Science & Sports 37 (2022) 633.e1—633.e10

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ORIGINAL ARTICLE

Pilates with whole body electromyostimulation exercise produces high levels of muscle damage

Le pilates avec électro-myo-stimulation du corps entier provoque une augmentation marquée des marqueurs de lésion musculaire

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Reçu le 23 août 2021 ; accepté le 17 janvier 2022
Disponible sur Internet le 15 June 2022

KEYWORDS
Muscle damage ;
Electrostimulation ;
Pilates ;
Creatine kinase ;
Oxidative stress

Summary
Objectives. — The use of whole body-electrostimulation (WB-EMS) in combination with strength exercises has been proposed in order to improve muscle strength and rehabilitation. However, the combination of stimulation of muscle with exercise can induce muscle fibers break. This manuscript study Pilates Mat without or in combination with WB-EMS in trained individuals in order to determine the level of muscle damage.
Methods. — We determined the effect of WB-EMS in combination of Pilates Mat in eighteen healthy and trained Intermediate Pilates Mat volunteers to determine the release of muscle damage biomarkers in plasma. Plasma levels of muscle damage markers (CK and transaminases) were determined by enzymatic assays.
Results. — We found that WB-EMS produced a high rise of the release of creatine kinase and transaminases in individuals whereas Pilates Mat did not produce such as effect. The levels of CK in plasma were very high indicating dangerous levels near rhabdomyolysis. This effect was not accompanied by a rise in oxidative stress damage.

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https://doi.org/10.1016/j.scispo.2022.01.005

Conclusions. — Our results indicate that WB-EMS must be used with precaution in trained and more importantly in non-trained individuals in order to avoid severe muscle damage.

MOTS CLÉS
Souffrance musculaire ;
Électro-myo-stimulation ;
Pilates ;
Créatine kinase ;
Stress oxydatif

Résumé
Objectifs. — Nous avons proposé l'utilisation de l'électro-myo-stimulation du corps entier (WB-EMS) en combinaison avec des exercices de force, afin d'améliorer la force musculaire et la rééducation. Toutefois, la combinaison de la stimulation des muscles peut provoquer la déchirure des fibres musculaires. Cette étude se focalise uniquement sur le Pilates Mat ou en combinaison avec le WB-EMS chez des individus entraînés, afin de quantifier la souffrance musculaire.
Méthodes. — Nous avons déterminé l'effet du WB-EMS en combinaison avec le Pilates Mat, chez dix-huit volontaires sains et entraînés d'un niveau moyen de Pilates Mat, pour déterminer la libération de biomarqueurs de souffrance musculaire dans le plasma. Les niveaux plasmatiques de marqueurs de souffrance musculaire (CK et transaminases) ont été déterminés par dosage enzymatique.
Résultats. — Nous avons observé que le WB-EMS provoque une grande augmentation de la libération de la créatine kinase et des transaminases chez les sujets étudiés, alors que le Pilates Mat n'a pas entraîné cet effet. Les niveaux de CK dans le plasma étaient très élevés, ce qui montre des niveaux dangereux proches de la rhabdomyolyse. Cet effet n'a pas été accompagné par une augmentation des indicateurs de souffrance liés au stress oxydatif.
Conclusions. — Nos résultats montrent que le WB-EMS doit être utilisé avec prudence chez les individus entraînés et plus encore chez les individus non entraînés, afin d'éviter une souffrance musculaire sévère.

1. Introduction

Whole-Body Electromyostimulation (WB-EMS) has gained increasing interest in professional and recreational sports within recent years [1,2]. It has been recommended as substitute of exercise and classical methods of training in different health groups including non-trained sedentary [3] and obese people [4,5], patients with haematological malignancies [6], cardiomyopathy [7] or cancer [8] and also in trained athletes [9,10].

WB-EMS has been considered as alternative and substitutive of a traditional overload-based resistance training program [11] although EMS was not better than the classical program. Among the scientific literature, there is a lack of consensus about the effectiveness of WB-EMS in whole population. In many studies, it has been shown that WB-EMS could be a danger for untrained and also trained people [5,12—14]. However, many other studies have shown positive although limited effects but without determining muscle damage after WB-EMS procedure [1,15—17].

WB-EMS has been used in the treatment of bariatric surgery patients [18], obese individuals [4], back pain [19], postmenopausal women [20] although showing negligible effects on body composition [21].

Pilates method is a training procedure that works core stability, strength, flexibility and muscle control, posture and respiration [22]. This training method is practised by healthy people aiming to maintain and improve their healthy status [23—25] and patients suffering different pathologies [26—29]. Pilates mat uses pilates training but on a mat and has been found to produce significant improvements in health and functionality perception, total physical self-concept, and other parameters related with the physical capacity and health [30]. Pilates has been also proposed as a putative strategy to improve capacity and reduce pain in elderly people [23,24,31].

