to ensure sufficient hydration (at least 500 ml within the last hour) to avoid circulatory problems and a loss of performance. The stimulation parameters were based on common WB-EMS protocols using a frequency of 85 heart, an impulse width of 350 µs, duty cycle 50 % (4 seconds impulse, 4 seconds break), bipolar impulse with an increasing impulse (0.4 seconds impulse increase) and a total duration of 20 minutes (Berger, Ludwig, Becker, Backfisch, et al., 2020; Kemmler et al., 2018). Intensity was controlled by means of a rating of perceived exertion (RPE) scale (0 = no exertion, 10 = maximum exertion), a subjective method for determining the intensity, which in practice represents the most adequate control of the training intensity for WB-EMS. The training was carried out at an intensity of RPE 6-8. The trainees were instructed not to exceed this value; furthermore, constant enquiry and individual regulation of the individual muscle groups ensured an effective training stimulus through constant adjustment of the impulse strength, as this can change both within a training session and over the course of the 6-week training program (Berger et al., 2019; Berger, Becker, et al., 2020). It was ensured that the selected impulse intensity had no negative influence on the economy of movement, that the exercises shown could be performed with the full range of motion (ROM) and thus dynamic WB-EMS training was realized. The catalogue of exercises carried out during the WB-EMS application is shown in table 1. The exercises represented training content typical for WB-EMS and especially focused long sequences of basic exercises to simultaneously stimulate as many muscle groups as possible.

Table 1. Exercises of the WB-EMS intervention.

Exercise	Repetitions
Basic position	6
Squat	12
Dynamic diagonal trunk flexion (left and right)	12 per side
Standing rowing	12
Dynamic overextension	12
Dynamic trunk rotation (left and right)	12 per side
Dynamic lunge (left and right)	12 per side
Dynamic crunches	12
Butterfly reverse	12
Dynamic arm extension	12

Outcomes

The primary outcome of the study was the measurement of the core stability using Mc Gill´s strength endurance test. The original study of McGill et al. (1999) showed good reliability coefficients with 0.97 for trunk flexion, 0.97 for extension and 0.99 for the lateral flexors (McGill et al., 1999). Secondary outcome measures were changes of the back pain determined by the Visual Analogue Scale (VAS) with a reliability of 0.99 (intra-class correlation coefficient (ICC)) and the strength endurance using the Plank test based on Spring et al. (1997), with an ICC of 0.99 (Tong et al., 2014). Before the test diagnostics, the participants performed a standardized warm-up to ensure optimal preparation for the upcoming diagnostics. This standardized warm-up included 15 squats, 30 seconds full body extension, 15 jumping jacks, 30 seconds of skipping, moving the hand towards the shins 5 times in opposite directions (stance wider than shoulder-width) and 30 seconds of heel lifts on the spot. After a 3-minute recovery break, the diagnostic exercises were carried out, except the following Visual Analogue Scale (VAS) which took place at the same time as the contraindication questionnaire due to the written implementation.

McGill Strength Endurance Test

The McGill Strength Endurance Test is a strength test used in the context of preventive and rehabilitative training for the trunk. The test consists of four positions and is carried out statically with isometric muscle tension. The extensors, flexors and lateral flexors of the spine are tested (McGill et al., 1999). Before starting the diagnostics, the test subjects perform a short exercise test lasting a maximum of 5 seconds to familiarise themselves with the position to be assumed and to avoid pre-fatigue. Subsequently, one measurement is carried out for each position to determine the maximum holding time in seconds as a criterion of strength endurance; all positions must be held statically until muscle failure. The end of the diagnostics is determined either by the test subjects themselves leaving the position or determined by the test leader due to incorrect posture of the test subjects during the exercise. Figure 1 shows the Mc Gill test.

The flexors of the spine are diagnosed by assuming a sit-up position with a fixed back, e.g. using a training bench at a 60° angle, with both knee joints and the hip joint fixed in a 90° flexed position. With arms crossed in front of the chest, palms resting on the opposite shoulder and feet fixed by the instructor, the test begins when the back fixation is released (by lowering the training bench or moving the test person forwards on the bench, see Figure 1 a)). This position with the upper body freely tilted back is held isometrically as long as possible, without the back touching the bench. The test is stopped when the trunk deviates either forwards or backwards from the 60° angle.

