

Pulsed Electromagnetic Therapy Versus Whole Body Vibration on Quadriceps Strength Post Burn

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Abstract

Severe burns are linked to significant muscular loss and atrophy. Muscle wasting refers to the involuntary loss of 5%–10% of muscle mass, while individuals with severe burns may experience an abrupt loss of up to 25% of total body mass. Whole-body vibration and pulsed electromagnetic field (PEMF) individually affected quadriceps strength post-burn. This work aimed to evaluate the effectiveness of either pulsed electromagnetic field therapy or whole-body vibration on quadriceps strength post-burn. This study involved thirty patients of both genders, aged 25 to 40 years, with second-degree burns covering 10%-25% of TBSA. They were recruited from Al-Ahrar Teaching Hospital at Alsharqiya Governorate, Egypt, and divided at random into two equal-sized groups. Group (A) was given whole-body vibration training three times weekly for 6 weeks, while group (B) was given pulsed electromagnetic field therapy, three sessions weekly for six weeks. The standard physical treatment program was administered to both groups (splinting, stretching, strengthening, and range of motion exercises) for quadriceps muscles and medical treatment. The strength of the quadriceps was assessed for both groups using a handheld dynamometer at baseline as well as six weeks post-intervention. Both groups' mean values of quadriceps strength increased significantly after therapy. Nonetheless, upon comparison, the enhancements in group B were statistically significant relative to those in group A. ($p = 0.002$). Pulsed electromagnetic field therapy was more effective than whole-body vibration in improving quadriceps strength post-burn.

Key words: Pulsed electromagnetic field; Whole-body vibration; Muscles; Strength; Burn.

Introduction

A burn occurs when heat, electricity, abrasion, radiation, or chemical exposure damages the skin or other organic tissues (1). Burn injuries are considered a major worldwide public health problem and constitute one of the most devastating injuries. Burns are the fourth most common type of trauma in the world, after falls, road accidents, and violence from others. About 90% of burns occur in nations with low- and middle-income nations, which often do not have the resources to adequately address the problem (2).

Post-burn muscle atrophy is becoming more widely recognized for its ability to worsen burn patients' illness burden from the first few days of hospitalization until long after they are discharged (3).

A number of factors, including inflammation, physical inactivity, hyper-metabolism, hyperglycemia, as well as hypercatabolism, contribute to postburn muscle atrophy, and these factors are most noticeable during a burn center

stay (3).

In the short term, muscular atrophy is linked to compromised wound healing, heightened infection risk, intensive care unit-acquired weakness, and difficulties in weaning off mechanical breathing, potentially resulting in an extended hospital stay as well as delayed recovery (4).

For more than two decades, the pulsed electromagnetic field has been utilized and researched as a non-invasive technique to accelerate and promote wound healing. It is a successful adjunct treatment for several conditions, including bone fractures, osteoarthritis, acute and long-term inflammation, swelling, discomfort, and persistent aches (5).

Recent evidence has verified that the PEMF can influence mitochondrial functions to enhance muscle growth. The application of PEMF in conjunction with regular exercise training may enhance muscle regeneration while promoting tissue repair (6).

Whole-body vibration (WBV) training, which involves maintaining various static postures or performing exercises on a vibrating platform, is marketed as an attractive as well as effective alternative or complement to resistance exercise (7).

WBV is an innovative neuromuscular training technique that delivers vibrations of varying frequencies to mechanically stimulate the body's receptors, such as muscle spindles (8).

Prior research indicates that WBV training can beneficially influence muscular strength, balance, and functional movement among diabetic patients having peripheral neuropathy as well as those with burn injuries (9).

Therefore, this work aimed to evaluate which intervention is more effective, PEMF or WBV, on quadriceps strength post-burn.

Method:

This prospective randomized controlled study was conducted from November 2023 to May 2024 in the Department of Physical Therapy for Burns, Al-Ahrar Teaching Hospital, located in Alsharqiya Governorate, Egypt, where patient recruitment also occurred. The research received approval from the Ethical Committee of the Faculty of Physical Therapy, Cairo University, Giza, Egypt (No: P.T.REC/012/004833). It was retroactively registered in the Clinical Trials Registry (NCT06525103).

This study involved thirty burn patients of both genders, aged 25 to 40 years, with a burned body surface area (BBSA) ranging from 10% to 25% following complete wound healing. Exclusion criteria encompassed unstable cardiovascular conditions such as arrhythmia as well as heart failure, diabetes mellitus, and chronic pulmonary illness, patients receiving pharmacological agents that influence muscle strength, such as steroids, or those had auditory and visual deficits, pregnancy, and lactation, patients with a history of epilepsy, peripheral vascular disease, musculoskeletal or neurological limitation to physical exercise, any cognitive impairment that interfere with prescribed exercise procedures, amputation of lower limb and cancer patients.