In general, many studies indicate a higher risk for health and muscle damage by using WB-EMS with negligible effects in comparison with classical training protocols. For this reason, the aim of the study was to compare the effects of a medium intense training procedure such as Intermediate Pilates Mat training with and without WB-EMS in Pilates familiarized healthy subjects for at least 2 years and to determine the levels of muscle damage and other plasmatic parameters in this population.

2. Material and methods

2.1. Participants

Nineteen healthy trained subjects of 39 ± 6 years of age participated in the study (4 men and 15 women). The participants were eligible if they met the inclusion criteria: healthy and between 20—50 years old, unfamiliar with WB-EMS, at least 2 years of experience in Intermediate Pilates Mat training (> 2 sessions/week). Participants also must satisfy the corresponding exclusion criteria of habitual smokers and drinkers and patients with medication/diseases affecting muscle metabolism or kidneys and conditions that prevent WB-EMS (e.g. epilepsy, cardiac pacemaker) as listed by the manufacturer (Miha Bodytec®, Gersthofen, Germany) (Fig. 1).

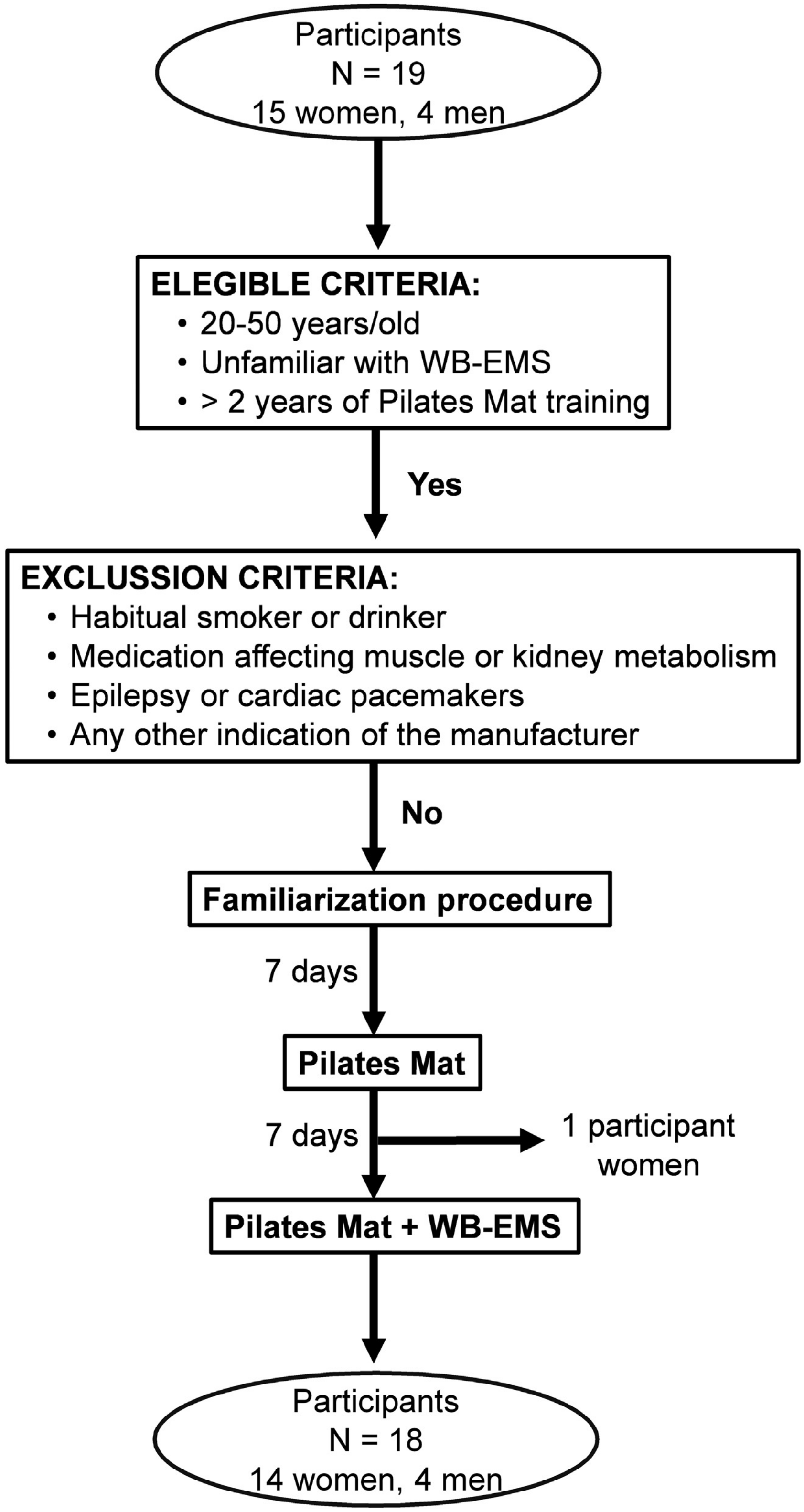

Figure 1 Flux diagram of the procedure.

