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# Effect of whole body vibration on leg muscle strength after healed burns: A randomized controlled trial

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ABSTRACT

*Objective:* To investigate the effects of eight weeks whole body vibration training program on leg muscle strength (force-producing capacity) in adults after healed burns.
*Design:* Randomized controlled trial.
*Setting:* Faculty of Physical Therapy, Cairo University.
*Subjects:* Thirty-one burned patients participated in the study and were randomized into whole body vibration group and control group. Non-burned healthy adults were assessed similarly to burned subjects and served as matched healthy controls.
*Methods:* The whole body vibration group performed an eight weeks vibration program three times a week on a vibration platform; the control group received home based physical therapy program without vibration training.
*Main measures:* Assessment of knee extensors and ankle planter flexor strength by isokinetic dynamometer at 150°/s were performed at the beginning of the study and at the end of the training period for both groups.
*Results:* Subjects with burns more than 36% TBSA produced significantly less torque in the quadriceps and calf muscle than non-burned healthy subjects. Patients in whole body vibration group showed a significant improvement in knee extensor and ankle planter flexor strength as compared with those in the control group. Knee extensor strength and percent improvement was $233.40 \pm 5.74$ ($64.93 \pm 3.03$ change score) and 38.54% for the vibration group and $190.07 \pm 3.99$ ($21.66 \pm 4.41$ change score) and 12.86% for the control group, ankle plantar flexor strength and percent improvement was $156.27 \pm 5.95$ ($54.53 \pm 6.16$ change score) and 53.70% for the vibration group and $116.13 \pm 3.24$ ($14.66 \pm 2.71$ change score) and 14.52% for the control group.
*Conclusions:* Participation in whole body vibration program resulted in a greater improvement in quadriceps and calf muscle strength in adults with healed thermal burn compared to base line values; a WBV program is an effective for strength gain in rehabilitation of burned patients.



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## 1. Introduction

Burns result in approximately two million injuries each year and leads to impairment or abnormality in psychological, psychosocial, physiologic or anatomic structure or function [1].

The immobilization period after burn is accompanied by numerous detrimental effect namely sever deconditioning such as sever weakness, impaired motor control decrease cognitive status, pain, risk of graft shearing and psychological factors [2].

Severe thermal injuries followed by a catabolic state leads to muscle wasting and weakness. Burn induces up regulation of acetylcholine receptors, altered mitochondrial function and apoptosis that begins about three to five days post burn and persists until 9–12 months which leads to atrophy of skeletal muscle cells [3].

Whole-body vibration (WBV), i.e. standing in different static positions or exercising on a vibrating platform, is being commercially promoted as an attractive and efficient alternative or complement to resistance training [4]. Specifically, long term WBV exercise suggested to have positive effects on knee extensors strength and power [5–8], and recommended as a therapeutic approach for sarcopenia and osteoporosis [9–11].

Whole body vibration platforms have become increasingly available and used at sports and rehabilitation institutes. There is an emerging profile of application of vibration as an exercise modality [12], mainly due to the documented effects of vibration on the neuromuscular and neuroendocrine systems [9].

Whole-body vibration (WBV) received a great deal of attention due to reports of enhanced physical performance [13,14]. The performance variables reported to be improved after acute WBV are muscle strength, power, rate of force development, and electromechanical delay [15–17]. Chronic vibration studies also have shown increases in similar neuromuscular variables such as muscle strength, power, and balance [18,19]. Improvement of these variables following WBV training result from neuromuscular adaptations resulting in enhanced neuromuscular activation [4,13].

The mechanical stimuli of vibration transmitted to the body and stimulate muscle spindles which activate the alpha motoneurons and initiates muscle contractions comparable to the "tonic vibration reflex". The effect of WBV on the neuromuscular properties of skeletal muscles and spinal mechanisms is demonstrated by a decreased electromechanical delay, increased rate of force development and the pre-synaptic inhibition of skeletal muscles [20], also there was significant increase in VO2 both during and following an acute WBV exercise session compared to the same exercise session without vibration [21] and WBV is effective for inducing a small degree of post activation potentiation [16,22].

