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The Use of Whole Body Electromyostimulation (WB-EMS) as a Golf Warm-Up - A Randomized Controlled Cross-Over Study

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Abstract

Background: *There is growing evidence that warm-up protocols favorably affect golf performance. Golf-specific movements superimposed by whole-body electromyostimulation (WB-EMS) might be a promising method to increase the efficiency of warm-up before a golf challenge, be it a match or driving range.*

Objectives: *The aim of this study was to determine the effect of a WB-EMS supported warm-up on clubhead speed and shot accuracy.*

Methods: *Using a cross-over design, 20 highly skilled golf players (handicap 6.4±2.6 points, 37.2±14.5 yrs.) were randomly allocated to a 12 min warm-up protocol starting with or without WB-EMS. The warm-up consisted of seven exercises that addressed all muscle groups involved in the golf swing. AWB-EMS protocol with 4s of impulse (bipolar, 85Hz, 350µs, rectangular) during the voluntary warm-up exercises, intermitted by 4s of rest was applied. Study endpoints were maximum clubhead speed and shot accuracy ("offline") averaged from 10 hits with participants' iron-7, as determined by the laser-based Foresight GC2 device.*

Results: *Two subjects quit the study due to reasons not related to the project. In summary, we observed a non-significantly higher effect (1.1±3.3%; p=.106) for the WB-EMS warm-up condition. Separating athletes with high versus low swing speed, we observed more pronounced improvements for clubhead speed in the slower cohort (2.8±4.0%, p=.055). No relevant effects were observed for "offline".*

Conclusion: *Although we failed to demonstrate significant effects in this highly skilled cohort of golf players, we conclude that WB-EMS supported warm-up protocols might be particularly helpful for athletes with low shot velocity to enhance clubhead speed without negative effects on shot accuracy.*

Keywords: *golf warm-up, whole-body electromyostimulation, golf performance, clubhead speed, shot accuracy.*

Introduction

The physical demands on hitting a golf ball are enormous. [1] Thus, adequate preparation is crucial for the successful completion of a golf challenge. Apart from its important role in injury prevention [2-4], there is a growing body of evidence that dedicated warm-up protocols favorably affect parameters crucial for golf performance. [5] This includes clubhead speed (e.g. [5-9]), shot accuracy [5, 9] and/or swing path. [9] Reviewing the predominately applied type of exercise in warm-up routines of highly skilled golfers [10], static stretching ranked first, although many studies reported unfavorable effects of static stretching warm-ups on golf performance. [9, 11-13] In contrast, warm-ups that applied dynamic stretching [9, 12-14] and/or slight dynamic strengthening exercises that address a large variety of muscle groups [1, 5] favorably affect golf specific skills. Considering the high velocity along with the large number of upper and lower body muscles involved in the driving swing [15], this result sounds plausible. However, warm-up routines previously applied during range sessions, practice rounds or competition are still limited to highly skilled athletes [10], while the majority of amateur golfers indicated that they never or seldom warmup. [16] Undeniably, addressing all the muscle groups involved in the golf swing during a warm-up is a drawn-out procedure. Exercise technologies that superimpose external strain on the voluntary activation of the neuromuscular system might increase the efficiency and effectiveness of the warm-up. Whole-body electromyostimulation (WB-EMS), a novel exercise technology able to stimulate up to 12 muscle areas each with dedicated impulse intensity, might be such a candidate. However, although the effectiveness of EMS on various athletic skills has been proved [17], no present study focuses on its application during warm-up previous to highly complex movements. Thus, the aim of the study was to determine the effects of a warm-up protocol that applied WB-EMS on golf performance in skilled golfers.

In detail, the primary hypothesis of the study was that WB-EMS application during warm-up significantly increases maximum clubhead speed compared with the identical warm-up procedure, albeit without adjuvant WB-EMS application.

The secondary study hypothesis was that WB-EMS application during warm-up significantly increases shot accuracy ("offline") compared with the identical warm-up procedure, albeit without adjuvant WB-EMS application.

An experimental hypothesis was that WB-EMS favorably affects the mental-psychological condition after the warm-up and/or during the practice round.