The research was carried out at the National Institute of the Pilates Method ''Isabel Rizo'' in Seville and at the Andalusian Center for Developmental Biology, Universidad Pablo de Olavide, Sevilla. The ethical principles for human medical research of the Helsinky Declaration were followed. The study protocol was approved by the ethics and research committee of the Olavide University. All the participants signed an informed consent after receiving detailed information about the study.

2.2. Measurements and testing

2.2.1. Anthropometry

Participants were anthropometrically characterized. Height and weight of the subjects were determined with devices calibrated following the ISAK protocol. Body composition was determined by electric bioimpedance (BIA) by using a Tanita BC-601F, following the manufacturer's protocol. The characteristics of the participants are shown in Table 1.

2.2.2. Blood samples extraction and determinations

Blood samples extraction was performed by a healthcare professional under non-fasting condition from an antecubital vein before, immediately after, 24 h and 48 h post-exercise (i.e. Pilates Mat with WB-EMS or Pilates Mat without WB-EMS). The same researchers consistently conducted procedures of blood sampling and analysis. In summary, creatine kinase (CK), lactate dehydrogenase (LDH), Aspartate transaminase (AST), Alanine transaminase (ALT), creatinine, total cholesterol (CHOL), Low-density lipoprotein cholesterol (LDL-Chol), High-density lipoprotein cholesterol (HDL), triglycerides (TG) levels were analyzed using Reflotron® Plus Roche device (Roche). Thiobarbituric acid species were determined by detecting the malonyl-dialdehyde (MDA) levels in plasma by using a specific test following the manufacturer instructions (Cayman Chemicals, USA).

2.2.3. Rating of perceived exertion

After sessions of acute exercise with and without WB-EMS, perceived effort was evaluated using Borg Rating of Perceived Exertion — Category-Ratio Scale (0 to 10 scale).

2.3. Interventions

All trials with WB-EMS followed a bipolar training protocol. WB-EMS equipment used in this study enabled the simultaneous activation of 8 muscle groups (both upper legs, both upper arms, buttocks, abdomen, chest, lower back, upper back, and latissimus dorsi) with selectable intensities for each region. Stimulation area of 2.800 cm^2.

The intervention followed a procedure with three different sessions. In a first session, participants were familiarized with WB-EMS seven days before the first exercise program. In this familiarization session participants followed a basic program of training, indicated by the manufacturer. The impulse frequency was set at 85 Hz with an impulse width of 350 μs. Impulse duration was 5-sec with a 2-sec break between impulses. Total time of the session was 10-min. The subjects experienced involuntary muscle contraction, compression of the rib cage and difficulty in making movements.

A qualified instructor (I.R.) designed and conducted all the training program with or without WB-EMS. Eight days after familiarization procerure, a Pilates Mat session consisting in a 35-min training program was performed. In order to exercise the whole body, 23 exercises of the Pilates Mat method composed of hundred, roll up, leg circle, rolling like a ball (pedagogical process), single leg stretch, double leg stretch, spine stretch forward, corkscrew, saw, saw dive (pedagogical process), single leg kick, side kicks (pedagogical process), teaser, mermaid, standing up, push up and seal (pedagogical process) were performed. The participants completed 1 set with 10—100 reps depending on the movement. Rest time between exercises was 10-sec.

Seven days after pilates session, participants performed the same exercise program in the same order but with less repetitions. Participants worn a WB-EMS suit Miha-Bodytech® technology during a 20 min training procedure accordingly the manufacturer instructions. The impulse frequency was set at 70 Hz with a continuous impulse width of 350 μs. Since Intermediate Pilates Mat permits a range of repetitions, this range was modified in the WB-EMS procedure to complete the 20 min of exercise without affecting the number of exercises.

