Püschel M[1], Kohl M[2], von Stengel S[1], Shojaa M[3], Filipovic A[4], Kemmler W[1]

Effects of Longitudinal Whole-Body Electromyostimulation on Muscular Power and Endurance Parameters in Sportspeople and Athletes

Effekte von Ganzkörper-Elektromostimulation auf die Entwicklung von Schnellkraft und Ausdauergrößen bei Sportlern und Athleten

REVIEW

ACCEPTED: January 2026

Püschel M, Kohl M, von Stengel S, Shojaa M, Filipovic A, Kemmler W. Effects of longitudinal whole-body electromyostimulation on muscular power and endurance parameters in sportspeople and athletes. Dtsch Z Sportmed. 2026; 77: 37-45. doi:10.5960/dzsm.2025.654

1. UNIVERSITY HOSPITAL ERLANGEN,
   Institute of Radiology, Erlangen, Germany
2. UNIVERSITY OF FURTWANGEN,
   Department of Medical and Life Sciences, Schwenningen, Germany
3. UNIVERSITY HOSPITAL TÜBINGEN,
   Institute of Health Science, Department Population-Based Medicine, Tübingen, Germany
4. SPORTSCLUB „VEREIN FÜR BEWEGUNGSSPIELE“ (VFB) STUTTGART,
   Stuttgart, Germany

Summary

- **Due to its time-efficient and joint-friendly character,** whole-body electromyostimulation (WB-EMS) attracts sportspeople and athletes of different disciplines. Nevertheless, whilst some trials reported positive effects of WB-EMS on performance parameters, the study situation is very inconsistent.
- **Thus, the present meta-analysis** aimed to summarize the effect of WB-EMS on maximum muscle power and endurance performance in sportspeople. Five electronic databases (Medline, CINAHL, CENTRAL, Web of Science, SportDiscus) were searched until 03/06/2025 according to the PRISMA scheme. Applying a random-effect model that includes the inverse heterogeneity model, effects sizes (SMD) and 95%-confidence intervals (95%-CI) were calculated. Subgroup-analyses focused on different modes of WB-EMS. The search identified 13 eligible trials with 14 WB-EMS and 13 control groups.
- **In summary,** we observed positive effects of WB-EMS on maximum hip/lower extremity power (13 studies, SMD: 0.48, 95%-CI: 0.04 to 0.91). Subgroup analyses revealed positive effects of superimposed WB-EMS versus underlying voluntary exercise (10 studies, SMD: 0.46, 95%-CI: 0.03 to 0.89). Heterogeneity between the trial results was moderate to substantial in both cases (I^2=58% and I^2=62%). The few WB-EMS trials (n=3) that addressed endurance performance (i.e. V̇O2peak) reported inconclusive and, on average, non-significant results (SMD: 0.32, 95%-CI: -0.19 to 0.84).
- **The present study** provided considerable evidence for a favorable effect of superimposed WB-EMS on maximum power in already well-trained sportspeople and athletes. By contrast, positive evidence for the effects of WB-EMS on endurance performance is lacking, particularly due to the varying research issues of the studies and diverging exercise protocols.

KEY WORDS:
Electrostimulation, Performance, Well-Trained People, Quantitative Analysis, Stystematic Review, Meta-Analysis

Introduction

Whole-body electromyostimulation (WB-EMS) can be considered as a joint friendly, time effective and highly customizable exercise technology - at least in the present commercial setting (22). These features might attract sportspeople and athletes of different disciplines to implement WB-EMS in their training routine. The reasons and aims for adding WB-EMS are diverse. While some athletes look to accelerate regeneration, others apply WB-EMS as a mean of injury prevention (36). However, the vast majority of studies with sportspeople and athletes focus on performance-related parameters (36). Considering that the conventional WB-EMS approach uses a resistance-type approach with low volume and short bouts of intermitted intense stimulation (4, 25), it is understandable that most studies with sportspeople and athletes focus on outcomes related to strength and power, while data on endurance performance on the other hand is rarely reported (36). Nevertheless, the net effect of WB-EMS, be it for power or endurance performance, has yet to be evaluated reliably. This relates in the main to two aspects: Firstly, all the systematic reviews that summarize and quantify the evidence in this area (16, 29) predominately included trials with locally applied EMS. Even more problematic, the majority of studies with sportspeople and athletes applied superimposed WB-EMS programs (36). Considering this combination of voluntary exercises superimposed by WB-EMS, it is clear that a considerable part of the effects can be attributed to voluntary exercise. One may argue that control groups that applied the identical voluntary exercise without WB-EMS (e.g. (11, 12) nevertheless might determine the proper WB-EMS effect. We agree. In spite of that, the approach of many studies of adding WB-EMS to high intensity voluntary exercise “as the cherry on the top”(22) requires high statistical power to address the limited, albeit potentially, relevant WB-EMS effects, which is usually not provided by studies involving sportspeople and athletes. A systematic review and meta-analysis that adequately considers the WB-EMS approach and its comparison with different control groups might be helpful to close this evidence gap. In order to address this question in a structured manner, we formulate the following hypotheses:

(a) Maximum power is affected significantly by WB-EMS in comparison to a non-specific control.
(b) Maximum power is affected significantly by superimposed WB-EMS in comparison to a control group that performed the underlying voluntary exercise.

›

CORRESPONDING ADDRESS:
Prof. Dr. Wolfgang Kemmler
University Hospital Erlangen (UKER),
Institute of Radiology
Henkestrasse 91, 91052 Erlangen, Germany
✉: wolfgang.kemmler@fau.de

Table 1

Study and participant characteristics of the studies. NCT=Non randomized controlled trial; RCT: Randomized controlled trial; RCOT=Randomized cross-over trial; [1]=If not specified, BMI was calculated based on body height and body mass (see BMI data without SD).