Materials And Methods

The study was designed and realized by the Institute of Medical Physics, Friedrich-Alexander University of Erlangen-Nürnberg (FAU), Germany. All parts of the project were conducted between June and December 2018 and complied with the Helsinki Declaration "Ethical Principles for Medical Research Involving Human Subjects". After detailed information, all participants gave their written informed consent. In this article, we follow the Consolidated Standards of Reporting Trials (CONSORT) guideline for reporting parallel group randomized trials [18] although we did not fully consider this project as a clinical trial.

Study Design

Using a crossover design, participants were randomly assigned to the Whole Body-EMS condition that started their warm-up procedure with WB-EMS application during phase 1 or to the control condition that started without WB-EMS. In parallel, participants who started with the control condition during phase 1 switched to the treatment condition in phase 2 and vice versa (Fig. 1).

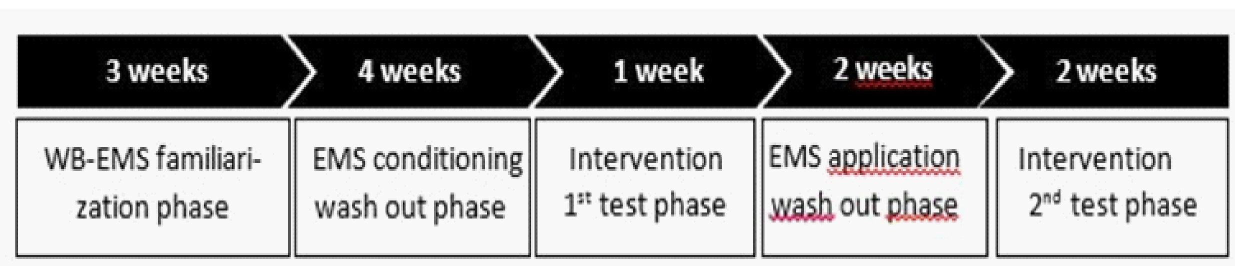

Fig 1. *Study design*

Participants And Selection Criteria

Using personal contacts and databases of two German golf clubs (GC Steigerwald, GC Mangfalltal) 28 male golf players with European Golf Association (EGA) classification 1 and 2 (i.e. Handicap 0 to -11.4) were personally contacted (Fig. 2). After detailed information given by the principal investigator (CZ), two men refused to participate. Applying our eligibility criteria (1) no WB-EMS contraindications (e.g. cardiac pacemaker); (2) no orthopedic problems with impact on testing; (3) no previous WB-EMS training; (4) absence during the familiarization and testing periods, 22 men were included in the WB-EMS familiarization phase (Fig. 1). However, during the first 7 weeks of the study period of 12 weeks, 2 men dropped out (Fig. 2), so that finally 20 golf players were randomly assigned to the conditions (i.e. with vs. without WB-EMS).

