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ORIGINAL RESEARCH

Effect of a Single Administration of Focused Extracorporeal Shock Wave in the Relief of Delayed-Onset Muscle Soreness: Results of a Partially Blinded Randomized Controlled Trial

Johannes Fleckenstein, MD,[a,b] Mara Friton, MD,[a] Heiko Himmelreich, MD, PhD,[a] Winfried Banzer, MD, PhD[a]

From the [a]Department of Sports Medicine, Institute of Sports Sciences, Goethe-University Frankfurt, Frankfurt, Germany; and the [b]Department of Traditional Chinese Medicine/Acupuncture, Institute of Complementary Medicine, University of Bern, Bern, Switzerland.

Abstract

Objective: To examine the effects of a single administration of focused extracorporeal shock wave therapy on eccentric exercise-induced delayed-onset muscle soreness (DOMS).

Design: Three-arm randomized controlled study.

Setting: University research center.

Participants: Participants (N=46; 23 women) had a mean age of 29.0±3.0 years and a mean body mass index of 23.8±2.8kg/m^2.

Interventions: Participants were randomly allocated to verum- (energy flux density, .06−.09mJ/mm^2; pulse ratio per point, 200) or sham-focused extracorporeal shock wave therapy (no energy) at 7 equidistant points along the biceps muscle or no intervention.

Main Outcome Measures: The primary outcome was the difference in pain intensity. Secondary outcomes included maximum isometric voluntary force (MIVF), pressure pain threshold (PPT), and impairment in daily life.

Results: Despite descriptive clinically meaningful differences, mixed-effects analysis (group × time) of changes to baseline did not reveal significant differences in the reduction of pain intensity between groups ($F_{2,42}$=2.5, P=.094). MIVF was not significantly different between groups ($F_{2,43}$=1.9, P=.159). PTT ($F_{2,43}$=0.2, P=.854) and daily life impairment ($F_{2,42}$=1.4, P=.248) were not significantly decreased over time, and there were no differences between groups in the post hoc analysis.

Conclusions: DOMS is a common symptom in people participating in exercise, sports, or recreational physical activities. A single treatment with focused extracorporeal shock wave therapy causes clinically relevant effects in the relief of pain, increase in force, and improvement of pain-associated impairments of daily living. Still, results need to be cautiously interpreted because of the pilot character of this study. Focused extracorporeal shock wave therapy might present an option in the midterm recovery from DOMS (72h) and be an approach to enhance the return to play in athletes.

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Muscle soreness is often induced by unaccustomed or eccentric exercise.[1] This condition is transient, and people normally do not seek medical advice. Longer-lasting impairment can be found in people with reduced physical activity[2] or in athletes.[3] Regarding athletes, muscle soreness accounts for reduced athletic performance, limiting the prospects in training, competition, and career.[4] In the long term, persistent delayed-onset muscle soreness (DOMS) may increase the risk of further injury.

It is debated whether DOMS-related symptoms (ie, pain, muscle weakness, disabilities in daily living) are protective and prevent further damage, or if they are just an indicator of muscular overuse with no subsequent benefit. A major trauma in acute DOMS can almost certainly be excluded: the mechanical stretching of the muscle elongates the weakest sarcomeres first, causing mechanical microtrauma, which has been described as the underlying mechanism.[5] Both mechanical irritation and

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inflammatory responses sensitize the muscle nociceptors.[6-8] Therefore, pain is not immediately evoked but starts gradually and increases over the ensuing 48 to 72 hours.[9] Pain can be regarded as a cardinal symptom in DOMS.