AUTHOR	PUBLICATION YEAR	STUDY DESIGN	STUDY GROUPS/ CONDITIONS [N]	TOTAL SAMPLE SIZE [N]	GENDER	AGE [YEARS]	BMI (KG/M2)[1]	STATUS	DISCIPLIN	PEDRO-SCORE
Amaro-Gahete et al.	2018	RCT	2	14	m	27±7	23±3	Hobby sportspeople	Runners	4
Dörmann et al.	2019	RCT	2	28	w	21±2	22±2	Advanced sportspeople	Allrounders	4
D'Ottavio et al.	2019	RCT	3	22	m+w	26±3	22±3	Advanced sportspeople	Allrounders	5
Filipovic et al.	2016	RCT	2	22	m	26±3	24±2	Semi-/full-professionals	Soccer players	5
Filipovic et al.	2019	RCT,	3	30	m	23±4	24±2	Semi-/full-professionals	Soccer players	6
Ilbak et al.	2022	RCT	2	20	m	15-20	22	Semi-/full-professionals	Basketball players	4
Jawad et al.	2020	NRCT	2	10	m	ng	ng	Semi-/full-professionals	Soccer players	3
Kacoglu et al.	2021	RCT	2	38	m+w	22±3	22±2	Advanced sportspeople	Allrounders	4
Martín-Simón et al.	2022	RCT	2	20	m+w	19-25	23	Advanced sportspeople	Allrounders	4
Mathes et al.	2017	RCT	2	24	m	23±5	23	Advanced sportspeople	Allrounders	5
Micke et al.	2018	RCT	2	18	m	23±3	22±2	Advanced sportspeople	Allrounders	5
Schuhbeck et al.	2019	RCOT	2	30	m	28±8	24	Advanced sportspeople	Ice-hockey players	5
Wirtz et al.	2015, 2016	RCT	2	20	m	22±2	24	Advanced sportspeople	Allrounders	5
Zhang et al.	2021	RCT	2	10	w	27±4	22	Hobby sportspeople	Resistance exercise	4

(c) Endurance performance is not affected significantly by present WB-EMS programs.

Materials and Methods

Briefly, the present work is based on a comprehensive systematic review and the evidence map of Reinhardt et al. (36). The project followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement and was registered under PROSPERO ID CRD420250646327.

Eligibility Criteria

We applied a two-stage approach. During the first step a comprehensive search according to the PICOS criteria below was conducted (36). Based on this comprehensive systematic review, additional eligibility criteria that emphasize "study outcomes" were applied for the present contribution.

Population: We included professional and semiprofessional "athletes" (3), advanced sportspeople and recreational/hobby sportspeople. Advanced sportspeople included competitive sportspeople and physical education/sport students, while cohorts of studies exercising at least twice weekly during the last 2 years (without competitions) were considered "hobby/recreational sportspeople".

Intervention: Only WB-EMS interventions according to the present definition (23) were included.
Comparators: Studies that compared WB-EMS with one or more active or non-training control group were eligible. In contrast, studies that compared two WB-EMS protocols (e.g. (1, 35)) without another control group were not considered.
Outcomes: The present study included only studies that reported outcomes related to lower extremity muscular power (including jumping) and endurance performance as determined from baseline to immediately post-intervention.
Study design: Longitudinal controlled trials (randomized or not) were included.

Information Sources

In summary, five electronic databases (CINAHL (via Ebsco) Host, CENTRAL, Medline (PubMed), SPORTDiscus (via Ebsco Host), Web of Science (via Clarivate)) were searched for publications from their initiation up to 6th March 2025 without language restrictions.

Literature Search

A standard protocol was developed and a controlled vocabulary (MeSH term for MEDLINE, CINAHL® Subject Headings for CINAHL) was applied. Keywords and their synonyms were used in the following queries: WB-EMS OR "whole body electro myo stimulation" OR electromyostimulation OR "electrical muscle

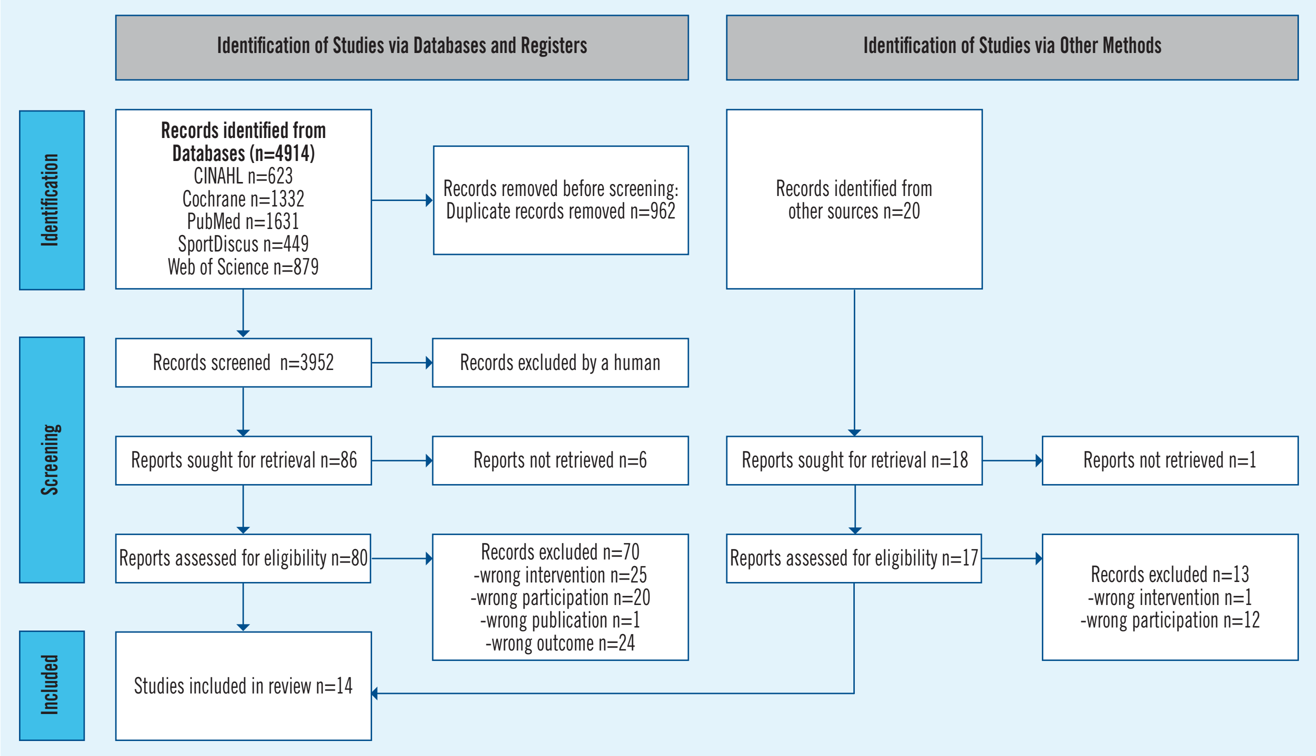

Figure 1

Flow-chart of the present systematic literature search according to PRISMA (32).

stimulation” OR electro-myo-stimulation OR electrostimulation OR “integral electrical stimulation” OR “whole-body electrical muscle stimulation”) AND (athletic OR athlete OR sport OR performance OR trained). Additionally, reference lists of eligible articles were screened (figure 1).

Selection Process

Titles, abstracts and full texts were independently screened against the eligibility criteria (PICOS) by three reviewers (SR, MP, WK). Disagreements were resolved by discussion. In cases of unclear or missing eligibility criteria, the corresponding authors were contacted by email three times in four weeks to provide missing, incomplete or unclear data.