Prior to the commencement of the study, a sample size estimation was conducted utilizing G*POWER statistical software (version 3.1.9.2), which determined that a sample size of 15 participants per group was necessary to mitigate type II errors. Calculations utilized the following parameters: $\alpha = 0.05$, $\beta = 0.2$, effect size = 0.74, as well as allocation ratio $N2/N1 = 1$.

Before being enrolled in our study and after being informed of its goals and methods, all participants were asked to sign a written agreement form. The randomization procedure included sealed envelopes containing cards associated with the PEMF or WBV group. Patients were instructed to select an envelope designating the appropriate group (A or B) for allocation. For six weeks, Group A participated in WBV training, which consisted of three sessions weekly, whereas Group B was given PEMT three times weekly. The standard physical treatment program was administered to both groups (splinting, stretching, strengthening, and range of motion exercises) for quadriceps muscle and

medical treatment.

Procedures

Outcome measures: Quadriceps muscle strength was evaluated by a handheld dynamometer (HHD). The HHD determines the starting minimum force by setting a high or low threshold. At 13.6 Newton, the test data started to be recorded at the high threshold. Peak force readings were displayed on the screen in increments of 4.4 Newton. The CompuFet HHD exhibited a testing range of 3.6 to 440 Newtons. A bolster was placed beneath the knee of the non-dominant limb, and the participants were instructed to lie supine on the Biodex couch (10).

The bolster's placement maintained the knee in a flexed position at an angle of 35° from full extension, as confirmed by a goniometer. The participants were directed and monitored to keep their knees in contact with the bolster during the assessment. The dominant (untested) leg was flexed at both the hip and knee, with the foot resting flat on the sofa to assist in stabilizing the pelvis. Additionally, the participants were told to keep a 35-degree angle with the bolster, maintain their buttocks flat against the settee, and maintain contact with their knees to the bolster. They were instructed to apply maximal force against the pad and attempt to extend their leg from the knee (11). The quadriceps muscle strength was assessed in both groups at baseline and 6 weeks following intervention.

Treatment Procedures

Whole body vibration (WBV) intervention:

This intervention was applied for all patients in group (A) using a crazy fit machine with the following parameters: an input voltage of 220 V, a frequency of 30 Hz, a maximum power output of 1500 W, and the intensity level ranged from 1 to 50 levels. On the vibration platform, each participant was instructed to stand in a squat stance with their knees flexed 90 degrees. This position was selected to mitigate the vibrating platform's vertical sinusoidal accelerations through the engagement of several muscles surrounding the lower limb joints during a duration of 6 weeks, comprising 3 sessions targeting the quadriceps muscle for 30 minutes each day, 3 times weekly (8).

Pulsed electromagnetic field therapy (PEMF) intervention:

This intervention was applied for all patients in group (B) using an EMSCULPT device (BTL Industries Inc., Boston, MA) based on HIFEM technology with the subsequent parameters: frequency 50 or 60 Hz, intensity ranged from 0-100, and the input voltage was 230 V. All participants were asked to lie down on their backs, and the treatment was performed by placing the applicator centered over their thigh region (quadriceps muscle's area) for 15 minutes daily, three times weekly, for a duration of six weeks (12).