The spine extensors are tested by positioning the participant on a raised surface (e.g. training bench, Figure 1 b)) in a prone position, with the upper body fully overhanging and forming a straight line with the hips and legs. The arms are crossed in front of the chest with the palms resting on the opposite shoulder. The test leader secures the participant's feet. This position is held isometrically as long as possible. The test is stopped if the test subject can no longer maintain the horizontal upper body fixation or if the upper body drops below the level of the horizontal.

When testing the lateral flexors of the spine, the participant assumes a lateral support position on the forearm with the knee joints extended and the upper foot placed in front of the lower foot for better stabilisation (Figure 1 c)). The upper body, pelvis and lower body form a line and the arm not involved is placed at the side of the torso. This position is held isometrically until muscle failure; the time stops when the hip is lowered or placed on the floor. The diagnostic test is performed on both sides.

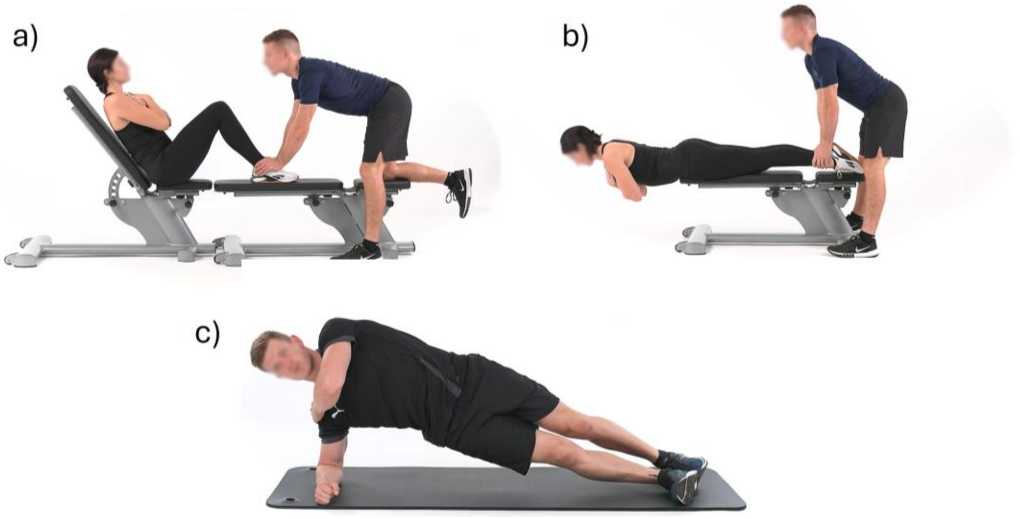

Figure 1. McGill strength endurance test.

Visual Analogue Scale
The Visual Analogue Scale (VAS) was used to determine the intensity of subjectively perceived back pain over the last 24 hours (VAS 24) or over the last 7 days (VAS 7) with the help of personal visual assessment. Like VAS 24, VAS 7 was recorded at the time of diagnosis and not over a 7-day period in the form of a pain diary. The pain intensity of the back pain is assessed using a 10 cm long and unscaled line, whereby the beginning of the line (0) means no pain and the end of the line (10) represents the maximum pain intensity possible. The participants mark their individual pain level on the line. The measurement is subsequently taken from the beginning of the line to the mark (in millimetres). This results in values for back pain in the last 24 hours (VAS 24) and 7 days (VAS 7) from 0 to 100 (Oesch, 2017).