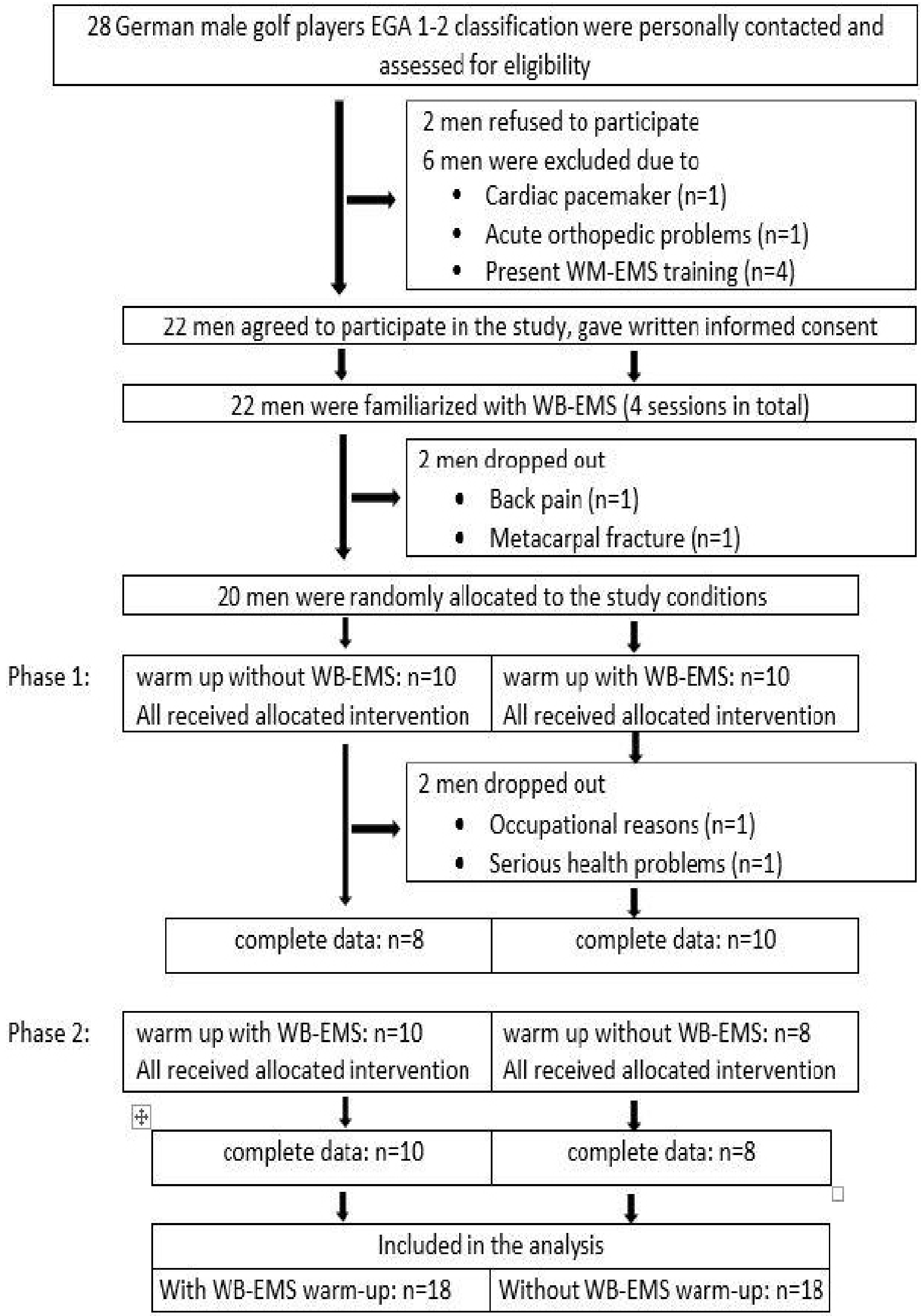

Fig 2. *Participants flow through the project [18].*

Study Procedure, Intervention

Subjects were extensively informed about the dos and don’ts by the principal study investigator (CZ). This includes restraining from intense physical activity or exercising 48 h pre-intervention. In addition, participants were not allowed to play golf or hit balls 48 h before the tests

WB-EMS Familiarization Phase

In order to familiarize participants with WB-EMS application four closely supervised and guided session were conducted. Using WB-EMS devices of miha bodytec® (Gersthofen, Germany we used a 12 minute intermitted WB-EMS protocol with 4 s of impulse (bipolar, 85 Hz, 350 µs, rectangular) and an impulse break of 4 s (i.e. duty cycle of 50%). During the impulse phase eight predominately non golf-specific voluntary exercises (semi-squat, crunch, lunge with trunk rotation, butterfly, rowing, reverse flies, biceps curls, table stance) were conducted with submaximum intensity while standing. Cumulated exercise intensity (i.e. WB-EMS and voluntary exercise) was prescribed 3-4 (moderate-somewhat hard) on the Borg CR 10 scale, which was generated and maintained during the session in close interaction between instructor and participant.

Warm-Up Approach

The warm-up approach consisted of seven slight resistance exercises conducted either with or without adjuvant WB-EMS application. In order to address the specific movement during the golf swing, the following exercises were performed.

- Squats
- Side planks
- Diagonal crunch in a standing position
- Biceps curls
- Table stance
- Rotation in the maximum upper position of the swing movement (upper part)
- Total golf swing movement (full amplitude)

In order to exactly standardize the movements and to allow the instructor to focus on the realization of an adequate impulse intensity (3-4 on Borg CR 10), warm-up exercises were video-guided.