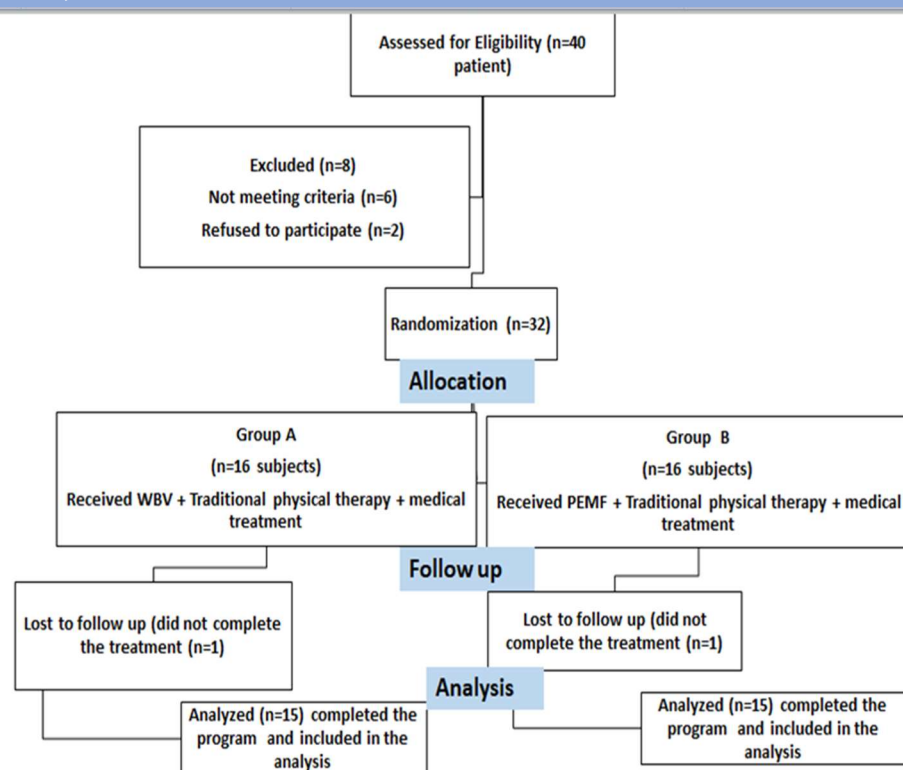


Figure 1. Consort flow chart.

Statistical analysis

Data were presented as the mean $\pm$ standard deviation. Comparisons between subjects' characteristics were conducted using an unpaired t-test. Data distribution normality was assessed utilizing the Shapiro-Wilk test. The effects of the measured variable within and between groups were compared using MANOVA. Data analysis was conducted using the statistical package for the social sciences computer program (version 20, SPSS Inc., Chicago, Illinois, USA). Significant was defined as a P-value of less than or equal to 0.05.

Results:

Demographic data of subjects:

As presented in Table (1), there was no significant difference among the mean value of age as well as BMI of both groups ($p = 0.882$ and 0.671 , respectively); also, there was no significant difference among both groups regarding sex distribution ($p = 0.427$).

Normality test:

The data were assessed for normality, homogeneity of variance, as well as the existence of outliers. The Shapiro-Wilk test for normality indicated that the measured variable exhibited a normal distribution ($p > 0.05$).

Quadriceps muscle strength results

Comparing both groups indicated no statistically significant change in the mean value of quadriceps muscle strength among both groups pre-study ($p = 0.779$), whereas there was a statistically significant change post-study ($p = 0.002$) in favor of group B (Table 2).

Regarding within-group comparison, in each group A and B, there were statistically significant improvements in the mean values of quadriceps muscle strength post-study than pre-study by 50% and 86%, respectively. ($p=0.001$) (Table 2).

Table (1): Demographic data of subjects of each group

Demographic data	Group A	Group B	t-value	p-value
Age (years)	32.3±4.9	32±4.8	0.15	0.882
BMI (kg/m ²)	24.9±4	25.5±4.2	-0.43	0.671
Sex distribution	N (%)	N (%)	$\chi^2 = 1.4$	0.427
Males	3 (20%)	6 (40%)		
Femlaes	12 (80%)	9 (60%)		

Data was expressed as mean $\pm$ standard deviation, χ^2 : chi square, p- value: significance

Table (2): Comparison between pre and post-study mean values of Quadriceps muscle strength between and within groups

Quadriceps strength (Newton)	Group A (n=15)	Group B (n=15)	f-value	P value
Pre-study	15.5 $\pm$ 4.4	15.9 $\pm$ 4.6	-0.47	0.779
Post-study	23.2 $\pm$ 5.6	29.6 $\pm$ 4.4	1.8	0.002*
% of improvement	50%	86%		
P-value ¹	0.001*	0.001*		

Data is represented as mean $\pm$ SD, p- value: significance level between groups, p-value¹: significance level within each group, *: significant.

Discussion

Burns are damage to the tissue caused by heat, excessive sun exposure, other radiation exposure, or contact with chemicals or electricity. Burns may range from mild medical issues to life-threatening crises. The management of burns is dependent upon the site and extent of the injury. Certain individuals require rehabilitation at specialized burn clinics along with prolonged follow-up care spanning several months (13).

Following the burn, the immobility period resulted in several adverse effects, such as significant weakening, compromised motor control, diminished cognitive function, discomfort, danger of graft shearing, and psychological problems (14).

Recent evidence has established that pulsed electromagnetic fields (PEMF) can influence mitochondrial functions to enhance muscle growth. The application of PEMF in conjunction with standard exercise training may enhance muscle regeneration along with tissue repair (8).

Whole-body vibration (WBV) has garnered significant attention because of claims of enhanced physical abilities. Performance indicators that have been shown to improve following acute WBV include muscular strength, power, and force output, as well as electromechanical delay (15). Research on chronic vibration has demonstrated enhancements in comparable neuromuscular parameters, including muscle strength, power, as well as balance (16). The findings of this study indicated a much superior strength of the quadriceps muscle in the PEMF group (group B) relative to the WBV group (group A). The following elucidates these results:

In response to PEMF, every cell in the body works to repair the damage. This includes the endothelial cells that line the blood vessels, the fibroblasts that grow and fix the damaged extracellular matrix, the cells in the muscles, the chondrocytes, as well as the osteoblasts that proliferate faster and more efficiently (17).