The rationale behind pain therapy in DOMS is not to alleviate the physiological alarm, which might be preventing further injury, but to reduce the subsequent autogenetic phase that is potentially enhancing muscle injury[9] by positively regulating the inflammatory and neurogenic response to the initial stimuli. Therefore, adequate pain therapy—besides reducing symptom severity—may promote a faster muscular recovery process.[10]

A novel approach to address this pathomechanism might be the use of focused extracorporeal shock wave therapy. Shock waves are 3-dimensional pressure pulses of nanoseconds duration with peak pressures of 35 to 120MPa. Focused shock waves represent the more established form of medical shock wave therapy. These are concentrated into small focal areas of 2 to 8mm diameter to optimize therapeutic effects and minimize effects on other tissues.[11] Several mechanisms seem to account for the effects of focused extracorporeal shock wave therapy on musculoskeletal tissue, including direct effects on tissue calcification, alteration of cell activity through cavitation, acoustic microstreaming, alteration of cell membrane permeability, and desensitizing effects on nociception.[12] Investigations on myofascial pain and fibromyalgia suggest that focused extracorporeal shock wave therapy can increase perfusion, promote angiogenesis, and alter the pain signaling in ischemic muscular tissues.[13] Cellular structures (eg, fibroblasts, mesenchymal stem cells, macrophages) seem to be involved via the so-called mechanotransduction pathways in the regulation of metabolism and cell cycle of wounded tissue.[14] All these are requirements to regulate the aforementioned inflammatory response. Whereas clinical data suggest the mechanism elicited by focused extracorporeal shock wave therapy to be effective in the treatment of soft tissue conditions,[12] tendinopathies,[15] or wound care management,[16] investigations regarding DOMS and muscular homeostasis have been infrequently published.

To our knowledge, this is the first study designed as a 3-arm randomized controlled trial to evaluate the effect of focused extracorporeal shock wave therapy on muscle soreness. We hypothesize that focused extracorporeal shock wave therapy reduces the inflammatory response after forced eccentric exercise, which is clinically expressed as reduced pain intensity. This hypothesis is assessed by comparing verum-focused extracorporeal shock wave therapy with sham-focused extracorporeal shock wave therapy and with a nonintervention group of subjects with experimentally induced DOMS.

Methods

Study design

The study is a partially blinded, randomized controlled trial to investigate the effects of focused extracorporeal shock wave therapy on DOMS of the nondominant biceps brachialis muscle in adult and healthy volunteers. Participants were assessed for study eligibility using the following exclusion criteria: pain; pregnancy; musculoskeletal disease; systemic neurologic disease; cancer; coagulation disorder; mental illness; drug addiction; allergy to the ultrasound gel; cardiac illness; vascular disease of the limbs or the central nervous system; regional scars; regional skin transplants or hypoesthesia; allergy or other forms of acute dermatitis; chronic intake of analgesics, neuroleptics, antidepressants, corticoids, or alpha-2 antagonists; current state of DOMS; and focused extracorporeal shock wave therapy within the last 2 weeks.

The study took place at the Sports Campus, Institute of Sports Sciences, Goethe-University Frankfurt, Frankfurt, Germany. Forty-six participants agreed to participate and signed written informed consent. After enrollment, muscle soreness was induced, and participants were subsequently randomized to receive (1) focused extracorporeal shock wave therapy (verum), (2) sham shock wave therapy (sham), or (3) no treatment. Thereafter, treatments were administered one time. Measures were repeated after 24, 48, and 72 hours. The primary outcome was the pain intensity at rest and in movement, assessed by the visual analog scale (VAS) in the elbow region of the nondominant arm. Secondary outcomes included the pressure pain threshold (PPT) over the biceps muscle belly, the maximum isometric voluntary force (MIVF) of the elbow flexors, and the impairment of activities of the daily living. Participants were followed for 72 hours after the induction of DOMS, and participants were told not to exercise during this time. The study was approved by the Ethics Committee of the Goethe-University Frankfurt, Frankfurt, Germany (reference no. 301/08) and is in agreement with the Declaration of Helsinki (Version Fortaleza 2012).

Sample size estimation

Sample size was based on previous results and estimated using the software BiAS.[17,a] With significance set at 5%, 11 participants were required in each group to have 80% power to detect a minimal difference in pain intensity of 1.6 points on the VAS for pairwise comparison (variance $\sigma^2 = 1.05$, obtained from preliminary experiments of our laboratory). Assuming a dropout ratio of 25%, the total group size was calculated as 45 participants (15 subjects in each group).