The identical WB-EMS procedure described above was applied during the WB-EMS warm-up condition again with exercises conducted during the impulse phase. No WB-EMS equipment (i.e. EMS vests or cuffs) was worn during the non-EMS condition. Immediately (<5 min) after the warm-up, the tests described below were conducted.

Study Outcome

Primary Study Endpoint

- Clubhead speed as determined by a laser based indoor system during warm-up with and without WB-EMS

Secondary Study Endpoint

- Shot accuracy (offline) as determined by a laser based indoor system during warm-up with and without WB-EMS

Experimental Study Endpoint

- Changes in mental-psychological condition as assessed by questionnaire after warm-up with and without WB-EMS

Measurements

Immediately after warm-up, participants hit 10 balls with their iron-7 without any time restriction or feedback. All tests were performed on an indoor golf facility either in Gerolzhofen or Feldkirchen-Westerham, Germany. However, all participants conducted their tests twice in the same facility. Of importance participants were familiar with the testing procedure due to previous tests with this system. Using the laser-based Foresight GC2 device (San Diego, USA) with its stereoscopic camera system, the device monitored the ball during the clubhead impact and analyzed the selected parameters (Fig. 3). Performance data were transferred to an external display and then stored on a PC. Figure 3 gives the test setting and device.

Fig 3. *Foresight GC2 monitor (left side) and golf shot experimental setup (right side).*

Clubhead speed is defined as the speed the clubhead is traveling immediately prior to impact. Clubhead speed and ball speed are related 1-1, however, we also gave the data for this parameter in order to allow a comparison with studies that focus on ball speed.

Offline was defined as the end position distance right or left measured from the target-line.

Lastly, using structured questionnaires based on the Perceived Physical State (PEPS) questionnaire suggested by Kleinert et al. [19], we asked participants to describe their subjective sensation after the WB-EMS warm-up. Further, (where applicable) we asked participants to report their experience when playing on the golf course immediately after the WB-EMS warm-up (n=9).

Changes of Trial Outcomes after Trial Commencement

No changes of study outcomes were conducted after commencement of this project.

Sample Size Analysis

We are unable to present a sophisticated power analysis for this novel method. However, based on the primary study endpoint "clubhead speed" and a recent study that applied whole body vibration (WBV) as a warm-up method in golf [6] we "expected" a difference between WB-EMS and non-WB-EMS condition of 2.0±2.5%. Applying $\alpha=0.05$ and $\beta\text{-}1=0.8$, in total 20 participants were required to achieve this assumption. However, we anticipated a drop-out rate of about 10%, thus we included all the eligible men in the study (n=22).

Randomization Procedures and Enrollment

Twenty eligible men were familiarized with WB-EMS and then randomly assigned to two conditions that started with or without WB-EMS warm-up during the first test period. Due to the crossover design of the study, we used only a simple but balanced random (1-1) allocation. Supervised by the researcher responsible for the randomization procedure (FR), the participants drew lots, and allocated themselves to the two conditions. Lots were put in opaque plastic shells and were drawn by the participants from one bowl in the order of their appearance. Of importance, neither participants nor researchers knew the allocation before hand. Finally, ten men started with and ten men started without WB-EMS warm-up during the first study period. Subsequently, status (starting with or without WB-EMS) of the participants was listed by the primary investigator (CZ) who enrolled participants and instructed them in detail about their status including corresponding dos and don'ts.

Blinding

While participants and investigators are aware of the actual status (with or without WB-EMS war-up), research assistants were kept blind to this allocation of the participants and were not allowed to ask, either.

Statistical Analysis

All the participants who competed both conditions were included in the analysis independently of compliance with the protocol. Data were given using mean values (MV) ± standard deviation (SD). Due to the directed hypotheses, we applied singletailed tests. After checking normal distribution by QQ plots and Shapiro-Wilks tests, we decided to perform the more conservative Wilcoxon rank-test to determine differences between the conditions. In parallel, the secondary analysis, i.e. WB-EMS induced differences in clubhead speed between men with high vs. low clubhead performance were addressed with non-parametric Mann-Whitney tests. Effects size were calculated using Cohens d´ [20]. Significance was accepted at p <0.05.