Plank
The plank exercise with alternating leg raises is part of the strength endurance test according to Spring et al. (1997) and is an easy-to-implement test instrument for strength endurance diagnostics that can generally be performed anywhere. The whole body is lifted with a straight back in a supporting position on the forearms (elbows below the shoulder joint, arms parallel) with the trunk muscles tensed. The head forms the extension of the spine and care must be taken to ensure that the subject does not fall into a hollow back position. From this position, the feet are lifted alternately by one shoe length in a one-second rhythm through unilaterally extending the hip with straight knees while the time is measured until the test is stopped. The test ends when the participant can no longer maintain the specified rhythm or leaves the plank position due to a hollow back posture or lowering of the hips (Spring et al., 1997). Figure 2 shows the plank assessment.

Figure 2. Plank Test.

Statistics

All statistical analyses were conducted using SPSS Statistics for Windows (IBM, Version 28, Chicago, IL, USA) setting level of significance at $p < .05$ (two tailed). All data are presented as means ± standard deviation (SD). For a better understanding of the development of the parameters measured before and after the training intervention, the delta values (absolute and relative) were determined (POST - PRE).

A two-way analysis of variance (ANOVA) with repeated measures (2 groups x 2 times) and adjustment for multiple testing was applied for all variables. Since ANOVA is known to be robust against infringements of the normal distribution and all variances were homogeneous (Levene test) it was applied for all parameters to compare the two groups (Blanca et al., 2017; Finch, 2005). Effect sizes were calculated by partial eta squared values (ηp^2). The limits for the size of the effect are .01 (small effect), .06 (medium effect) and .14 (large effect) (Cohen, 1988; Field, 2009).

RESULTS

Due to health complications and other personal reasons (not related to WB-EMS), eleven people did not complete the intervention, resulting in 81 male and 67 female participants (n = 148) being included in the study. Participants' characteristics are shown in Table 2.

Table 2. Descriptive data of participants.

Outcome parameter	**Total**	**CON**	**WB-EMS**
	n = 148 (m = 81; w = 67)	n = 67 (m = 41; w = 26)	n = 81 (m = 40; w = 41)
Age [years]	34.9 ± 13.6	34.4 ± 14.9	35.2 ± 12.5
Height [cm]	174.3 ± 9.3	175.5 ± 9.1	173.3 ± 9.4
Bodyweight pre [kg]	78.3 ± 15.3	80.1 ± 14.3	76.6 ± 15.9
Bodyweight post [kg]	78.2 ± 15.3	80.4 ± 14.4	76.5 ± 15.8
BMI pre [Index]	25.7 ± 4.4	25.9 ± 4.3	25.4 ± 4.6
BMI post [Index]	25.6 ± 4.4	26.1 ± 4.2	25.3 ± 4.5

Table 3. Descriptive data of participants.

Outcome parameter	**Group**	**Pre**	**Post**	**Delta**	**% Delta**	**Time x Group**
				Post – Pre	Post – Pre	
VAS 24 [mm]	CON	21.6 ± 25.4	24.6 ± 26.6	2.9 ± 11.5	2.9 ± 11.5 a)	*p*<.001; ηp^2=.220
	EMS	22.5 ± 22.8	11.2 ± 16.6	-11.3 ± 14.9	-11.3 ± 14.9 a)	
VAS 7 [mm]	CON	26.3 ± 24.9	26.1 ± 26.4	-0.2 ± 15.9	-0.2 ± 15.9 a)	*p*<.001; ηp^2=.088
	EMS	25.3 ± 23.7	13.7 ± 19.3	-11.6 ± 20.4	-11.6 ± 20.4 a)	
Lateral right [s]	CON	57.8 ± 22.9	56.3 ± 22.9	-1.5 ± 5.1	-1.5 ± 13.3 %	p<.001; ηp^2=.235
	EMS	55.0 ± 24.4	66.3 ± 26.6	11.3 ± 14.9	27.6 ± 34.8 %	
Lateral left [s]	CON	55.9 ± 23.4	54.8 ± 23.7	-1.2 ± 4.9	-1.3 ± 19.0 %	*p*<.001; ηp^2=.288
	EMS	55.8 ± 25.4	66.6 ± 28.5	10.7 ± 11.8	24.8 ± 30.4 %	
Trunk flexion [s]	CON	84.1 ± 38.0	83.5 ± 40.6	-0.6 ± 17.5	-0.5 ± 19.3 %	*p*<.001; ηp^2=.145
	EMS	84.0 ± 51.5	111.3 ± 74.9	26.8 ± 43.1	40.1 ± 47.2 %	
Trunk extension [s]	CON	89.9 ± 52.6	88.9 ± 51.1	-1.1 ± 11.1	0.5 ± 18.4 %	*p*<.001; ηp^2=.275
	EMS	97.1 ± 55.3	119.6 ± 57.3	22.3 ± 23.9	32.0 ± 35.9	
Plank [s]	CON	55.7 ± 26.4	54.9 ± 26.8	-0.8 ± 6.2	-0.2 ± 17.7 %	*p*<.001; ηp^2=.358
	EMS	52.8 ± 25.3	67.8 ± 28.8	14.9 ± 13.1	38.9 ± 46.1 %	