Data Management

Endnote (Clarivate, Philadelphia, US) was used to download search results and to conduct title, abstract and full-text screening. Duplicates were identified and excluded using the approach suggested by Bramer et al. (5) .

Data Extraction

Data from eligible studies were extracted by two reviewers (WK, MP) using a Microsoft Excel table. Disagreements between the reviewers were resolved by discussion.

Risk of Bias in Individual Studies

Using the Physiotherapy Evidence Database (PEDro) Scale Risk of Bias Tool (26) two reviewers (FH and WK) assessed studies for risk of bias. Disagreements were resolved by discussion. Methodological quality of the studies was classified <5 score points: low, 5-7 score points: moderate and >7 score points: high (37).

Data Synthesis

Missing standard deviations (SD) were converted into standard errors (SE) and confidence interval (CI) (6) or (in cases of missing variations of changes) by imputing using the correlations between baseline and final values from the other studies (6). In cases of more than one power outcome, maximum hip/low extremity power as determined by squatting or leg press exercises was preferably included in the analysis. When multiple maximum jumps tests were performed, preferably counter movement jump were included in the analysis (table 3).

Statistical Analysis

Random-effects meta-analyses (34) were calculated applying the robust inverse heterogeneity (IVhet) model (8) as the primary analyses. Continuous outcome data were synthesized using standardized mean differences (SMDs) with 95% confidence intervals (95% CI). Cochran Q test and the I^2 statistic were used to determine heterogeneity between the trials results (I2 0-40% = low, 30-60% = moderate, 50-90% = substantial, 75-100% = considerable heterogeneity (17)). We applied funnel plots with trim and fill analysis (10), regression and rank correlations, Doi plots and the Luis Furuya-Kanamori index (LFK index ±1 to ±2: minor asymmetry; > ±2: major asymmetry) (14) to check asymmetry and corresponding small study/publication bias. The subgroup analyses focused on different scenarios when comparing WB-EMS and control groups.

Results

In summary, the search identified 13 trials (2, 7, 9, 13, 18-20, 27, 28, 30, 38, 42, 43) with 14 WB-EMS (145 participants) and 13 control groups (141 participants) that focused on maximum hip/lower extremity power and which were included and considered for the analysis (figure 1). In parallel only three WB-EMS projects (2, 11, 28, 41) with three WB-EMS (27 participants) and four control groups (36 participants) were found that focused on endurance parameters. Of note, two of the three studies reported power and endurance exercise.

›

Table 2

Exercise characteristics of the included studies ^{1}=Studies with two control groups; DRT=dynamic resistance exercise; nRM=non repetition maximum; reps=repetitions; RPE=rate of perceived exertion; RT= resistance exercise; FU=Follow-up; ng=not given

AUTHOR	STUDY LENGTH [WEEKS]	SUPER-IMPOSED EXERCISE?	COMPARABLE VOLITIONAL EXERCISE IN CONTROL GROUP?	EMS-SESSIONS (N/WEEK X LENGTH [MIN])	EXERCISE/WB-EMS PROTOCOL; IMPULSE FREQUENCY (HZ), -WIDTH (μS), -DURATION (S), -BREAK (S), -INTENSITY (RPE) (ADDITIONALLY TO SPORT-SPECIFIC EXERCISE)	EXERCISE/ACTIVITY IN THE CONTROL GROUP(S) (WITHOUT WB-EMS) (ADDITIONAL TO SPORT-SPECIFIC EXERCISE)	LOSS TO FU (%) / ATTENDANCE (%) / ADVERSE EFFECTS
Amaro-Gahete et al. 2018	6	yes	no	1x12-20	High intensity DRT, power and (interval) running (HIT)superimposed by WB-EMS: Variable, undulated periodized WB-EMS: 12 and 90Hz, 350µs, 4-30s, 4-30s, 10-17 [CR 20]	Regular running routine only (2 sessions/week)	14/96/no
Dörmann et al. 2019	4	yes	yes	2x20	DRT (see control) superimposed by WB-EMS, 85Hz, 350µs, impulse during exercises, RPE ≥16 (CR20)	(1) DRT: 4 ex.., 3x 8-10 reps RPE ≥16, Power: 5 ex., 3x 5-10 reps/3x 8 s	21/100/no
D'Ottavio et al. 2019	6	yes	no	2x20	Ten isometric exercises superimposed by WB-EMS: 350µs, RPE 14-16: (a) 50 Hz, 4s-6s versus (b) 85 Hz, 4s-4s	DRT: 7 exercises, 3x 10 reps 65% 1RM	0/100/no
Filipovic et al. 2016	14	yes	yes	2x9	Squat jumps: 3x 10 reps superimposed by WB-EMS 80Hz, 350 µs, 4s-10s, up to RPE 18-19 (CR20)	Squat jumps: 3x 10	0/100/no
Filipovic et al. 2019	7	yes	yes/no^1	2x9	Squat jumps: 3x 10 reps superimposed by WB-EMS: 80Hz, 350 µs, 4s-10s, RPE 16-19 (CR20)	(1) Squat jumps: 3x 10 reps (2) Regular soccer routine only	4/100/no
Ilbak et al. 2022	12	yes	yes	2x20	Plyometric jumping exercises (8 ex, 3x 10-12 reps) superimposed by WB-EMS: 20 Hz, 350 µs, 10s-10s, 50-80% maximum tolerable intensity	Plyometric jumping exercises (8 ex, 3x 10-12 reps) only	0/100/no
Jawad et al. 2020	8	no	no	3x20	WB-EMS: 85 Hz, 350 µs, continuous impulse , RPE 6-8 (CR10)	Rehabilitation program (19 DRT exercise, 3-4x 10-20 reps) only	ng
Kacoglu et al. 2021	6	yes	yes	2x25	DRT: seated leg press (3x 20 reps) superimposed by WB-EMS: 100 Hz, 400 µs, 5s-10s, RPE 8-9 (CR 10)	DRT: seated leg press (3x 20 reps)	ng
Martín-Simón et al. 2022	6	yes	yes	1x13	3 sessions, 100-140 jumps with 1 session superimposed by WB-EMS: 120 Hz, 350 µs, 5s-10s, max. tolerable intensity	3 sessions, 100-140 jumps only	ng
Mathes et al. 2017	4	yes	yes	3,5x60	Cycling at 60% peak power output, superimposed by WB-EMS: 80 Hz, 400 µs, 10s-2s, maximum tolerable intensity	Cycling at 60% peak power output	13/100/no
Micke et al. 2018	8	yes	yes	2x≈25	DRT: 5 ex, 3x5-10 reps, RPE>16 (CR20) superimposed by WB-EMS: 85 Hz, 350 µs, adjusted to exercises 70% max. intensity	DRT	0/100/no
Schuhbeck et al. 2019	12	yes	no	1x20	6 weeks of static, 6 weeks of dynamic RT exercise supe-imposed by WB-EMS 85 Hz, 350 µs, 4s-4s, ≥75% max Intensity (additionally to normal training)	Static and dynamic resistance exercise	13/100/no
Wirtz et al. 2015/2016	6	yes	yes	2x10	Back half squats, 4x 10 reps to RM, superimposed by WB-EMS, 85 Hz, 350 µs, 5s-1s at 70% max. tolerable intensity	Back squats, 4x 10 reps to RM	0/100/no
Zhang et al. 2021	6	yes	yes	2x20-25	DRT: 4 exercises, 5x to nRM at 85% 1RM superimposed by WB-EMS 85 Hz, 350 µs, EMS during sets, 60-100% device capacity	DRT	17/100/no