2.4. Statistical analysis

Graph Prism 6.0 software was used for statistical analysis and drawing of figures (GraphPad Software, California, USA). All data are expressed as means $\pm$ S.E.M. For all experiments, 18 subjects per group were analyzed. The information obtained from each group was statistically processed pursuant to the most suitable technique for each case. Normal distribution was checked by the Shapiro—Wilk test. Paired Student *t*-test or one way Analysis of Variance (ANOVA) followed by post-hoc pairwise multiple comparison procedures (Bonferroni *t*-test) were performed depending on the number of parameters compared. The critical significance level α was = 0.05 and then, statistical significance was defined as $P < 0.05$. To determine the magnitude of the difference, ESs according to the Cohen D procedure were calculated. It was considered that values lower than 0.41 indicate a small effect, from 0.41 to 0.70 moderate and greater than 0.70 indicates a high magnitude effect [32]. Two-tailed Pearson's Correlation between parameters was performed by using Graph Prism 7.0 version software.

3. Results

As expected, among the participants, women showed significant lower height, weight, BMI, fat free mass, body water mass and muscle and bone mass. Their metabolic rate was also lower than in men and their diary calorie intake (Table 1).

After each session, participants were asked to indicate their perception of the effort performed accordingly to the Borg scale. In Fig. 2, we can find that almost all the participants indicated a higher perception of the effort in the Pilates WB-EMS session in comparison with the Pilates Mat session (Fig. 2B) despite the shorter effort time in WB-EMS sessions. In order to determine if the perception of the effort correlated with the intensity of muscle activity

Table 1 Characteristics of the participants.

Parameter	Total	Male	Female	*P*
Age (y)	39.9 ± 1.6	40.7 ± 4.3	38.5 ± 3.9	0.5593
Height (cm)	168.9 ± 2.0	178.88 ± 4.3	166.07 ± 4.3	0.0036
Weight (kg)	62.4 ± 3.0	81.3 ± 4.9	57.0 ± 1.8	< 0.0001
BMI (kg/m^2)	21.7 ± 0.7	25.4 ± 1.1	20.7 ± 0.5	0.0008
Body fat %	22.7 ± 1.3	19.3 ± 1.7	23.7 ± 1.5	0.1520
Body fat mass (kg)	14.2 ± 1.0	15.9 ± 2.1	13.8 ± 1.2	0.4189
Fat Free Mass (kg)	48.2 ± 2.4	65.4 ± 3.0	43.3 ± 0.9	< 0.0001
Visceral fat rating	3.6 ± 0.6	7.0 ± 3.0	2.6 ± 0.4	0.0004
Body water (%)	53.5 ± 0.9	55.8 ± 2.0	52.8 ± 1.0	0.1792
Body water mass (kg)	33.3 ± 1.6	45.0 ± 1.5	30.0 ± 0.7	< 0.0001
Muscle mass (kg)	45.7 ± 2.3	62.1 ± 2.9	41.0 ± 0.9	< 0.0001
Bone mass (kg)	2.4 ± 0.1	3.3 ± 0.1	2.2 ± 0.1	< 0.0001
Basal metabolic rate (kcal)	1424 ± 66	1899 ± 86	1289 ± 25	< 0.0001
Metabolic age (y)	28.2 ± 2.2	34.0 ± 5.4	26.6 ± 2.3	0.1735
Diary calorie intake (kcal)	2417 ± 135	3381 ± 153	2141 ± 54	< 0.0001
n	18	4	14	

Participants were 14 female (80%) and 4 male (20%).