*Note. * CON = Control group, INT = intervention group, VAS = Visual analogue scale, a) percentage points.*

The descriptive values of the parameters at PRE and POST as well as the difference between the times of measurements are illustrated in Table 3. The baseline data did not differ significantly at PRE between the groups.

Statistical analysis revealed a significant main effect of time ($p < .001$, $\eta p^2 = .490$) and time x group effect for all outcomes addressed in the present study ($p < .001$, $\eta p^2 = .614$). Furthermore, significant time effects were detected for VAS 24 ($p < .001$, $\eta p^2 = .087$), VAS 7 ($p < .001$, $\eta p^2 = .092$), lateral flexion of the right side ($p < .001$, $\eta p^2 = .151$), lateral flexion of the left side ($p < .001$, $\eta p^2 = .207$), trunk flexion ($p < .001$, $\eta p^2 = .135$), trunk extension ($p < .001$, $\eta p^2 = .239$) and the plank position ($p < .001$, $\eta p^2 = .311$). The interaction time x group of parameters is shown in Table 3. The intervention group showed significant changes in the strength parameters and a reduction in pain intensity, whereas no significant change could be determined for the control group based on the descriptive values.

DISCUSSION

WB-EMS has proven to be an effective and efficient training method with broad applicability, ranging from competitive sports to therapeutic contexts with different groups of people (Kemmler et al., 2022). Despite the extensive studies on the effects of WB-EMS on maximum strength, the findings on strength endurance are still limited. However, strength endurance is an important indicator of muscle health and function in middle-aged and older adults and could therefore be an effective and easy-to-measure parameter in the application of health diagnostics in a commercial setting (Wang et al., 2023). Although strength endurance capacity appears to be directly related to maximum strength and can therefore be positively influenced by an increase in the latter (Naclerio et al., 2009), the extent to which it can be influenced by WB-EMS is not yet sufficiently known. The McGill Strength Endurance Test conducted in this study provides information on the improvements in strength endurance of the extensor, flexor and lateral flexor muscles of the spine following WB-EMS interventions. Significant improvements in strength endurance were observed, which was demonstrated by longer holding times for the exercises (see Table 3).

Previous studies found similar changes in strength endurance performance as a result of conventional strength training. A twice-weekly bodyweight training exercise protocol led to an improvement in the McGill test after a 6-week intervention period, although the changes in the lateral flexors remained clearly behind the changes observed in this study. Furthermore, with a training duration of approximately 25 minutes and a total of 12 training sessions during the intervention period, a clearly higher time investment was required for comparable results, which illustrates the efficiency of the WB-EMS (Schilling et al., 2013). In a study by Saki and colleagues, 8 weeks of core training 3 times a week with athletes (rehabilitation programme after reconstruction of the anterior cruciate ligament) resulted in a significant improvement in trunk strength measured by the McGill strength test. Improvements of 42% in trunk flexion, 60% in trunk extension, 62% in right-sided lateral flexors and 58% in left-sided lateral flexors were measured, which clearly exceeds the results presented in this study (Saki et al., 2023). However, it should be noted that with a training duration of approximately 25 minutes and an absolute number of 24 training units, the effort involved was significantly higher and therefore a complete comparison would only be possible if future WB-EMS studies examined a longer intervention period.