Summary of Study and Publication Characteristics

All but one (19) of the WB-EMS trials were randomized controlled studies (table 1). Apart from two studies that implemented either two control (11) or two WB-EMS (7) groups, all the studies compared a single WB-EMS with a single control group.

Summary of Participant Characteristics

Table 1 shows the participant characteristics of the studies. Two studies included hobby sportspeople, eight studies focused on advanced sportspeople (including sport students) and four trials included semi-professional/professional athletes (11). In most cases the cohorts can be considered as "allrounders", five studies focused on sport games, and one each addressed hobby runners and resistance exercisers. All the studies focused on healthy male participants. Participants were on average 20-30 years old and of normal weight (table 1).

Summary of Exercise and WB-EMS Characteristics

Thirteen of 14 studies applied superimposed WB-EMS protocols (table 2), i.e. added WB-EMS to exercise with high voluntary muscle activation. Underlying types of exercise included isometric and dynamic RT, power/ jumping exercises, interval

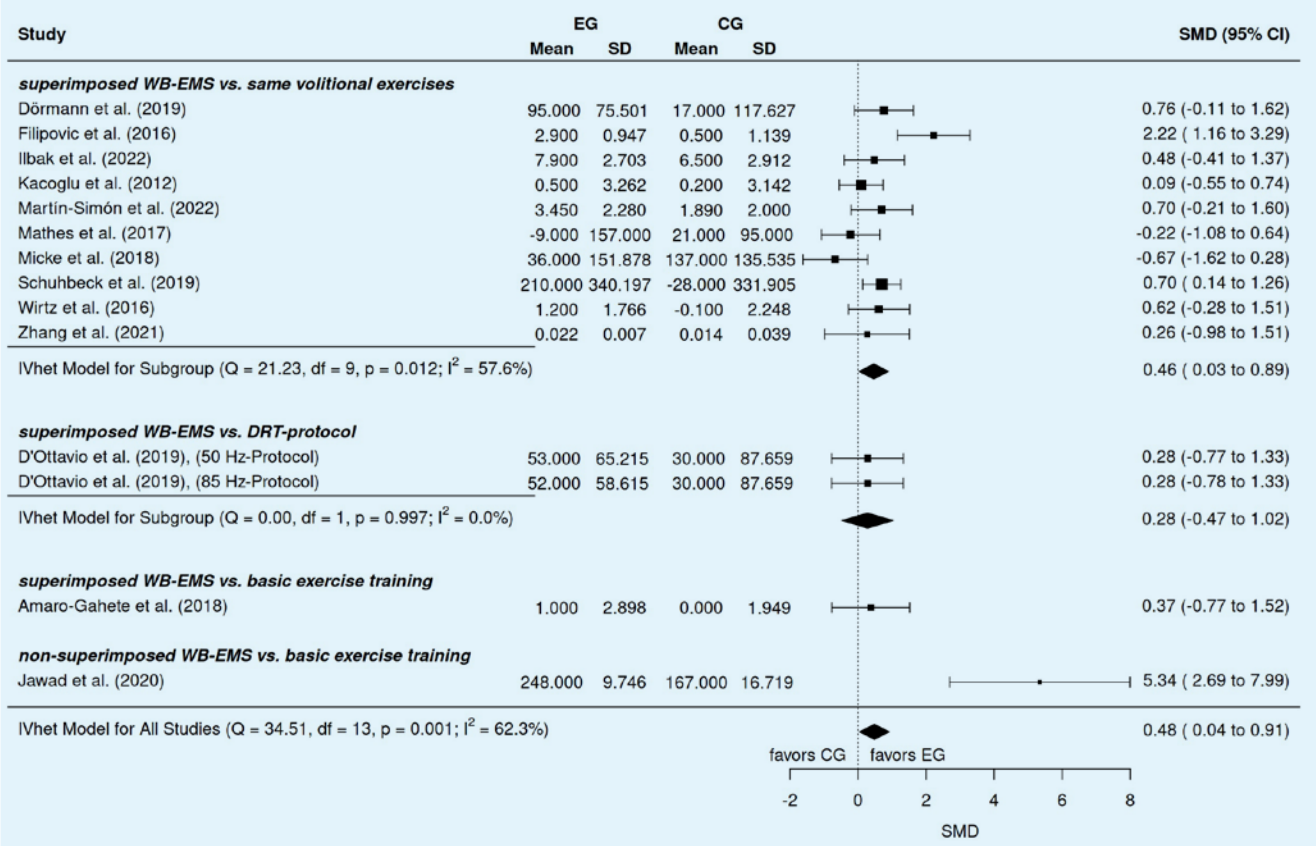

Figure 2

Forest plot of WB-EMS effects on maximum power in sportspeople and athletes. CG=control group; EG=exercise group; SD=standard deviation.

running and cycling (table 2). with 4 to 14 weeks, study duration was mostly short (table 2). Weekly exercise volume in the WB-EMS groups ranged considerably between 1x 12-20 min (2) to 3.5x 60 min/week (28). All the studies applied bipolar low frequency impulse protocols. Impulse breadth was scheduled 350 µs and 400 µs. All but one study (19) applied an intermitted impulse protocol with 4s-30s of impulse and 1s-30s of impulse break. Although not always clear whether only WB-EMS per se or the combined superimposed approach was implied, impulse intensity as scheduled by rate of received exertion range was high to maximum tolerable (table 2).

Outcome Characteristics

Table 3 shows the outcomes addressed by the 14 studies. Briefly, of the 13 studies that reported data on maximum power performance, six reported jumping performance only as jumping height in cm. As stated, we preferably included power as assessed by leg-press and squatting in the analyses. The three studies on endurance performance (2, 12, 41) all applied incremental step tests (ergometer or treadmill) to a voluntary maximum. The one study (28) that considered aerobic and anerobic capacity as the core outcome also determined a 20 min time trial and a 30 s sprint test on a bicycle ergometer. While all the studies reported data on V̇O2peak, other endurance performance parameters of the tests were not consistently reported (2, 11, 41) (table 3).