Randomized treatment allocation

Participants were randomly assigned to 1 of the 3 study groups using sequentially numbered opaque envelopes with a ratio of 1:1:1. The randomization sequence was generated by the Department of Sports Medicine, using the computer-based randomization program (BiAS).

Induction of DOMS

At baseline, DOMS of the nondominant elbow flexors was experimentally induced using a previously described standardized exercise protocol.[18] The nondominant biceps brachialis muscle was selected to provoke DOMS. All participants were seated at a preacher bench and performed isolated biceps curls with a dumbbell. At first, their individual 1 repetition maximum (ie, maximum weight lifted with one concentric contraction) was

List of abbreviations:

CI	confidence interval
DOMS	delayed-onset muscle soreness
MIVF	maximum isometric voluntary force
mTrP	myofascial trigger point
PPT	pressure pain threshold
VAS	visual analog scale

determined for the elbow flexors by loading the dumbbell with free weights in 0.5-kg increments. Participants were encouraged verbally to elicit their maximal effort. The 1 repetition maximum was then used to provoke DOMS through eccentric contractions. For this, the experimenter lifted the dumbbell until the participant's elbow was fully flexed, and the participant lowered the weight eccentrically as slowly as possible until the elbow was fully extended. This procedure continued until the participants' subjective exhaustion.

Interventions

All interventions were performed by one author (H.H.), a specialized orthopedist and sports physician. Treatments started immediately after the induction of DOMS and lasted approximately 5 minutes. Participants were in the supine position on a therapy table, with no resting time thereafter.

Verum-focused extracorporeal shock wave therapy was applied at 7 equidistant points, perpendicular to the belly of the biceps brachii muscle on a virtual line between the radial tuberosity and the coracoid process.[b] Shock waves were generated by electrohydraulic mechanisms. According to clinical practice, and depending on the compliance of the participants, the concentrated shock wave energy per unit area (energy flux density) could vary from .06 to .09mJ/mm^2. The pulse ratio per point was 200. Taking all 7 point together, participants received 1400 pulses, with a total energy between 10.3 and 15.4mJ per point.

Sham shock wave was performed using the same device as previously stated, but using a special applicator that has been isolated with layers of metal and water by the manufacturer, extinguishing the transmitted energy. The study personal was blinded to the applicators. All handling, adjustments, and noises were the same in this group.

Participants in the nonintervention group remained in the supine position on the same therapy table for 5 minutes receiving no intervention.

Blinding procedure

Participants were focused extracorporeal shock wave therapy naive. The study personnel attempted to give equal attention to all participants. People involved in the assessment of outcomes and assessors were blinded to group allocation. In addition, we performed a credibility assessment to assure the quality of blinding.

Outcome measures

Pain intensity at the elbow region during active movement of the biceps muscle was assessed using a VAS ranging from 0 to 10cm (with 0 indicating no pain and 10 indicating experiencing the worst imaginable pain) after the induction of DOMS and at 24, 48, and 72 hours after induction.

PPT was assessed using a mechanical pressure algometer[c] at 7 equidistant points (as previously discussed). Pressure was applied to each of these points with increasing force at a rate of approximately 1kg/cm^2/s, until the participant reported a painful sensation; then the force value was recorded (kg/cm^2). An upper limit of the PPT was set at 5kg/cm^2 to avoid bruising. Each point was measured 3 times, with 10-second intervals between trials, and the mean of the second and third trials was used for the analysis.

MVIF was measured using a strain-gauge force transducer.[d] Participants were seated at a preacher bench with the elbow flexed at 90° and performed maximum isometric contractions against an inelastic strap that was placed around the wrist and connected to the force transducer (100-Hz sampling rate). Three trials were performed with contractions lasting 5 seconds, separated by 2-minute rest intervals. Participants were encouraged verbally to elicit their maximal effort, and force was displayed on a visual display in real-time providing immediate feedback. Peak strength values (N) were recorded, and the highest of the 3 repetitions was used for statistical analysis. PPT and MIVF were assessed after the induction of DOMS and at 24, 48, and 72 hours after induction.

To evaluate the impairment of some activities of daily living after 24, 48, and 72 hours, 6 complex movements as described within the modified Morrey score[19] were assessed by the means of the perceived pain for each movement on a 10-cm VAS. The mean is kept to describe the impairment.