The existing research on the effects of WB-EMS on strength endurance performance of the trunk is limited, although isolated studies have examined local neuromuscular electrical stimulation (NMES) in this context in the past, which allows at least a rough comparison with the results presented in this study. Local stimulation of the abdominal muscles (20-40 minutes 5 times a week over an 8-week period) led to a 100% increase in abdominal strength endurance measured with the ACSM curl-up test in healthy subjects, while the maximum strength of trunk flexion was also increased by 58%. Despite the different stimulation protocol and a significantly higher time expenditure, this study provides a first insight into the positive effects of involuntary electrical stimulation of the trunk muscles on strength endurance performance (Porcari et al., 2005). In a study by Dimer da Luz et al. (2019), 4 weeks of trunk muscle training three times a week (static exercises, total duration approximately 25 minutes) with combined NMES (gluteus maximus, gluteus medius, rectus abdominis and bilateral transverse abdominis) resulted in a significant improvement in the holding time of the static trunk endurance test as well as both sides of the side bridge test. The combined training method was the most effective compared to the parallel training groups that performed training without NMES or isolated NMES training, which illustrates the effective application of EMS superimposed on an existing exercise catalogue. To the authors' knowledge, only one study by Shalamzari et al. (2023) has investigated the effects of WB-EMS on strength endurance performance. In this study, a significant improvement in the holding time in the McGill test was observed after 6 weeks of training twice a week, although the exact holding time in seconds could not be taken from the study for better comparability. Almost identical stimulation parameters were used (apart from the stimulation duration of 6 seconds instead of 4 seconds) and the exercises performed were similar to those in the present study in terms of scope and type of selection, as they were easy to implement, slightly dynamic exercises that are often used in a commercial context (Shalamzari et al., 2023). In the present study, significant improvements in the holding time of all exercises of the McGill test and the plank were observed, confirming the positive influence of a WB-EMS intervention on strength endurance.

By strengthening the core muscles, WB-EMS not only promotes the stability and posture of the spine, but also reduces the risk of back injuries and musculoskeletal complaints (Kemmler et al., 2018). Strong back muscles play an essential role in supporting the spine, maintaining correct alignment, and facilitating movement during daily activities such as lifting, bending, and twisting. People with well-trained back muscles are able to withstand the demands of daily life more effectively and reduce the likelihood of strain or injury during routine tasks (Ludwig et al., 2019; Ludwig et al., 2018). In addition, improved strength endurance of the back muscles increases overall functional capacity, which contributes to improved performance at work, in leisure time and during sport. Therefore, the targeted effects of WB-EMS on specific parts of the back muscles provide added value in promoting spinal health, relieving back pain and improving overall physical function (Weissenfels et al., 2018; Weissenfels et al., 2019). These findings can be of particular importance for older people, as WB-EMS not only has a positive effect on maximum strength, increasing this can also have a positive impact on fall prevention, early sensory processing and cognitive abilities (Ozkaya et al., 2005), which contributes positively to coping with everyday life. Despite the improved strength endurance capacity because of the WB-EMS intervention in this study, a reduction in subjectively perceived back pain of 11.3 ± 14.9 in the last 24 hours and 11.6 ± 20.4 in the last 7 days (indicated in millimetres on the VAS scale) was measured, which equates a reduction of approx. 50% of the previous back pain (see Table 3).

The reduction of back pain through WB-EMS has been demonstrated in previous studies. In a study by Weissenfels et al. (2019), a 12-week WB-EMS intervention reduced pain intensity and increased core strength in a cohort aged between 40-70 years with chronic non-specific back pain (LBP) (Weissenfels et al., 2019). Another individual case study was able to identify a reduction in VAS in a young road cyclist after an 8-week WB-EMS intervention, which supports its applicability in a competitive sports context as well as in young athletes and can also be used both for muscular development and the treatment of back pain (Berger, Ludwig, Becker, Kemmler, & Fröhlich, 2020). In summary, it can be said that WB-EMS has a positive influence on the reduction of back pain. Furthermore, the VAS seems to be an easy-to-implement measure in different individuals as well as in the commercial EMS context and can be used in all facilities, which confirms the multicentre application in the present study.