Results

Fig. 2 shows participant flow through the study. Two participant quit the study after the randomization procedure due to reasons not related to this project. All further participants passed through the project strictly according to the study protocol. Table 1 gives general and golf specific characteristics of the 18 participants that completed the study.

Table 1. *General and golf specific characteristics of the cohort.*

Variable	MV ± SD	Minimum	Maximum
Age [years]	37.2 ± 14.5	18	62
Body height [cm]	178.8 ± 7.8	166	193
Body mass [kg]	83.0 ± 22.0	65	129
Body Mass Index [kg/m^2]	25.7 ± 5.2	20.2	42.6
Handicap [points]	6.4 ± 2.6	2.8	11.4
Golf competitions [n/yr.]	15.6 ± 9.1	2	30

Table 2 gives the effect of the WB-EMS warm-up for the study endpoint "clubhead speed" (and the related parameter "ball speed") hit by participants' own iron-7 as determined by the Foresight GC-2 systems.

Table 2. *Raw values for clubhead speed and ball speed for both conditions along with differences between warm-up with and without WB-EMS along with exact p-values.*

Variable	Without WB-EMS MV ± SD	With WB-EMS MV ± SD	Difference MV ± SD	p-value
Clubhead speed [mph]	79.97 ± 9.31	80.80 ± 8.36	0.83 ± 2.79	.106
Ball speed [mph]	108.8 ± 12.7	109.9 ± 11.4	1.1 ± 3.8	.106

In summary, we determined a non-significantly higher (1.1 ± 3.3%; p=.106) effect for the WB-EMS warm-up condition. Thus, we have to reject our primary hypothesis that a WB-EMS warm-up protocol significantly improves clubhead (and ball) speed compared with the same warm-up protocol without WB-EMS application.

Reviewing the variance of the differences between WB-EMS and non-WB-EMS warm-up for clubhead speed (Tab. 2), there is an obvious variation between players with higher versus lower clubhead speed. After separating the cohort (Tab. 3), we observed relevant differences (d´=.83, p=.137) between the groups. While the effect of WB-EMS warm-up is borderline non-significant (p=.055) in the players with slower clubhead speed, no relevant changes (p=.767) were observed in their faster peers.

Table 3. *Differences (WB-EMS versus non EMS warm-up) in clubhead speed for players with high versus low clubhead speed, corresponding effects size (ES) and exact p-values.*

Variable	"slower" (n=9) MV ± SD	"faster" (n=9) MV ± SD	ES (d´)	p-value
Changes in clubhead speed [mph]	1.82 ± 2.74	-0.15 ± 2.61	.73	.137

Shot accuracy as determined by the "offline" parameter of the Foresight GC-2 systems was only slightly (non-significantly) higher (Tab. 4) when applying a WB-EMS warm-up.

Table 4. *Raw values for offline for both conditions along with differences between warm-up with and without WB-EMS along with exact p-values.*

Variable	Without WB-EMS MV ± SD	With WB-EMS MV ± SD	Difference MV ± SD	p-value
"Offline"[yard]	5.04 ± 9.25	3.61 ± 13.41	1.43 ± 16.70	.322

Thus, we also have to reject our secondary hypothesis that a WB-EMS warm-up protocol significantly improves offline compared with the same warm-up protocol without WB-EMS application.

Addressing our experimental endpoints, only one participant gave a negative feedback ("groggy") after the WB-EMS warm-up. On the other hand, all the participants who started to play the golf course immediately after the WB-EMS condition reported higher preparedness than after usual warm-up. Five out of nine golf players stated they have improved their handicap; however, this was not validated by the researchers.

Discussion

In summary, we observed a favorable effect of WB-EMS application compared with the identical warm-up protocol without WB-EMS, however we failed to demonstrate significant effects between the conditions. This result refers to both clubhead speed and shot accuracy ("offline"). Although borderline non-significant, players with lower clubhead speed benefit from WB-EMS with higher increases in speed versus participants with higher initial speed, who did not show any WB-EMS induced changes. Since clubhead speed negatively correlate with age in the present study (r=.73), older players benefitted more from WB-EMS application compared with their younger peers. This finding however is in diametral contrast to the results of Bunker et al. [6] that reported significant improvements in ball speed after whole body vibration warm up for their younger (<45 vs. >45 years) only. On the other hand, Vandervoort [21] concluded, that due to age related changes in motor and skeletal systems that inhibit the ability to perform a full repeatable swing with optimal tempo and rhythm, warm up might be particularly valuable for older golf players.