Whole-body vibration enhances muscle power [23], improve muscular performance via neurogenic potentiation involving the spinal reflexes and muscle activation [15,18]. Practically, WBV application enhances anaerobic power [23,24]. Previous work demonstrates that WBV leads also to a rapid increase in intra-muscular temperature [25]. Intra-muscular temperature in itself enhances muscle power [26].

Whole-body vibration has been suggested to elicit a high degree of muscle activation [13]. So our study hypothesized that the addition of WBV to home based exercise program for patients with healed burn will result in more gain in muscle strength compared to an identical home based exercise program performed in absence of vibration.

Therefore the aim of our study was to investigate whether the combination of WBV and home based exercise program during 8 weeks has any additional effect on knee extensors and ankle planter flexor compared to an identical exercise program without vibration on patients with healed thermal burn.

## 2. Materials and methods

Burned patients (men and women) were recruited from the burn unit in Umm Almasryeen Hospital after agreement to the participation in the study by instructing two physical therapists who were working in the burn unit to report all patients who fulfilled the inclusion criteria of the study and had no exclusion criteria. They were between 30 and 40 years age. The patients were categorized as having circumferential lower limb deep second to third degree thermal injury extends from the lower trunk to the foot. They received the same physical therapy program during the acute stage (mean time $28.26 \pm 3.39$ days) which includes positioning, range of motion, stretching exercise for lower limb muscles, daily walking, and isometric and isotonic exercise. *Inclusive criteria*: Burned patients, with percentages of burn ranged from 36 to 45% total body surface area, non-smokers, non-athletes. *Exclusion criteria*: prosthesis; any neurological, musculoskeletal, or other chronic disease; participation in an outside resistance training programs, recent fracture or bone injury; any medication that could affect strength adaptations and adversely affect the results of the study, previous brain injury or any disease affecting balance, vestibular or visual disorders and history of epilepsy.

Patients were randomly assigned to one of two groups; whole body vibration (WBV) group who received vibration training on vibration platform (Power Plate International, Irvine, CA, USA) plus home based physical therapy program (range of motion exercise, splinting, stretching exercise for lower limb muscles, daily walking, functional training for ambulation, resistance exercise and activities of daily living) and control group who received the same home based physical therapy program without vibration. All participants in this study follow exercise guidelines prescribed the exercise performed at home (three days/week) regarding the intensity, type and duration to control any variation between groups and instructions about there was no exercise done on the rest of the week. Random assignment of patients was conducted into two stages. Stage one involved instructing two physical therapists who were working in the faculty of physical therapy outpatient clinic to report all patients who fulfilled the inclusion criteria of the study (registration diagnosis, age, total body surface area burned) and had no exclusion criteria. The second stage involved randomly assigning the patients to either the whole body vibration group or the control group, random process that involved opening an opaque envelope prepared by an independent person with random number generation. The randomization process was carried out by a registration clerk who was not involved in any part of the study. Outcome measures include knee extensor strength and planter flexor by using isokinetic dynamometer. A written informed consent form giving agreement to participation and publication of results was signed by the patients and the study was approved by the departmental council. The study was approved by the ethics committee of the Faculty of Physical Therapy, Cairo University.

Non-burned healthy controls; the burned patients were pair-matched with 18 unburned healthy subjects who were recruited from the community. They were assessed similarly to burned subjects by isokinetic dynamometer and served as matched healthy controls. They were paired as closely as possible to the burn subjects for sex distribution, age, weight and height.