Credibility assessment

Expectations about outcomes are the main modifying variables of the placebo effect according to Strauss-Blasche.[20] Patients were asked to evaluate whether their satisfaction and expectations were met after randomization through the 3-items questionnaire according to Vincent:[21]

(1) (Alleviation) How confident do you feel that this treatment can alleviate your complaint? (2) (Recommendation) How confident would you be in recommending this treatment to a friend who suffered from similar complaints? (3) (Logic) How logic does this treatment seem to you? All items are answered on a VAS ranging from 0 (disagreement) to 10 (full agreement).

Statistics

Baseline characteristics were analyzed with analysis of variance (for continuous measures) and the chi-square test (for nominal data) to assess for differences among the 3 study groups.

Statistical analysis was conducted for comparison of the primary and secondary outcome measures between the 3 study groups. No evidence was found that the parametric tests used were inappropriate. Because data are longitudinal, we applied a mixed-effects analysis (ie, 4×3 model; time × group) to analyze the effects on force, pain intensity, and PPT, with the levels after the induction of DOMS and at 24, 48, and 72 hours compared with baseline. Impairment (activities of daily living) was analyzed using a 3×3 model. Data were analyzed according to the Mauchly test for sphericity, and the Greenhouse-Geisser correction was used in case sphericity was not present. If statistically significant, the mixed model used for each outcome variable was followed by 3 post hoc pairwise comparisons of change scores between each of the 3 time points and baseline. This resulted in 9 or 12 post hoc tests for each outcome; therefore, we adjusted for multiple comparisons among these tests using the Sidak correction. This corresponds to using a threshold for significance in post hoc testing of $\alpha = .00568$ (3×3 model) or $\alpha = .00427$ (4×3 model). The level of significance was achieved at $P < .05$ if corrections were not needed.

Demographic data are presented as mean ± SD, whereas all other data, and all parametric data, are displayed as mean ± SEM.

Data analysis was performed with SPSS statistical software version 21.0.[e]

Table 1 Demographics

Demographic	Verum Group (n=16)	Sham Group (n=15)	Nonintervention Group (n=15)	P*
Age	29.0±3.8	28.5±3.1	29.6±1.8	.603
Sex, n (f/m)	7/9	10/5	6/9	.284
Height (cm)	172.1±8.2	179.5±9.3	176.9±10.1	.093
BMI (kg/m^2)	24.1±3.0	23.1±2.9	24.0±2.4	.551
Weight (kg)	68.9±13.1	78.0±13.3	75.8±13.0	.152
Muscle mass (kg)	30.6±7.6	36.7±8.2	34.5±8.1	.104

NOTE. Data are presented as mean ± SD or as otherwise indicated.
Abbreviations: BMI, body mass index; f, female; m, male.
* Analysis of variance (for continuous measures) and chi-square test (for nominal data) were used to compare the baseline characteristics among the 3 groups.

Results

Demographics and baseline data

Forty-six participants (23 women and 23 men; age, 29.0±3.0y; weight, 74.3±13.4kg; height, 176.3±9.6cm; body mass index, 23.8±2.8kg/m^2) were included in the study, and 1 dropout occurred after completing 24 hours. Measures at baseline were as follows: PPT of 4.3±0.7kg/cm^2, VAS of 0.0±0.0cm, and MIVF of 69.5±26.5N. Demographics are presented in table 1. There were no significant differences between the 3 groups.

Pain intensity

The pain intensity (on the VAS) is summarized in table 2, and changes to baseline are shown in figure 1A. Mixed-effects analysis over time (4×3 model) revealed no significant differences between groups ($F_{2,42}=2.5$, $P<.094$).

Post hoc analyses did not show significant effects between groups.

Mean isometric voluntary force

MIVF (N) is summarized in table 2, and changes to baseline are shown in figure 1B. Mixed-effects analysis over time (4×3 model) did not show significant differences between groups ($F_{1,43}=1.9$, $P=.159$).

Post hoc analyses did not show significant effects between groups.