Our finding of non-significant effects are also in contrast to several studies that determined significant changes of clubhead speed and/or shot accuracy after active warm-up protocols (e.g. [5-9, 13]. However, all these trials used inactive [5, 7-9] and/or passives tretching regimes [9, 12, 13] as the control condition. One study [6] compared a dynamic stretching protocol performed on vibration platforms (WBV) versus the usual pre-golf warm-up of the participants (if any; details not given). Thus, it is unclear which explanatory contribution was provided by the WBV versus the active stretching aspect of the warm-up. In contrast, the present study aimed to determine the independent effect of WB-EMS. Thus, we applied the same potentially effective warm-up protocol for both groups and superimposed it by WB-EMS in the experimental group. Comprehensibly, differences between the groups should be less pronounced compared with the comparison of an experimental versus a non-warm-up control.

Although clubhead speed and shot accuracy might be crucial factors of successful performance in golf, mental and psychologic factors are also of high relevance. All but one participants gave a positive feedback after the WB-EMS application. Most players agreed with the items "prepared" and "activated", a feature that was frequently expressed after conventional WB-EMS training sessions.

With respect to the applicability of WB-EMS (or WBV) during golf specific warm-ups, one may argue that the logistic demands will limit the use of these training technologies. This might be the case particularly with WB-EMS, which should be considered as a kind of personal training with a maximum of two applicants closely supervised by one instructor. [22] However, considering the highly professional setting of golf sports, the application of WB-EMS as a warm-up previous to a range/practice session or competition is a realistic option for the ambitious golf athlete.

Some features and study limitations might decrease the evidence of the present project or at least aggravate its proper interpretation. (a) By accident, we failed to realize our calculated sample size of 20 participants per group. Considering the border line non-significant results for clubhead speed in the "slower" cohort, this feature might have prevented a significant difference between the conditions. (b) We focus on a cohort of skilled golfers, EGA classification 1 and 2, representing only 4.6% of the German golf community. One may speculate that due to their much higher room for improvements players with minor rankings might provide more favorable EMS-induced changes in clubhead speed and shot accuracy. We agree with this viewpoint, however, considering the low enthusiasm for warm up in the lower class/ recreational golf community [16], it is arguable whether these sophisticated methods will be practiced by less ambitious golfers. (c) One may criticize that we did not discuss the potentially underlying mechanisms of WB-EMS. This is correct, however although several rationales for a favourable modus operandi of a WB-EMS-supported warm-up protocol (e.g. higher amount of motor units recruited, activation of fast-twitch fibers at relatively low force levels, synchronous recruitment of muscle fibres and increased firing rate, recruitment of fibres in the depth of the muscle) could be applied, we focussed on a "proof of principal" approach and thus abstain from discussing potential modes of operations. (d) Due to logistic reasons and time constraints, only half of our participants were able to play the golf course immediately after the warm-up and test procedure. Although faster clubhead speeds and related longer hitting distances along with increased or at least maintained shot accuracy are important surrogates, the overall course score has to be considered as the most meaningful endpoint of golf performance. However, to reliably determine this outcome, a much more elaborate protocol with several practice rounds or competitions per participant would have to be applied.

Conclusion

In this project, we observed a favorable effect of a WB-EMS supported protocol on clubhead speed versus the identical warm-up protocol without WB-EMS. Although, we failed to determine significant effects in this cohort of highly skilled athletes, we conclude that warm-up protocols with adjuvant WB-EMS application might contribute to higher driving performance particularly in athletes with lower clubhead speeds. Future studies however should focus on the more meaningful effect of WB-EMS based warm-ups on the overall score as the definite outcome in golf competition.

Data Availability Statement

The raw data used to support the findings of this study are available from the corresponding author upon request.

Acknowledgement

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