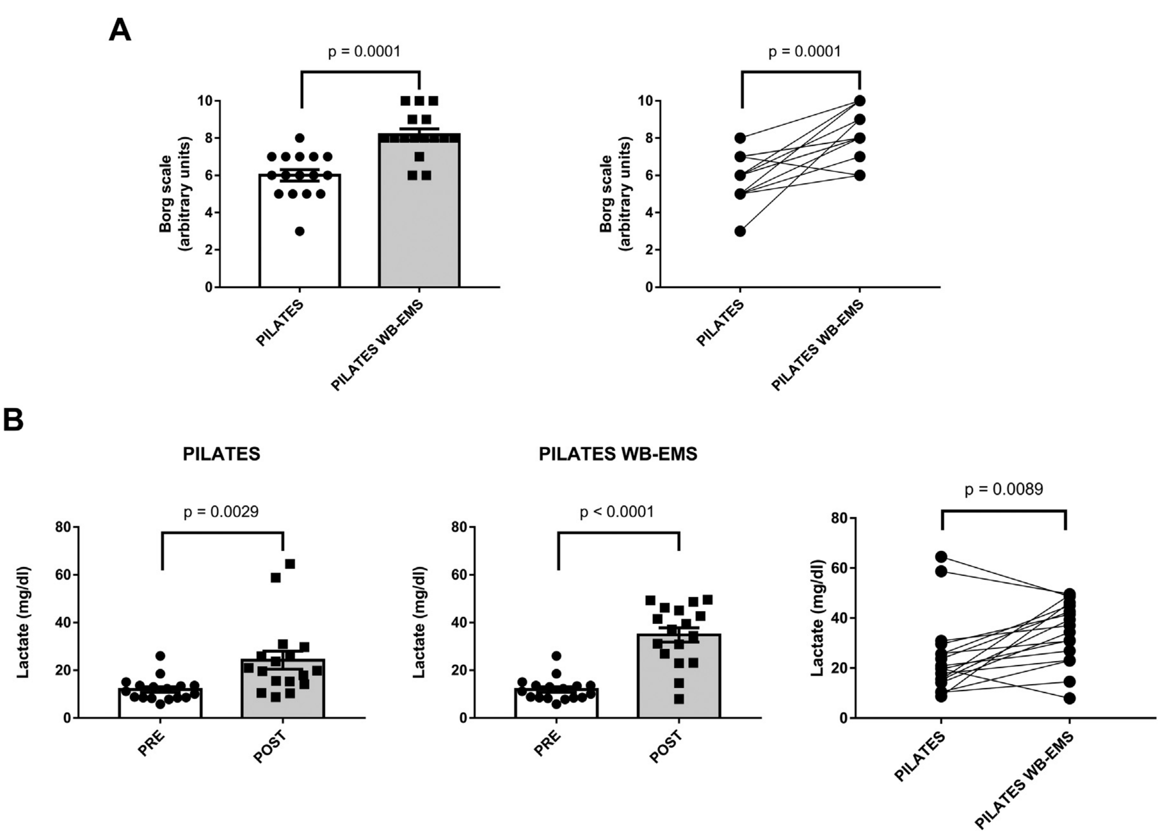

Figure 2 Determination of performance degree after Pilates and/or Pilates WB-EMS session. A. Borg scale of effort just after session (left). Comparison of the effort indicated by the participants juts after the session. Statistical significance was determined by paired *t*-test. B. Lactate levels after pilates (left) or Pilates WB-EMS (center). Comparison of lactate levels just after Pilates and Pilates WB-EMS sessions (right). Data represent the mean ± SEM. Statistical significance was determined by paired *t*-test.

during sessions, we determined the levels of lactate in plasma just before and after sessions. Lactate levels in plasma increased after both, Pilates Mat and WB-EMS sessions but in the case of the WB-EMS session, this release was significantly higher indicating a higher anaerobic activity in muscle during the session (Fig. 2B). Most of the participants showed higher release of lactate after WB-EMS session (Fig. 2C). It seems that the intensity and muscle activity

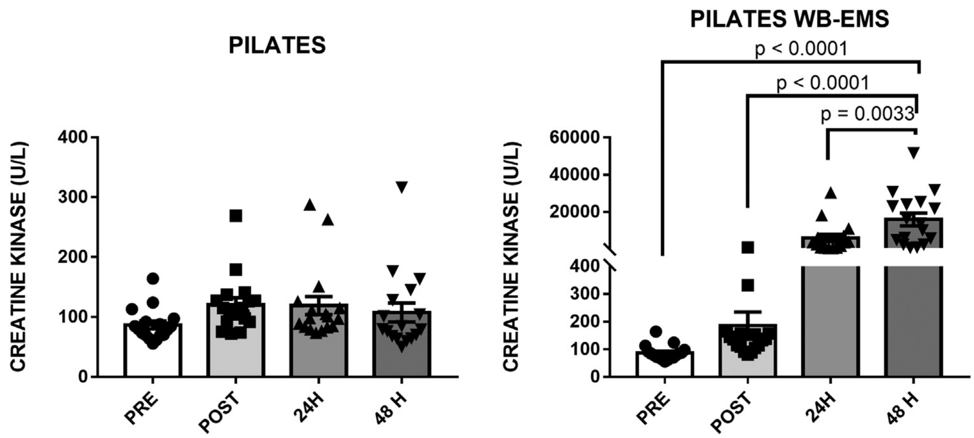

Figure 3 Levels of muscle damage markers after Pilates Mat (Pilates) of Pilates Mat + WB-EMS sessions (WB-EMS). Muscle damage was determined by the levels of CK in plasma. Left: pilates and right: pilates + WB-EMS. Data represent the mean ± SEM. Significant differences were determined by two tailed ANOVA test.

was high in Pilates WB-EMS session despite the 15 minutes shorter activity and lower number of repetitions.