Methodologic Study Quality

Methodologic quality according to PEDro (26) of the studies ranges between 4 and 6 score-points (table 1). The main reasons for this low-to-moderate result relate to the aspects of "allocation concealment", "blinding of participants" and/or "blinding of therapists", with the latter two being hardly applicable in exercise studies.

Adverse Effects

None of the studies reported adverse effects. Nevertheless high CK values compared to voluntary exercise control were observed in the superimposed WB-EMS studies of Filipovic et al. (13) and Mathes et al. (28), which normalized by the end of the intervention however (22).

Meta-Analysis Results

WB-EMS Effects on Maximum Power

Figure 2 shows the significant effects of WB-EMS compared to control for maximum power performance in sportspeople and athletes (SMD: 0.48; 95%-CI: 0.04 to 0.91). More specifically, the subgroup analysis that focused on the effects of superimposed WB-EMS versus underlying voluntary exercise (upper graph) resulted in similar positive results (10 studies, SMD=0.46; 95%-CI: 0.03 to 0.89). Heterogeneity between study results was moderate (full data set) or substantial (specified analysis). Unfortunately, for the other comparisons only one study each (with 1-2 comparisons) was available. Nevertheless the findings clearly confirmed hypotheses (a) and (b) that expected a superiority of (superimposed) WB-EMS vs. control.

WB-EMS Effects on Endurance Performance

The present analysis focuses on changes in relative V̇O2peak as a strong predictor for endurance performance and the only parameter that was consistently reported by all studies. In summary, the number of studies (or comparisons) was too low to generate a reliable analysis even when ignoring the

›

Table 3

Power-related outcomes reported by the included studies. ABJ=Abalakov Jump Test; CMJ=Counter Movement Jump; DJ=Drop Jump; SJ=Squat Jump.

AUTHOR	OUTCOMES
Amaro-Gahete et al. 2018	CMJ, ABJ (cm) // peak running speed, rel. V̇O2peak, speed/V̇O2 at ventilatory thresholds, running economy
Dörmann et al. 2019	Isometric peak power (Pmax, W) leg press, leg extension, leg curl (leg flexion)
D'Ottavio et al. 2019	Force velocity curves (15, 35, 65, 85% 1 RM, W) for squatting1
Filipovic et al. 2016	SJ, CMJ, DJ (cm)
Filipovic et al. 2019	Running time, rel. V̇O2peak, maximum lactate, maximum heart rate
Ilbak et al. 2022	CMJ (jump and reach, cm)
Jawad et al. 2020	Vertical jump (N)
Kacoglu et al. 2021	SJ, CMJ (cm)
Martín-Simón et al. 2022	Relative Pmax jumping: CMJ (W/kg)
Mathes et al. 2017	SJ, CMJ, DJ (cm) // Cycling: Peak power output, rel. V̇O2peak, anaerobic threshold
Micke et al. 2018	Isometric peak power (Pmax, W) leg press , SJ, CMJ, DJ, SLJ
Schuhbeck et al. 2019	Vertical jump power: CMJ (W)
Wirtz et al. 2015/2016	Relative Pmax leg press (W/kg)
Zhang et al. 2021	SJ, CMJ, ABJ (cm)

WB-EMS approach and corresponding control. Nevertheless, we provided the corresponding results in figure 3 to graphically present the results of the single studies. Briefly, superimposed WB-EMS did result in positive effects independently of whether compared with the underlying voluntary exercise(I^2=0%) or (less expected) with the usual training routine (I^2=69%) without newly added interventions. Thus we accepted our hypothesis (c) of missing effects of WB-EMS on endurance parameters.

Small Study/Publication Bias, Asymmetries

For the analyses of small study/publication bias and asymmetries for maximum power, we used the full data set. In summary, no studies had to be imputed in the funnel plot with trim and fill (figure 4), further regression (p=.15) and rank correlation test (p=.59) did not indicate funnel plot asymmetry. In addition, the LFK index (0.93) revealed no relevant asymmetry. Due to the low numbers of WB-EMS studies that focus on endurance performance, we did not calculate any funnel plot, regression or rank correlation tests or the LFK index.

Discussion

In contrast to WB-EMS application in the fitness and health domain (4, 25), the majority of studies with sportspeople and athletes understood WB-EMS much more as a vehicle for increasing the effect of intense voluntary exercise (36). This concept of superimposed WB-EMS (33) makes the reliable validation of WB-EMS effects by means of systematic reviews and meta-analyses a daunting task – largely independently of the outcome. Considering the large number of potential protocols when combining various types of exercise and exercise/stimulation parameters, no two exercise/WB-EMS protocols are exactly alike – an aspect that frequently leads to an apples-and-oranges problem in meta-analyses (15, 21). Although the studies included in the present analysis all applied a superimposed WB-EMS approach with similar impulse parameters (table 2), large differences exist for the type of exercise to be superimposed (i.e. strength/power/HIIT vs. squat jumps vs. cycling) and weekly training volume (1x 12-15 min vs. 2x 9 min, 3.5x 60 min). These flaws might still be tolerable; however the main limitation of the present meta-analysis is the comparators of the WB-EMS approach. Considering the superimposed WB-EMS application, the most reliable option for determining the (largely) isolated effect of WB-EMS will be the comparison with a control group that conducted the identical exercise protocol but without WB-EMS. However, even common sense suggests that differences between WB-EMS superimposed vs. non-superimposed exercise protocols will be much more discreet compared with superimposed exercise protocols versus ongoing training routines. It might be the most striking results of the present (subgroup-) analyses (table 2) that we observed a significant albeit low effect (10 studies; SMD: 0.46) of superimposed WB-EMS versus the underlying voluntary exercise that is predominately applied with near-maximum to maximum intensity (e.g. (1, 9, 11, 13)) on maximum power performance. Unfortunately, evidence for the other comparison (figure 2) is limited. While the result of D'Ottavio et al. (7) who compared superimposed WB-EMS versus traditional DRT (comparable effects) sounds reasonable, the result of the trial of Amaro-Gahete et al. (2) on power (figure 2) and relative V̇O2peak (figure 3) is more challenging. In detail the authors (2) replaced one of two sessions of running routine by one 12-20 min session WB-EMS superimposed on HIT-endurance, DRT and power training. Surprisingly, the authors reported no significant effects of WB-EMS on maximum power (figure 2), but on rel. V̇O2peak (figure 3). One may argue that rel. V̇O2peak might not be the most reliable predictor of endurance performance development in this context, nevertheless other performance parameters (e.g. maximum speed) confirmed these results. Lastly, the study of Jawad et al. (19) reported very high but nonetheless plausible effects on maximum power (figure 2), when considering that the trial addresses injured athletes during their rehabilitation program with and without adding (non-superimposed) WB-EMS.