The activity of immune system cells, particularly the inflammatory component, is suppressed (resulting in decreased interleukin levels); while the monocytes-to-macrophages activation is promoted to cleanse the damaged zone of bacteria, foreign entities, and necrotic cells. Lastly, PEMF enhances the regenerative outcomes of cells and tissues

while inhibiting the first two of the three possible effects of acute inflammation: necrosis, persistent inflammation, and healing (18).

PEMF stimulation enhances oxygen delivery to muscles during exercise by facilitating enhanced oxygen release and uptake. PEMF stimulation may enhance muscle responsiveness by increasing the amplitude of muscular activation through improved contraction mechanisms (19).

WBV is a therapy technique that mechanically activates the musculoskeletal system. It can significantly enhance muscle strength, improve balance and proprioception, alleviate discomfort, and promote functional activity. Therapists might utilize it for the recovery of muscle strength among burn patients (20).

The results of this study align with the subsequent prior research:

Duncan and Dinev indicated that PEMF enhances muscle mass density by 20.56%. WBV training enhances muscle hyperplasia by 8.0%. Two weeks after therapy, the mean size of muscle fibers increased by 12.15%; however, there were no notable changes in fiber density or hyperplasia in the control group. The researchers propose that PEMF may facilitate non-invasive muscle growth stimulation (21).

Liu et al. indicated that PEMF facilitates myoblast development and proliferation while mitigating muscle atrophy among individuals with diabetes by enhancing protein synthesis and diminishing its breakdown (22).

Plotkin et al. demonstrated that magnetic fields inhibited atrophy, especially in type II fibers (fast-twitch). The rectus femoris possesses a greater proportion of type II fibers compared to the other muscle groups within the quadriceps femoris. Moreover, type II fibers have been demonstrated to possess a high concentration of dihydropyridine receptors (DHPR) among other metabolic distinctions between these fiber types (23).

Venugobal et al. demonstrated that oxidative muscle responded to magnetic exposure. Five weeks of PEMF therapy (10 minutes per week) significantly enhanced the mice's running performance relative to their unexposed counterparts (24).

Coletti et al. reported that a static magnetic field (SMF) facilitated hypertrophy by enhancing the synthesis of both myosin and actin in the myogenic cell line L6 (25).

Jeon et al. examined the impact of PEMF on pain as well as muscle force generation related to delayed-onset muscle soreness (DOMS) throughout recovery following isometric exercise. PEMF therapy applied to the biceps brachii for 10 minutes post-training diminished the intensity of subjective DOMS symptoms in subsequent days, hence improving recovery level. PEMF therapy elevated the frequency of muscle contraction and diminished the electromechanical latency during isometric contraction the day following training, indicating a shorter recovery period (26).

Our investigation corroborated the findings of Osawa et al., who examined the effectiveness of WBV compared to control groups and noted moderately significant impacts on the strength of knee extensors (involving four randomized controlled trials (RCTs)) and countermovement jump performance (using two RCTs), with moderate effect sizes (27).

Artero et al. demonstrated that WBV training enhanced muscle strength more effectively than moderate resistance training (28). Kohan et al. exhibited enhancements in the strength of knee extensors shortly after WBV, with these increases being significantly superior to those observed in a group executing identical exercises without vibration (12).

Gomah et al. determined that WBV serves as an effective alternative to resistance training, as it induces neural adaptations. Additionally, they observed a greater increase in muscle strength among patients subjected to WBV compared to those undergoing conventional physical therapy without vibrations following 8 weeks of treatment (29).

Despite this, Ebid found that WBV exercise, which involves body weight and reflex muscle action, increased

muscular strength more than moderate-resisted training (30).

Conversely, the results of our study contradict several prior investigations:

Rogan et al. examined the impact of WBV training on isometric muscular strength, encompassing 14 RCTs. The authors identified no significant variations in dynamic muscular strength and power among the WBV and control groups (each comprising six RCTs). No changes were detected among WBV and traditional exercises in these analyses (31). Lau et al. identified moderately significant impacts of WBV in comparison to control groups on the strength of knee extensors (encompassing 2 RCTs), lower limb extensors (involving 2 RCTs), countermovement jump performance (involving 2 RCTs), and the five-times-sit-to-stand test (involving 3 RCTs), with no notable difference among WBV as well as traditional exercises (32).

Conclusion:

Pulsed electromagnetic field therapy is considered an effective complementary intervention for quadriceps strength post-burn compared to whole-body vibration training.

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