### 2.1. *Evaluation of muscle strength*

After complete healing of burn wound (about three weeks) the torque of knee extensors (Quadriceps muscle) and ankle planter flexors (calf muscle) were recorded by using biodex isokinetic dynamometer (Biodex Medical System, Shiley, NY, USA) for both groups and compared with each other at the beginning of the study (Pre) and after eight weeks (Post). Non-burned adults were assessed similarly to burned subjects and served as matched healthy controls; strength was measured as torque. A standardized warm-up of four sub maximal muscle contractions was performed prior to each isokinetic test velocity. The angular velocity for knee and ankle was 150°/s; tests were performed in the following order: (1) knee and (2) ankle. Isokinetic testing involved four cyclic (uninterrupted) maximal repetitions, performed twice. Maximum muscle strength was recorded for the two sets and then reported as an average. In between trials, a 1-min rest period was imposed. Before each trial, participants were instructed to contract specific muscles as fast and as hard as possible. Verbal encouragement was given during the test. Isokinetic testing of the knee extensors, and ankle planter flexors involved standardized body positioning. For all isokinetic tests, participants were strapped securely at the waist and chest. Each participant was instructed to fold their arms across the chest for each contraction to minimize any contribution of the upper body. For each participant, specific set-up measures at the pretest were recorded as well as at the post testing occasion. Knee strength was assessed in the isokinetic chair with the back positioned at 100°. The participants 'knees hung' over the edge of the chair, with the lateral femoral condyle of the tested leg aligned with the axis of rotation of the dynamometer. The dynamometer arm was secured 5 cm superior to the medial malleolus. Knee extensor strength was measured from 90° to full extension. Ankle strength was measured with the participants in seated position with the back positioned at 100°. The tested foot was fixed to the dynamometer footplate, with the ankle maintained at 10° of dorsiflexion. The lateral malleolus was aligned with the dynamometer's axis of rotation. The biodex dynamometer was calibrated prior to testing, using known masses placed on the lever arm.

### 2.2. *Vibration program for WBV group*

On the WBV exercise days the subjects warmed up by walking 3 min on a treadmill at a velocity of 4 km/h. The interventions consisted of three sessions per week for total period of 8 weeks. The total duration of the WBV training stimulus was 10 min in first week and progress gradually to 25 min in the 8th week. The WBV training program consisted of five sets of three repetitions from 1st to 4th week and five sets of four repetitions from 5th to 8th weeks and the duration of each stimulus was 40 s in the first week reaching to 75 s in the eight week, the rest between the sets and repetitions equal to the duration of exercise. The program was comprised of static exercise: squatting 90° knee angle. The frequency of vibration was set at 30 Hz, which produced a peak-to-peak amplitude ranging from 4 to 7 mm and an acceleration of 2.28 g. Recovery periods between the repetitions were 1 min see Table 1. As there is no scientific-based whole body vibration programs the training program of our study was modified from protocols that resulted in significant changes in muscle performance [13,27]. All subjects was individually instructed at the first training session how to perform the vibration training (whole body vibration group), also subjects was supervised during this session.

All subjects was asked to stand in a squat position on the vibration platform with the knees bent 90° this position was chosen because the vertical sinusoidal accelerations of the vibration platform had to be damped by the different muscles around the joints of the lower extremity [28]. Standing in this position induces involuntary muscular contractions (tonic vibration reflex) in the different muscles of the lower

**Table 1 – Training volume and training intensity of the whole-body vibration program.**

| | Sets | Repetition each set | WBV[a] duration (s) | Rest (s) | Amplitude (mm) | Frequency (Hz) | Exercise |
|---|---|---|---|---|---|---|---|
| Week1 | 5 | 3 | 40 | 40 | 4 | 30 | SWBK[a] |
| Week2 | 5 | 3 | 45 | 45 | 4 | 30 | SWBK |
| Week3 | 5 | 3 | 50 | 50 | 5 | 30 | SWBK |
| Week4 | 5 | 3 | 55 | 55 | 5 | 30 | SWBK |
| Week5 | 5 | 4 | 60 | 60 | 6 | 30 | SWBK |
| Week6 | 5 | 4 | 65 | 65 | 6 | 30 | SWBK |
| Week7 | 5 | 4 | 70 | 70 | 7 | 30 | SWBK |
| Week8 | 5 | 4 | 75 | 75 | 7 | 30 | SWBK |

[a] SWBK, standing with bent knees; WBV, whole body vibration.

extremity [18,28,29]. In the first sessions, each subject's position was checked and corrected if necessary.