Compared to conventional strength training, WB-EMS offers significant advantages in improving physical performance, depending on the user. WB-EMS stimulates all large muscle groups simultaneously up to the individual maximum. By stimulating the motor units of the nerve fibres and thus both the superficial and the deeper muscle fibres, WB-EMS enables comprehensive muscular adaptation and improves strength endurance as well as other parameters of physical performance and reduces subjectively perceived back pain. In contrast, conventional strength training usually targets specific muscle groups per exercise and therefore requires separate exercises to train the whole body (e.g. in the form of circuit training), which demands more time and voluntary effort. As an example, a 10-week WB-EMS programme led to significantly higher performance improvements in elite male youth football players compared to an athletic training of the same duration, which also underlines the effectiveness of WB-EMS in an athletic context (Ludwig et al., 2020). Furthermore, WB-EMS minimizes stress on the joints compared to conventional strength training and is therefore particularly suitable for people with joint problems and for rehabilitation after musculoskeletal injuries, as no weights must be moved through several muscle-joint systems to stimulate the muscles. The low load of WB-EMS reduces the risk of injury and enables safe and effective training, even for older people or people with musculoskeletal limitations (Kemmler et al., 2022).

The results of the study presented here highlight the practical benefits of WB-EMS in increasing strength endurance and relieving back pain, which is of particular interest to populations for whom traditional training methods may be difficult or contraindicated. In addition, the study design with a non-randomized, parallel group, multicentre approach increases the external validity of the study by capturing a diverse sample that reflects real-world WB-EMS users.

However, several limitations warrant consideration. The lack of randomization may introduce bias, although efforts were made to mitigate this through multicentre recruitment and standardized protocols. Additionally, the study's short duration limits the assessment of long-term effects and sustainability of outcomes beyond the intervention period. Furthermore, the physical activity was not recorded apart from the training, which could also have an influence on the results. The recruited subjects did not all suffer uniformly from back pain, so the potential for positive changes in the VAS was limited. The use of different WB-EMS devices could also have an influence on the outcomes. Even if this is rather unlikely due to the identical device specifications and training carried out with identical stimulation parameters, which therefore results in an identical influence on the organism, future studies should use the same devices for all subjects. Furthermore, future research should explore the mechanisms underlying the observed improvements in strength and pain reduction following WB-EMS interventions. Longitudinal studies and diverse populations could elucidate the optimal dosage and duration of WB-EMS for maximizing benefits. Moreover, comparative studies evaluating WB-EMS against conventional exercise modalities would provide valuable insights into its relative efficacy and clinical relevance.

CONCLUSIONS

In conclusion, this study adds to the growing body of evidence supporting the effectiveness of WB-EMS as a time-saving and versatile training method. By improving strength endurance and reducing back pain, WB-EMS holds promise for improving physical function and well-being in various populations. The present study also demonstrates simple diagnostic tools that can be used to replicate the results in a commercial context for everyday use, allowing easy visualization of performance development for exercisers.

AUTHOR CONTRIBUTIONS

Conceptualization, J.B. and C.E.; methodology, J.B. and P.B.; software, J.B.; validation, C.E., W.K. and M.F.; formal analysis, C.E., W.K. and M.F.; investigation, J.B. and P.B.; resources, C.E.; data curation, J.B. and P.B.; writing—original draft preparation, J.B.; writing—review and editing, P.B., C.E., W.K. and M.F.; visualization, P.B.; supervision, C.E.; project administration, J.B. All authors have read and agreed to the published version of the manuscript.

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No potential conflict of interest was reported by the authors.

INSTITUTIONAL REVIEW BOARD STATEMENT

The study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of the German University for Prevention and Health Management (02/17, 11.09.2017).

INFORMED CONSENT STATEMENT

Informed consent was obtained from all subjects involved in the study.

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The experiments comply with the current laws of the country in which they were performed.

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