Pressure pain threshold

PPT (kg/cm^2) is summarized in table 2, and changes to baseline are shown in figure 1C. Mixed-effects analysis over time (4×3 model) did not reveal significant differences between groups ($F_{2,43}=0.2$, $P=.854$).

Post hoc analyses did not show significant effects between groups.

Activities of daily living

The impairment in activities of daily living (VAS) is summarized in table 2 and figure 1D. Mixed-effects analysis over time (3×3 model) did not reveal significant differences between groups ($F_{2,42}=1.4$, $P=.248$).

Post hoc analyses did not show significant effects between groups.

Credibility assessment

Alleviation, recommendation, and logic scores are summarized by group in table 2. Analysis of variance models indicated there were no significant differences among the groups in alleviation scores ($P=.057$) or logic scores ($P=.083$); there were however significant differences among the groups in recommendation scores ($P=.023$). Post hoc analyses indicated that the verum group had significantly lower recommendation scores than the sham group (difference, −1.37; SE, 0.54; 95% confidence interval [CI], −2.46 to −0.27; $P=.016$); recommendation scores were not significantly different between the verum and nonintervention groups (difference, .63; SE, .47; 95% CI, −.32 to .47; $P=.19$) or between the sham and nonintervention groups (difference, −0.73; SE, 0.42; 95% CI, −1.58 to 0.12; $P=.089$).

Discussion

We present the results of a study investigating the effects of focused extracorporeal shock wave therapy on symptoms and muscle function in experimentally induced muscle pain. Muscle soreness (DOMS model) was successfully induced as evidenced by the increase in pain threshold, pain intensity, and functional impairment. Our results need to be interpreted carefully because this represents a study with pilot character. Adjusting our results for multiple comparisons leads to the study being underpowered because we tested against a significance level much lower than .05. From a clinical point of view, focused extracorporeal shock wave therapy reduced pain by 47% when compared with the nonintervention group (42% with the sham group). The magnitude of the loss of MIVF was >25% in the sham and nonintervention groups, but not for the verum-focused group. The impairment in activities of daily living was almost half in the verum-focused group when compared with the sham or nonintervention groups. Calculating the effect sizes shows that these descriptive effects might still be of clinical relevance. Focused extracorporeal shock wave therapy when compared with the nonintervention group at 72 hours showed large effect size in reducing the pain intensity (Cohen *d*, 3.19), in increasing the MIVF (Cohen *d*, 2.39), or in reducing the impairments of activities of daily living (Cohen *d*, 2.44). Our study could not show the statistical superiority of a verum treatment to sham or nonintervention treatment, but suggests clinically considerable effects of focused extracorporeal shock wave therapy on DOMS.

Our results are in accordance with other studies investigating muscular effects. Extracorporeal shock waves have been seen favorable in children with spastic movement disorders[22] and patients after stroke.[23] Arentz et al[24] described effects of symptom