In order to determine the effect of the different sessions on the levels of muscle damage, we measured plasma levels of CK just after exercise and after 24 h and 48 h post-exercise. After the Pilates Mat session, no significant changes in the levels of plasma CK were found. Only a slight and no significant increase in CK levels could be seen just after exercise returning to control levels at 48 h (Fig. 3A). However, after the Pilates WB-EMS session, the levels of CK in plasma already increased just after the session over the levels found at any moment in the Pilates Mat session. Determinations 24 and 48 h after the session demonstrated a 500 and 1,500 times increase in plasma CK levels indicating a intense muscle damage (Fig. 3B).

Transaminases are not only biomarkers of liver damage, they also are released after muscle damage [33]. Then, we also determined the levels of ALT and AST in plasma. ALT (Fig. 4A) and in AST (Fig. 4B) levels showed a clear significant increase 48 h after WB-EMS session. The increase respecting basal levels was 3 times in the case of ALT and 15 times in the case of AST. On the other hand, AST/ALT ratio is not only considered a marker of liver disease [34] but also can be considered a marker of muscle damage after exercise [35]. In our study, the AST/ALT ratio was significantly higher 24 and 48 h after Pilates WB-EMS session without showing any change after Pilates Mat session (Fig. 4C).

Interestingly, no significant correlations between muscle mass, fat mass, BMI or basal metabolic rate and CK release were found, indicating that these characteristics did not influence the levels of muscle damage markers (data not shown).

On the other hand, we also determined oxidative stress and damage by measuring the levels of TBARS in plasma (Fig. 5). Neither Pilates Mat not Pilates WB-EMS produced high levels of TBARS. However, just after WB-EMS procedure a trend to increase was not found. This increase affected many of the participants.

In general, our results indicate that in healthy and trained individuals for Intermediate Pilates Mat, the combination of WB-EMS with Pilates exercises can induce higher muscle damage accompanied by a modest increase in oxidative stress.

4. Discussion

Our study demonstrates that the use of WB-EMS in combination with Pilates Mat in trained healthy people with this training procedure increases the risk of suffering high muscle damage just after the first session of WB-EMS. Differently to other studies in which the main group is divided in randomized subgroups [11], in our study, the same group of individuals participated in both procedures and the results can easily be compared. The enormous increase in CK and in AST and ALT in participants after WB-EMS session in comparison with Pilates Mat session, despite the lower repetitions and the shorter time, indicates that the risk is too high in comparison with the benefits.

Although it has been used in trained and non-trained individuals, in general, the effect of WB-EMS produces limited effects on performance. For example, in people showing back pain 10 weeks of WB-EMS only produce minor effects on performance. In these participants, body posture or trunk strength was treated with 10 weeks with 85 Hz WB-EMS training in contrast with 20 Hz training. The treatment improved strength but not body posture [17]. As in many other studies, no CK as muscle damage marker was determined. In the FITAGEING program, directed to elderly people, a 12 weeks randomized trial, the combination of High Intensity Interval Training (HIIT) with WB-EMS only produced slightly better results than HIIT without WB-EMS [36]. In physical trained females, the use of WB-EMS did not produce significant improvement on short-term strength training, although its use was considered a reasonable alternative to classical training [15]. In other studies, negligible effects have been found in sprint and jump performance in comparison with risk [37]. In all these procedures, no determination of CK was performed.

In professional athletes such as soccer players, a 7-weeks of training of groups with superimposed WB-EMS did