Due to diverging research issues, corresponding heterogeneity between the protocols (table 2) and the paucity of studies, results on endurance performance are also difficult to interpret. When switching to an individual study level, two comparisons (11, 28) focused on a superimposed WB-EMS approach vs. underlying voluntary exercise, while two other projects (2, 11) compared their superimposed WB-EMS with control groups with ongoing training routine (running, soccer). Indisputably, the latter approach also makes perfect sense when considering superimposed WB-EMS as a whole, intended to partially replace (2) or time-efficiently complete (11) the previous training regime. As already reported, Amaro-Gahete et al. (2), who adopted this superimposed strategy, reported significant effects on endurance performance. In contrast, Filipovic et al. (11), who compared maximum jumping exercise superimposed by WB-EMS, i.e. a rather unspecific protocol for running endurance with habitual training routine, observed no favorable effects. Lastly, Mathes et al. (28), who applied a traditional high volume cycling endurance protocol (3-4x 60 min/w.), superimposed by WB-EMS or not, reported negligible effects on endurance performance in non-specifically trained sports students. A present network meta-analysis on local and whole-body EMS

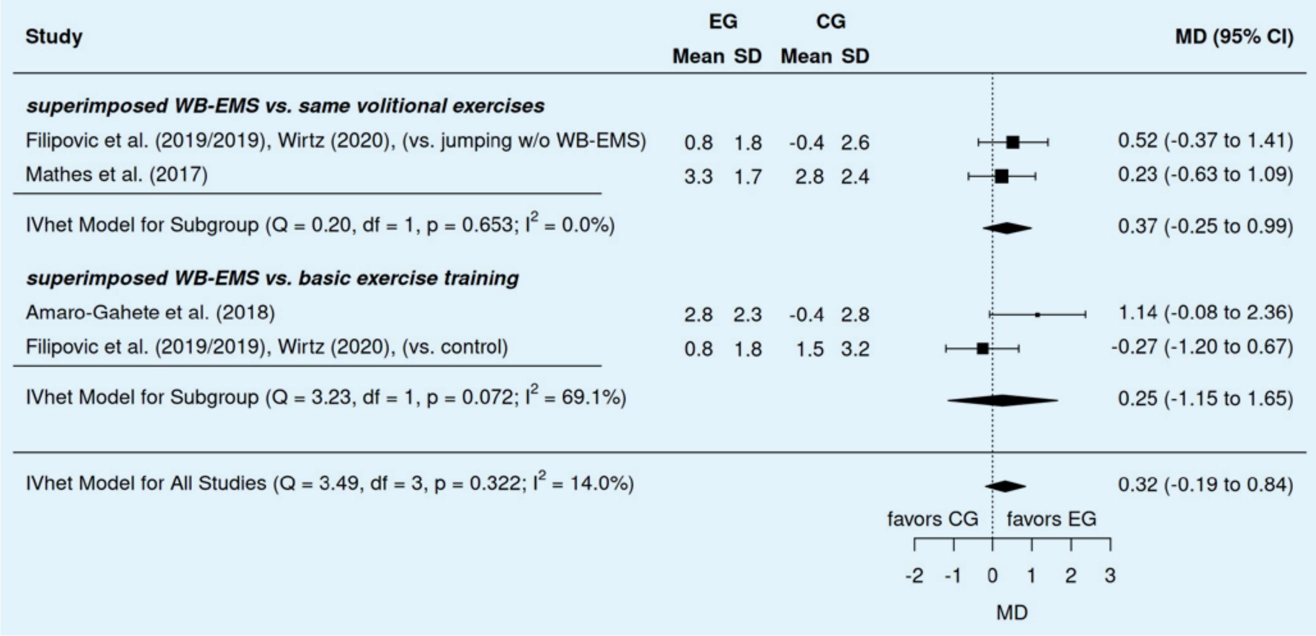

Figure 3

Forest plot of WB-EMS effects on relative V̇O2peak in sportspeople and athletes. CG=control group; EG=exercise group; SD=standard deviation.

in athletes, Micke et al. (29) confirmed the non-significant WB-EMS effects on aerobic capacity compared to “active control”.

Apart from the study limitations listed above a few other flaws and biases aggravate a reliable conclusion of WB-EMS effects on endurance performance. (a) In general, the limited number of eligible studies and their low sample sizes complicate a meaningful meta-analysis on the effect of WB-EMS, particularly for the issue of endurance performance. (b) Unfortunately, the studies were not consistently reported in adequate details. Although most authors responded to our queries, not all issues could be resolved, which might have resulted in inadequate categorization. (c) Methodological quality was rated by the PEDro (26), which is not perfectly applicable for randomized cross-over trials and in particular non-randomized trials (table 1). (d) The application of WB-EMS in sportspeople and athletes does not necessarily have to focus on performance. Apart from general injury prevention, WB-EMS is a validated method for time-efficiently addressing of low back pain (24, 31), a performance reducing complaint quite prevalent in sportspeople and athletes (39, 40). (e) The degree to which the present research findings can be generalized to other populations (e.g. non-athletic cohorts) is unclear. Most importantly, superimposed WB-EMS based on intense volitional exercise is less popular in scientific or traditional WB-EMS protocols for the general population (4, 22), thus our findings that is predominately based on superimposed WB-EMS trials cannot reliably be transferred to this cohort.

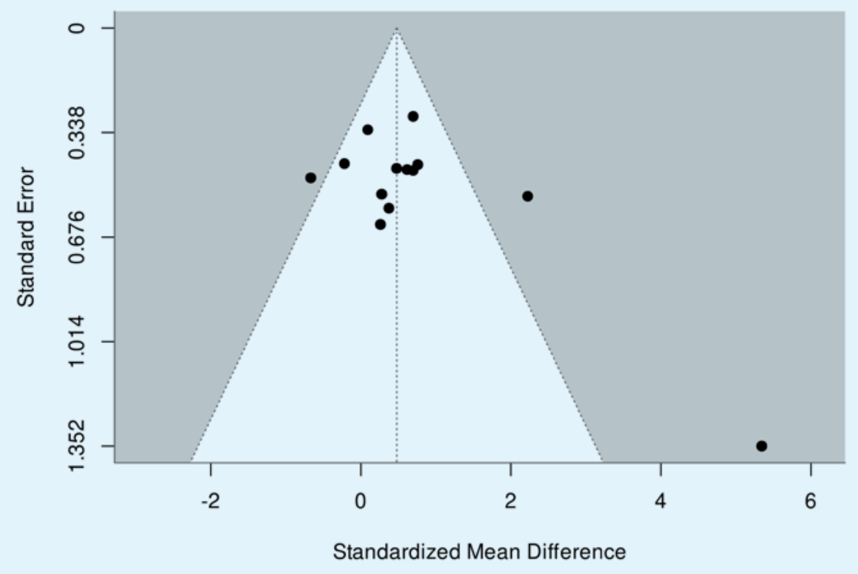

Figure 4

Funnel plot of WB-EMS effects on maximum power in sportspeople and athletes. White=0.05<p≤1.00; grey=0.00<p≤0.05; black dots=observed studies.