Table 2 Outcome measures

Measure	Verum Group (n=16)	Sham Group (n=15)	Nonintervention Group (n=15)	Mixed-Methods Analysis, *P*	Post Hoc *t* Tests: Verum vs Nonintervention	Verum vs Sham	Sham vs Nonintervention
Pain intensity (VAS)				.094			
After induction	1.8±2.3	2.3±2.1	2.3±3.0		.550	.485	.994
24h	3.0±2.2	3.1±2.0	3.7±2.5		.395	.845	.494
48h	3.3±2.3	4.6±2.4	5.0±2.5		.064	.148	.669
72h	2.6±2.9	4.5±2.3	5.0±3.1		.041	.054	.653
MIVF (N)				.159			
After induction	61.1±29.7	41.6±25.8	55.7±27.0		.228	.542	.531
24h	63.4±25.0	42.1±28.9	56.2±27.7		.126	.219	.562
48h	70.3±32.3	42.9±29.5	62.4±39.0		.254	.081	.540
72h	75.4±31.7	41.0±24.7	56.7±28.8		.221	.378	.692
PPT (kg/cm^2)				.854			
After induction	4.5±0.5	4.0±0.7	4.5±0.3		.867	.133	.187
24h	4.0±0.8	3.7±0.7	3.8±0.6		.426	.799	.600
48h	3.9±0.7	3.3±0.7	3.7±0.6		.248	.101	.672
72h	4.1±0.8	3.5±0.7	3.7±0.8		.057	.040	.851
Impairment (VAS, cm)				.248			
24h	1.5±1.4	1.7±1.4	2.1±1.9		.314	.611	.562
48h	2.2±2.2	2.8±2.4	3.2±2.4		.241	.467	.664
72h	1.8±2.8	3.0±2.2	3.5±2.8		.103	.189	.593
Credibility (VAS, cm)				ANOVA			
Alleviation, baseline	5.6±1.6	6.6±1.0	6.5±0.8	.057	.079	.052	.692
Logic, baseline	5.6±1.6	6.0±1.3	6.5±0.9	.083	.171	.054	.331
Recommendation, baseline	5.3±2.0	6.7±1.5	5.9±1.1	.023*	.186	.016*	.089
Alleviation, 72h	6.3±2.0	7.2±1.2	6.5±0.8	.243	.803	.172	.073
Logic, 72h	6.4±2.4	7.4±1.5	6.6±0.8	.273	.744	.171	.117
Recommendation, 72h	6.0±2.4	7.2±1.4	5.9±1.2	.091	.961	.112	.010

NOTE. Pain intensity was measured on a VAS ranging from 0 (no pain) to 10 (maximum pain); MIVF, PPT, and impairment were measured on a VAS ranging from 0 (no impairment) to 10. All data are displayed as mean ± SD or as otherwise indicated. Mixed-methods analysis was the global test indicating differences within and between groups. Post hoc testing was performed with unpaired *t* tests by comparing change since baseline between groups. The respective thresholds for significance using the Sidak correction are $\alpha=.005$ (3×3 model) or $\alpha=.004$ (4×3 model). ANOVA was used as the global analysis of the credibility assessment with post hoc unpaired *t* tests and a level of significance <.05.

Abbreviation: ANOVA, analysis of variance.

* Significant difference.

relief with myogelosis in elite table tennis players during the European Championship 2003. Several articles describe the effectiveness of extracorporeal shock waves in the treatment of myofascial pain syndromes.[25-28] However, none of these investigations has been performed as a randomized controlled study.

In a review article by Gleitz and Hornig,[27] the authors suggest that myofascial trigger points (mTrPs) may be a primary diagnostic finding indicating the use of extracorporeal shock waves. To our knowledge, the existence of mTrPs has not yet been mechanistically linked to the occurrence of DOMS. According to Simons et al,[29] a myofascial pain syndrome relates to pain or autonomic phenomena referred from active mTrPs with associated dysfunction. The mTrP is defined as a hyperirritable spot in skeletal muscle that is associated with a hypersensitive palpable nodule in a taut band. The spot is painful on compression and can give rise to characteristic referred pain, referred tenderness, motor dysfunction, and autonomic phenomena. Whereas both types of pain include derangement of the local biochemical milieu of the muscle,[30] the major difference between DOMS and myofascial pain is the lack of referred pain patterns in muscle soreness. Referred pain has been attributed to a complex modulation of spinal nociception. Myofascial pain at some point causes the activation of nociceptive central neurons at the dorsal horn, facilitating the appearance of new receptive fields.[31] It has been proposed that DOMS is predominantly locally generated at the muscle nociceptors, without major effects on spinal sensitization and neural plasticity.[32] Altogether, DOMS can be described as a self-limiting local process, which has no major role in facilitating other pain-contributing mechanisms. This is in accordance with Myburgh et al,[33] who showed that the appearance of DOMS is independent of the presence of mTrPs. Therefore, besides muscle as the target tissue, the treatment of DOMS with focused extracorporeal shock wave therapy is not the same as treating mTrPs.