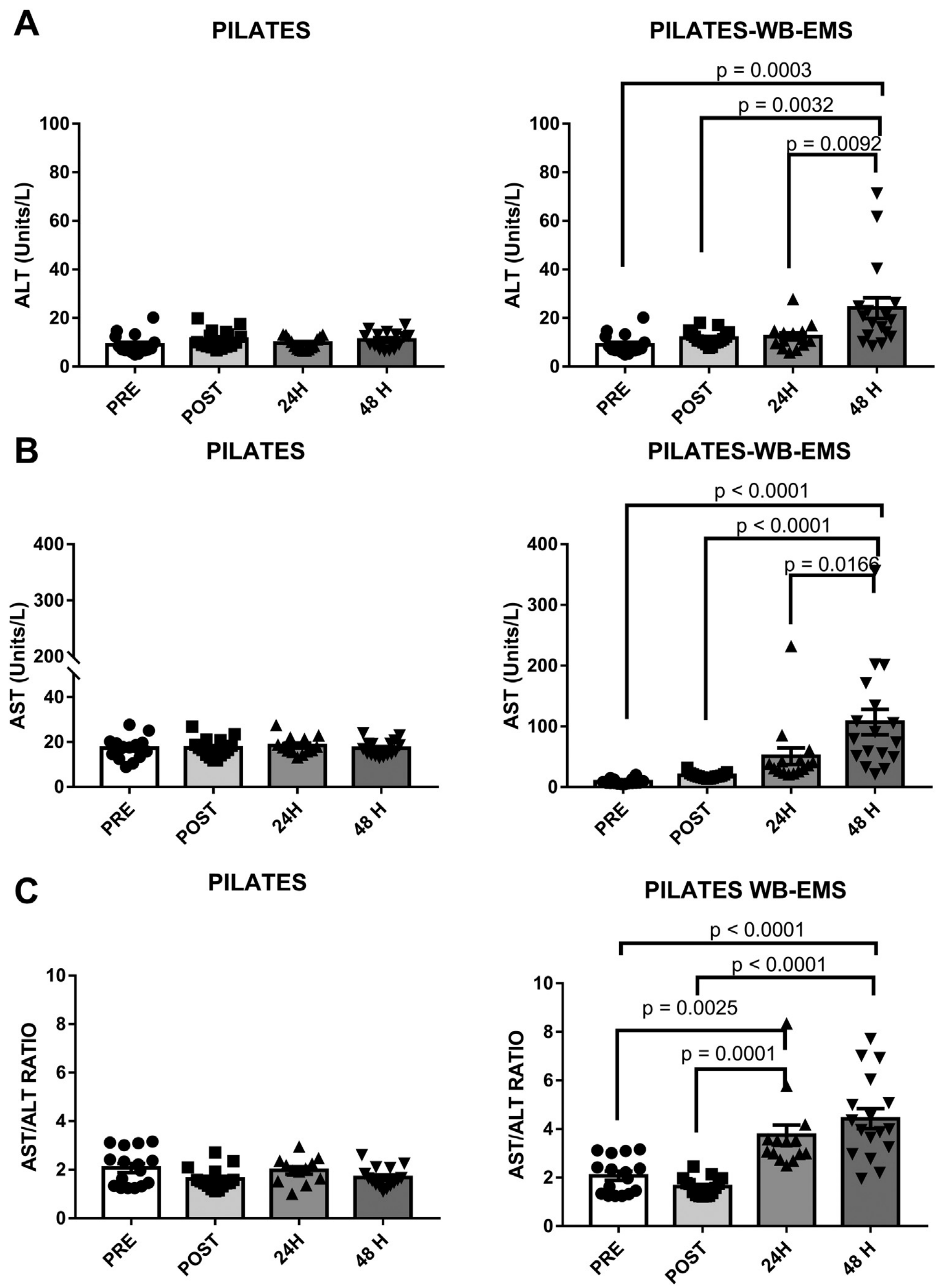

Figure 4 Transaminase levels in plasma before and after sessions. A. ALT levels. Left: Pilates and right: Pilates with WB-EMS. B. AST levels. Left: Pilates and right: Pilates with WB-EMS. C. AST/ALT ratio in plasma. Left: Pilates and right: Pilates with WB-EMS. Data represent the mean ± SEM. Significant differences were determined by two-tailed ANOVA test.

not relevantly influenced aerobic performance or density of monocarboxilate-transported, an important factor for explosive actions during soccer game [38]. On the other hand, a 10-weeks of superimposed WB-EMS training improved strength of certain leg, hip and trunk muscles in male adolescent elite soccer players in comparison with pure athletic strength training [9]. In some of these participants, the levels of CK after the first WB-EMS session exceeded 5000 U/L [9]. Also in soccer players, 7 weeks of WB-EMS treatment during competition increase the strength capacities and type II fibers growth when combined with resistance training [16], but there was no effect in endurance capacity [16]. In this late case, again no determinations of CK were performed.

In ice hockey players, additional WB-EMS training has been proposed to increase performance even in non-professional league [1] considering more effect in leisure athletes than in professional athletes. In comparison with HIIT, the WB-EMS did not show significant improvement on cardiorespiratory fitness, indicating the lack of effect [3]. Again, in these studies, no CK levels in plasma were determined.