In conclusion, there is considerable evidence that even in well-trained sportspeople, maximum power performance can be increased by WB-EMS protocols. In contrast, there is limited evidence for WB-EMS effects on endurance performance. Nevertheless, even small absolute changes in performance can be highly relevant for well-trained athletes. Thus, future WB-EMS studies with an adequate sample size and comprehensible methodology should address the question of endurance performance in more depth. This includes addressing different types of endurance (e.g. general/local, short/moderate/long-term) more distinctly.

Conflict of Interest

All authors have completed the ICMJE Uniform Disclosure Form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organization for the submitted work; no financial relationships with organizations that may have an interest in the submitted work in the past three years; no other relationships or activities that may have influenced the submitted work.

Funding

no funding

Ethical Approval

Approved by the ethics committee of the German Sport University Cologne (032-2018). Written informed consent was obtained from all participants in accordance with the Declaration of Helsinki (2013).

Data Sharing

n.a.

Acknowledgement

We thank all the authors who provided missing data. The present study was performed in (partial) fulfillment of the requirements for Michael Püschel obtaining the degree Dr. med. dent.

Summary Box

The present work provides considerable evidence for the favorable effect of WB-EMS on maximum power in already trained cohorts. Notably, even superimposed WB-EMS protocol produced superior results when compared with the underlying, usually near-maximum to maximum voluntary exercise. In contrast the results of the few studies focusing on endurance performance vary widely and indicate on average non-significant effects.

References

(1) **Amaro-Gahete FJ, De-la OA, Sanchez-Delgado G, et al.** Functional Exercise Training and Undulating Periodization Enhances the Effect of Whole-Body Electromyostimulation Training on Running Performance. Front Physiol. 2018; 9: 720. doi:10.3389/fphys.2018.00720

(2) **Amaro-Gahete FJ, De-la OA, Sanchez-Delgado G, et al.** Whole-Body Electromyostimulation Improves Performance-Related Parameters in Runners. Front Physiol. 2018; 9: 1576. doi:10.3389/fphys.2018.01576

(3) **Araújo CG, Scharhag J.** Athlete: a working definition for medical and health sciences research. Scand J Med Sci Sports. 2016; 26: 4-7. doi:10.1111/sms.12632

(4) **Beier M, Schoene D, Kohl M, et al.** Non-athletic cohorts enrolled in longitudinal whole-body electromyostimulation trials - An evidence map. Sensors (Basel). 2024; 24: 972. doi:10.3390/s24030972

(5) **Bramer WM, Giustini D, de Jonge GB, et al.** De-duplication of database search results for systematic reviews in EndNote. J Med Libr Assoc. 2016; 104: 240-243. doi:10.3163/1536-5050.104.3.014

(6) **Cochrane.** Cochrane Handbook for Systematic Reviews of Interventions: The Cochrane Collaboration; 2016.

(7) **D`Ottavio S, Briotti G, Rosazza C, et al.** Effects of Two Modalities of Whole-body Electrostimulation Programs and Resistance Circuit Training on Strength and Power. Int J Sports Med. 2019; 40: 831-841. doi:10.1055/a-0982-3311

(8) **Doi SA, Barendregt JJ, Khan S, et al.** Advances in the meta-analysis of heterogeneous clinical trials I: The inverse variance heterogeneity model. Contemp Clin Trials. 2015; 45: 130-138. doi:10.1016/j.cct.2015.05.009

(9) **Dörmann U, Wirtz N, Micke F, et al.** The Effects of Superimposed Whole-Body Electromyostimulation During Short-Term Strength Training on Physical Fitness in Physically Active Females: A Randomized Controlled Trial. Front Physiol. 2019; 10: 728. doi:10.3389/fphys.2019.00728

(10) **Duval SJ, Tweedie RL.** A nonparametric "trim and fill" method of accounting for publication bias in meta-analysis. JASA. 2000; 95: 89-98. doi:10.1080/01621459.2000.10473905

(11) **Filipovic A, Bizjak D, Tomschi F, et al.** Influence of Whole-Body Electrostimulation on the Deformability of Density-Separated Red Blood Cells in Soccer Players. Front Physiol. 2019; 10: 548. doi:10.3389/fphys.2019.00548

(12) **Filipovic A, DeMarees M, Grau M, et al.** Superimposed Whole-Body Electrostimulation Augments Strength Adaptations and Type II Myofiber Growth in Soccer Players During a Competitive Season. Front Physiol. 2019; 10: 1187. doi:10.3389/fphys.2019.01187

(13) **Filipovic A, Grau M, Kleinoder H, et al.** Effects of a Whole-Body Electrostimulation Program on Strength, Sprinting, Jumping, and Kicking Capacity in Elite Soccer Players. J Sports Sci Med. 2016; 15: 639-648.

(14) **Furuya-Kanamori L, Barendregt JJ, Doi SAR.** A new improved graphical and quantitative method for detecting bias in meta-analysis. Int J Evid-Based Healthc. 2018; 16: 195-203. doi:10.1097/XEB.0000000000000141

(15) **Gentil P, Arruda A, Souza D, et al.** Is There Any Practical Application of Meta-Analytical Results in Strength Training? Front Physiol. 2017; 8: 1. doi:10.3389/fphys.2017.00001

(16) **Happ KA, Behringer M.** Neuromuscular Electrical Stimulation Training vs. Conventional Strength Training: A Systematic Review and Meta-Analysis of the Effect on Strength Development. J Strength Cond Res. 2022; 36: 3527-3540. doi:10.1519/JSC.0000000000004119

(17) **Higgins J, Thomas J, Chandler J, et al.** Cochrane Handbook for Systematic Reviews of Interventions version 6.2 (updated February 2021). Cochrane, 2021 [Internet]. [15.11.2025.] www.training.cochrane.org/handbook.www.training.cochrane.org/handbook

(18) **Ilbak I, Acak M.** The effect of plyometric training combined with electrical muscle stimulation on sports performance parameters in basketball players. Spor ve Performans Arastırmaları Dergisi. 2022; 13: 189-200. doi:10.17155/omuspd.1078740

(19) **Jawad W, Mohammed L, Atiyah W.** The Effect of Rehabilitation Exercises and Electric Muscle Stimulation (X Body) on Optimizing Leg Connective Muscles Strength and Biomechanical variables for Injured Athletes. Int J Psychosoc Rehabil. 2020; 24: 216-223. doi:10.37200/IJPR/V24I2/PR200326

(20) **Kacoglu C, Kale M.** Effects of lower-body electromyostimulation training and detraining on anthropometric parameters and muscular performance. VIREF Revista de Educación Física. 2021; 10: 156-176.