Regarding the clinical effect of our study, results warrant cautious interpretation. During the first 24 hours, there were only smaller effects on the PPT. Therefore, focused extracorporeal shock wave therapy cannot be considered a therapy with immediate effects. However, in the midterm, focused extracorporeal shock wave therapy reduced perceived pain and impairment. The pain intensity was reduced by almost 50% when compared with the nonintervention group, indicating clinical relevance. Strength returned to baseline after 48 hours, but was not significantly different when compared with the nonintervention group. Both results are corroborated by a similar reduction in

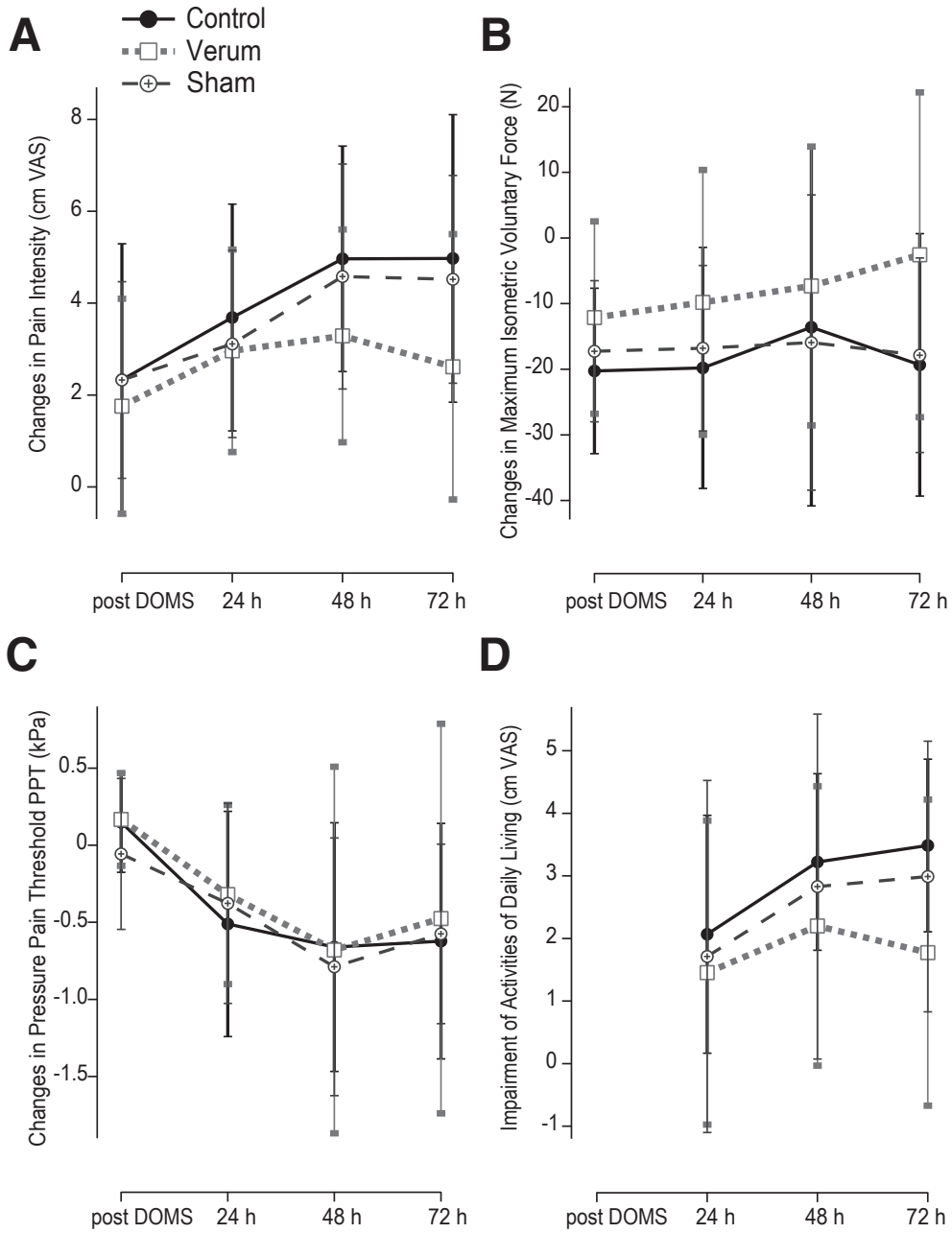

Fig 1 Pain, force, and impairment display the outcome parameters VAS, MIVF, PPT, and impairment at 24, 48, and 72 hours after induction of DOMS. VAS, MIVF, and PPT have also been assessed right after the induction of DOMS and, other than VAS, at baseline. (A) Course of the mean VAS (cm). (B) Course of the mean MIVF (N). (C) Mean change of the PPT (kg/cm^2). (D) Course of the impairments in daily living (VAS). Data are expressed as mean ± SEM.