## 3. Data analysis

All data were examined using SPSS version 16.0. Data were collected and statistically analyzed using repeated measures ANOVA to test hypothesis and to control both within and between variabilities. Results are reported as means and standard deviations. For all procedures, significance was accepted at the alpha level of 0.05.

## 4. Results

For this study, forty burned patients were identified as potential participants (Fig. 1). Of these, six were excluded because they failed to fulfill the inclusion criteria and three refused to participate in the study. Thus, of the original pool, 31 patients with healed thermal burn included in the study .The demographic characteristics of participants in both groups are listed in Table 2. Prior to the training period, there was no difference in the age, weight and height among all groups ($P > 0.05$) as in Table 2. The average length of hospitalization (37.53 ± 2.69 days vs. 39.25 ± 2.20 days), and the length of time between injury and initial evaluation before the study (48.73 ± 3.12 vs. 50.93 ± 4.20 days) were similar in both groups of patients ($P > 0.05$). In this study, the data collected for both groups before treatment (pre) and after eight weeks (post) and were compared with each other and compared with non-burned healthy subjects at the beginning of the study.

### 4.1. *Muscle strength*

The mean values of peak torque for knee extension and ankle planter flexion are reported in Table 3. Peak torque values of knee extensor and ankle planter flexors for non-burned healthy control subjects were (240.39 ± 3.16 Nm and 158.22 ± 1.55 Nm). In all burned patient's peak torque values for knee extensor and ankle planter flexors were (168.47 ± 5.43 Nm and 101.67 ± 1.54 Nm). There was a significant difference in the amount of peak torque between the burned and non-burned healthy control subjects. The burned group had (29.91% and 35.74%) decreased peak torque for knee extensor and ankle planter flexors compared with age non-burned healthy subjects at the beginning of the study. The data concerning the non-burned healthy control (peak torque as mean ± SD) was presented in Table 3.

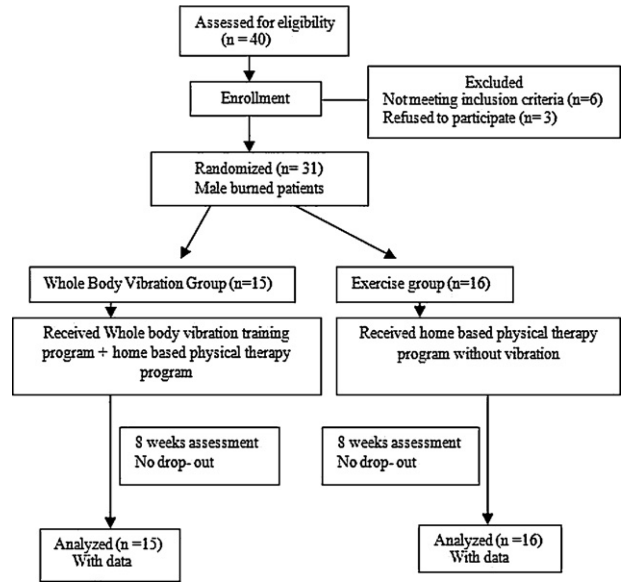


**Fig. 1 – Flow diagram showing the patients participating in the study.**

There was a significant increase in peak torque after 8 weeks in the WBV group and control group with favours to WBV group. Peak torque of knee extensor and ankle planter flexors was (233.40 ± 5.74 Nm vs. 190.07 ± 3.99 Nm and 156.27 ± 5.95 Nm vs. 116.13 ± 3.24 Nm). The WBV group had (38.54% vs. 12.86% and 53.70% vs. 14.52%) increased peak torque compared with the control group. Comparison of the mean percent change obtained revealed a significant increase in peak torque in the WBV group compared to the control group (Figs. 2 and 3).