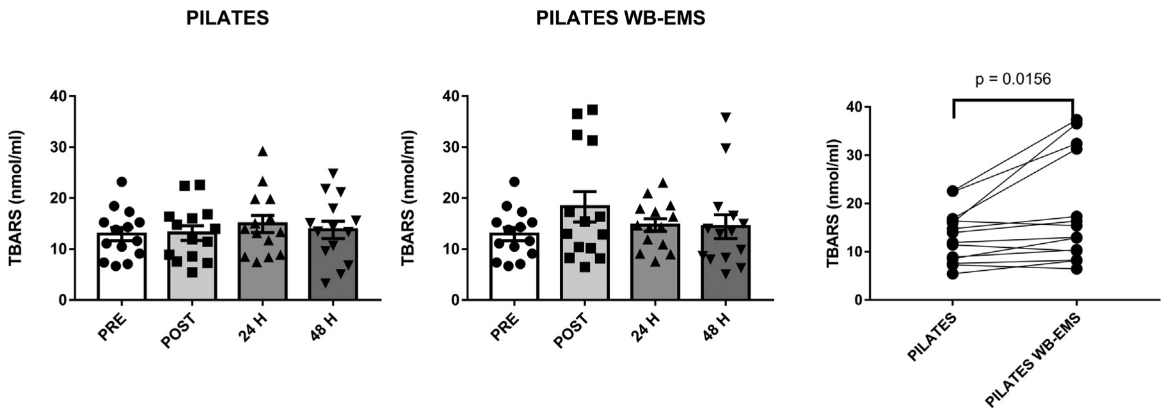

Figure 5 Oxidative damage in plasma after Pilates or Pilates with WB-EMS sessions. Left: TBARS levels before and after Pilates session. Center: TBARS levels before and after Pilates with WB-EMS. Right: comparison of TBARS levels just after session. Data represent the mean ± SEM. Significant difference is indicated after paired *t*-test.

For non-trained individuals, WB-EMS has been considered a time-effective, joint-friendly, and high customizable training technology in comparison with HIIT for maintenance of muscle mass during energy restriction in premenopausal women [39]. Due to the time effectiveness and low time-consuming WB-EMS has been proposed as alternative to conventional back-strengthening protocols for low back pain patients [40]. Furthermore, the use of WB-EMS has been considered to prevent muscle injuries in many patients since this technique do not use weights [41]. In healthy patients, a grade active exercise test followed by a recovery protocol consisting in walking at 40% of the maximum aerobic capacity with WB-EMS stimulation at 7 Hz showed greater peak blood velocity and lower gain/discomfort level and no-significant levels of blood lactate [42] probably due to the low Hz used in this study. Moreover, a recent article showed beneficial effects, efficacy and safety of WP-EMS in cardiopulmonary variables in humans [43], but in this study, very young people (around 21 years old) were used and the levels of damage in muscle were not determined.

In another study, high intensity interval training (HIIT) plus WB-EMS produced a significant increase in the metabolic rate and fat oxidation in sedentary middle aged people in comparison with non-exercised, classical trained and HIIT without EMS. In this study, WB-EMS plus HIIT increased β-oxidation and metabolic rate during exercise [44]. Authors suggested that EMS could be used to combat chronic metabolic disease in middle-aged sedentary adults. However, no levels of muscle damage were, again, determined.

In agreement with our results, it is clear that WB-EMS increases muscle damage. WB-EMS produces significant, partly extreme distractions of markers of muscular damage being CK the most common marker [37]. In our study, the levels of CK extremely increased 24 and 48 h after WB-EMS session accordingly with other studies that measure CK levels as muscle damage marker. In agreement with other studies, levels reached by most of the participants exceeded those considered as risk levels. In 2015, Kemler et al., showed very high levels of CK, even higher than after a Marathon and even after 48, 72 and 96 h after exercise [45].

Notwithstanding the different studies about the beneficial effects of WB-EMS that have been performed, only a few reported the levels of plasma CK after the sessions. However, our results indicate that these levels can rise enormously just after one session of WB-EMS. In healthy volunteers, enormous CK rise was reported after these sessions [46,47]. In other trials in which CK was not determined, some patients abandoned the study indicating ''muscular discomfort''. It seems clear that in some cases rabdomyolysis after WB-EMS is produced specially after the first session [47]. Further, severe rabdomyolysis after electrostimulation with MIHA-bodytech has been also reported in people with previous mild hyper-CK-emia [14]. Rabdomyolysis can produce severe kidney injury disrupting the capacity of filtration and impairing the levels of many damaging markers in plasma [48]. In spite of its potential damaging effect on kidney function, only one article has considered the kidney dysfunction in WB-EMS trained individuals [45].

The high risk of muscle damage and probably kidney damage after the use of WB-EMS in non-trained and also in trained individuals and the low improvements found to date indicate that the use of WB-EMS must be considered with severe precautions and participants must be follow in order to detect rapidly putative damaging effects, especially if they are not familiarized with this procedure. In our opinion, the use of classical training techniques reduces the level of damage and produce almost the same beneficial effects than this technique.

Disclosure of interest

The authors declare that they have no competing interest.

Acknowledgements

Authors declare that this study has been financed by the PAIDI BIO-177 group funded by the Andalusian Government. Further, funding for open access publishing: Universidad Pablo de Olavide/CBUA.

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