perceived impairment. Taken together, focused extracorporeal shock wave therapy appears to be a rehabilitative technique enhancing a return to physiological functioning, rather than another analgetic therapy option in the treatment of DOMS. Previous trials on clinical treatments in DOMS have focused on prevention and decrease of symptoms.[34-36] Our results are still in line with these previous investigations. Considering that this is the first study of focused extracorporeal shock wave therapy in DOMS, the observed late onset of effects could imply that focused extracorporeal shock wave therapy is not only part of a symptomatic pain treatment, but also a rehabilitation approach (eg, enhancing athletes to return to play).

Study limitations

The major limitation of this study is its relatively small sample size and its pilot character. The correction for multiple comparisons led to the study being underpowered. Therefore, our study shows the proof of concept, but larger confirmatory studies will be needed to validate these potential clinical effects.

Other limitations of this study include the single use of the focused extracorporeal shock wave therapy. Because many clinicians in their private practice report to perform this way, we decided to design our study similarly. It can be debated whether continuous treatments would have enhanced the observed effects.

In addition, molecular measures could have been involved to quantify the extent of the biochemical response (ie, creatine kinase,[37] but also serum levels of leukocytes, cytokines, growth factors, or hormones).[38] All participants appeared compliant and motivated at all study visits; however, we cannot fully exclude the possibility of bias in the nontreatment group. In addition, our model only investigated effects on DOMS of the upper extremities, which are more likely to be affected in team sports athletes. To our knowledge, there are only a limited number of studies investigating the comparability of DOMS in experimental models of the upper and lower limbs. The cardinal clinical symptoms seem comparable. One study demonstrated a minor decrease in maximum strength of the upper extremities when compared with the lower extremities in a model of muscular fatigue[39]; this was associated with possible postural stability requirements. Still, this would justify the choice of the biceps brachialis model being more sensible to detect clinically relevant changes. In this context, it might also be of interest to expand the experimental induction of DOMS to protocols involving functional movements. It has been discussed that muscular fatigue or even DOMS obtained this way would possibly better reproduce clinical states in athletes, especially in team sports.[40] Finally, the chosen observational period was at least 1 day shorter than previous studies.[32] The observation that shock waves seem to elicit their largest therapeutic effects in the midterm would justify measures after 96 and up to 120 hours.

Conclusions

The use of single-dose focused extracorporeal shock wave therapy did not lead to a significantly improved relief of experimentally induced DOMS when compared with nonintervention or sham treatment. Still, effects observed in the relief of pain intensity, pressure pain, and daily impairments were of clinical relevance when compared with nonintervention or sham treatment. Our data do not imply significant effects in the early stage of DOMS; however, focused extracorporeal shock wave therapy could possibly aid in the midterm recovery from DOMS (48−72h). Further studies are needed to determine if the principle mechanisms of focused extracorporeal shock wave therapy yield on analgesia (recovery) or function (performance).

Suppliers

a. BiAS Version 1.00; EPSiLON-Verlag.
b. Dermagold120; Tissue Regeneration Technologies.
c. Mechanical pressure algometer; pdt.
d. Strain-gauge force transducer; ASYS SPOREG.
e. SPSS Statistics 21.0; IBM.

Keywords

Inflammation; Integrative medicine; Rehabilitation

Corresponding author

Johannes Fleckenstein, MD, Department of Sports Medicine, Institute of Sports Sciences, Goethe-University Frankfurt, Ginnheimer Landstr 39, 60487 Frankfurt am Main, Germany. *E-mail address:* johannes.fleckenstein@sport.uni-frankfurt.de.

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