(21) **Kemmler W.** Meta-analysis and exercise related sports medicine [Meta-Analysen im trainingswissenschaftlichen und sportmedizinischen Spannungsfeld]. Dtsch Z Sportmed. 2013; 64: 96-98. doi:10.5960/dzsm.2012.062

(22) **Kemmler W, Fröhlich M, Eifler C.** Whole-Body Electromyostimulation. Effects, Limitations, Perspectives of an Innovative Training Method. Cham, Switzerland: Springer; 2024.

(23) **Kemmler W, Kleinoder H, Fröhlich M.** Editorial: Whole-Body Electromyostimulation: A Training Technology to Improve Health and Performance in Humans? Front Physiol. 2020; 11: 523. doi:10.3389/fphys.2020.00523

(24) **Konrad KL, Baeyens J-P, Birkenmaier C, et al.** The effects of whole-body electromyostimulation (WB-EMS) in comparison to a multimodal treatment concept in patients with non-specific chronic back pain—A prospective clinical intervention study. PLoS One. 2020; 15: e0236780. doi:10.1371/journal.pone.0236780

(25) **Le YE, Schoene D, Kohl M, et al.** Outcomes addressed by longitudinal whole-body electromyostimulation trials in middle aged-older adults - An evidence map. Japan J Med Sci. 2024: 2: 01-22. doi:10.20944/preprints202403.0183.v1

(26) **Maher CG, Sherrington C, Herbert RD, et al.** Reliability of the PEDro scale for rating quality of randomized controlled trials. Phys Ther. 2003; 83: 713-721. doi:10.1093/ptj/83.8.713

(27) **Martín-Simón MA, Rojano-Ortega D.** Effects of simultaneously combined whole-body electrostimulation and plyometric training on vertical jump performance, 20 m sprint-time and handgrip strength. Pol J Sport Tour. 2022; 29: 30-35. doi:10.2478/pjst-2022-0012

(28) **Mathes S, Lehnen N, Link T, et al.** Chronic effects of superimposed electromyostimulation during cycling on aerobic and anaerobic capacity. Eur J Appl Physiol. 2017; 117: 881-892. doi:10.1007/s00421-017-3572-6

(29) **Micke F, Held S, Lindenthal J, et al.** Effects of electromyostimulation on performance parameters in sportive and trained athletes: A systematic review and network meta-analysis. Eur J Sport Sci. 2023; 23: 1570-1580. doi:10.1080/17461391.2022.2107437

(30) **Micke F, Kleinoder H, Dormann U, et al.** Effects of an Eight-Week Superimposed Submaximal Dynamic Whole-Body Electromyostimulation Training on Strength and Power Parameters of the Leg Muscles: A Randomized Controlled Intervention Study. Front Physiol. 2018; 9: 1719. doi:10.3389/fphys.2018.01719

(31) **Micke F, Weissenfels A, Wirtz N, et al.** Similar Pain Intensity Reductions and Trunk Strength Improvements Following Whole-Body Electromyostimulation vs. Whole-Body Vibration vs. Conventional Back-Strengthening Training in Chronic Non-specific Low Back Pain Patients: A Three-Armed Randomized Controlled Trial. Front Physiol. 2021; 12: 664991. doi:10.3389/fphys.2021.664991

(32) **Page MJ, McKenzie JE, Bossuyt PM, et al.** The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021; 372: n71. doi:10.1136/bmj.n71

(33) **Paillard T, Noe F, Passelergue P, et al.** Electrical stimulation superimposed onto voluntary muscular contraction. Sports Med. 2005; 35: 951-966. doi:10.2165/00007256-200535110-00003

(34) **R_Development_Core_Team.** R: A Language and Environment for Statistical Computing. Vienna, Austria. R Foundation for Statistical Computing Vienna. 2025.

(35) **Rappelt L, Micke F, Held S, et al.** Effects of four weeks of static vs. dynamic bodyweight exercises with whole-body electromyostimulation on jump and strength performance: a two-armed, randomized, controlled trial. J Sports Sci Med. 2023; 22: 226. doi:10.52082/jssm.2023.226

(36) **Reinhardt S, Berger J, Kohl M, et al.** Outcomes addressed by whole-body electromyostimulation trials in sportspeople and athletes - An evidence map. Sports (Basel). 2025; 13: 302. doi:10.3390/sports13090302

(37) **Ribeiro de Ávila V, Bento T, Gomes W, Leitão J, Fortuna de Sousa N.** Functional Outcomes and Quality of Life After Ankle Fracture Surgically Treated: A Systematic Review. J Sport Rehabil. 2018; 27: 274-283. doi:10.1123/jsr.2016-0199

(38) **Schuhbeck E, Birkenmaier C, Schulte-Gocking H, et al.** The Influence of WB-EMS-Training on the Performance of Ice Hockey Players of Different Competitive Status. Front Physiol. 2019; 10: 1136. doi:10.3389/fphys.2019.01136

(39) **Trompeter K, Fett D, Brüggemann G-P, et al.** Prevalence of Back Pain in Elite Athletes. German Journal of Sports Medicine. Dtsch Z Sportmed. 2018; 69: 240-246. doi:10.5960/dzsm.2018.336

(40) **Trompeter K, Fett D, Platen P.** Prevalence of Back Pain in Sports: A Systematic Review of the Literature. Sports Med. 2017; 47: 1183-1207. doi:10.1007/s40279-016-0645-3

(41) **Wirtz N, Filipovic A, Gehlert S, et al.** Seven Weeks of Jump Training with Superimposed Whole-Body Electromyostimulation Does Not Affect the Physiological and Cellular Parameters of Endurance Performance in Amateur Soccer Players. Int J Environ Res Public Health. 2020; 17. doi:10.3390/ijerph17031123

(42) **Wirtz N, Wahl P, Kleinoder H, et al.** Acute metabolic, hormonal, and psychological responses to strength training with superimposed EMS at the beginning and the end of a 6 week training period. J Musculoskelet Neuronal Interact. 2015; 15: 325-332.

(43) **Zhang D, Fernández Elías VE, Burgos Postigo S.** Effects of Whole Body Electromyostimulation Training on Maximum and Explosive Strength of Trained Female. A Pilot Study. Kronos: revista universitaria de la actividad física y el deporte. 2021; 20: 1579-5225.