There was statistically significant improvement in knee extensor and ankle planter flexors peak torque was observed between subjects in the WBV group and their non-burned healthy control subjects after 8 weeks of training. By contrast knee extensor and ankle planter flexors strength was not completely recovered in the exercise group compared with their non-burned matched healthy controls after 8 weeks.

**Table 2 – Subject characteristics (Mean ± SD) for both groups.**

| Variables | Burn subjects | | Non burned |
|---|---|---|---|
| | Whole body vibration group ($n$ = 15) | Control group ($n$ = 16) | Healthy subjects ($n$ = 18) |
| Age (year) | 35.86 ± 2.35 | 36.06 ± 2.40 | 35.66 ± 2.35 |
| Height (cm) | 172.33 ± 5.06 | 172.67 ± 5.24 | 172.17 ± 5.17 |
| Weight (kg) | 76.13 ± 3.13 | 76.46 ± 3.33 | 75.05 ± 3.35 |
| Total body surface area (%) | 38.93 ± 2.52 | 38.93 ± 1.53 | – |
| Gender (male/female) | 10/5 | 10/6 | 12/6 |

There were no significant differences between burn groups, no significant differences between all patients and non-burned healthy.

**Table 3 – Knee extensor and ankle planter flexors peak torque (Nm) in subject with burn and their matched healthy.**

| Isokinetic test 150°/s | Burn subjects | | | | Non burned | | |
|---|---|---|---|---|---|---|---|
| | Whole body vibration group ($n$ = 15) | | Control group ($n$ = 16) | | Healthy subjects | Change score | |
| Knee extensor strength (Nm) | Pre | Post | Pre | Post | | Whole body vibration | Control group |
| Mean ± SD | 168.47 ± 5.43 | 233.40 ± 5.74* | 168.40 ± 5.06 | 190.07 ± 3.99* | 240.39 ± 3.16 | 64.93 ± 3.03 | 21.66 ± 4.41 |
| Percentage of improvement | 38.54% | | 12.86% | | | | |
| Ankle planter flexor strength (Nm) | Pre | Post | Pre | Post | | Whole body vibration | Control group |
| Mean ± SD | 101.67 ± 1.54 | 156.27 ± 5.95* | 101.40 ± 1.45 | 116.13 ± 3.24* | 158.22 ± 1.55 | 54.53 ± 6.16 | 14.66 ± 2.71 |
| Percentage of improvement | 53.70% | | 14.52% | | | | |

Values are mean ± SD.
Nm: Newton meter; Pre: before treatment assessment; Post: post-treatment assessment.
* $P < 0.05$ significant increased compared to pre value for whole body vibration and exercise groups.

## 5. Discussion

This study was designed to test whether the combination of WBV and home based physical therapy exercise program has any additional effect on knee extensors and ankle planter flexor muscles strength compared to an identical exercise program without vibration on patient with healed thermal burn. The results indicate that 8 weeks of combined WBV and home based physical therapy exercise program increased muscle strength (as measured by isokinetic dynamometer at 150°/s) more than home based physical therapy exercise program in the absence of vibrations (Table 3). These strength measures illustrate that the whole body vibration increase lower-limb strength after thermal burn, with significantly larger gains observed in plantar-flexor strength and quadriceps. Our finding showed that whole body vibration induced larger gains in ankle plantar-flexor strength in accordance with previous research demonstrating that vibration applied at the foot predominantly recruits the calf musculature to dampen the stimulus [30]. Whole body vibration induced reflex muscle activity of the ankle plantar flexors is higher than that of the knee extensors [27].

This is the first study to investigate the effects of whole body vibration exercise on muscle strength of lower-limb in adults with healed thermal burn. However, the muscle group closer to the vibration platform will attenuate more of the vibration stimulus than muscles higher up the leg, thus eliciting a greater training response [31].

For an optimal vibration training design, proper parameters need to be determined that include, frequency and amplitude of the vibration used, exposure time to vibration, posture held on the platform, and whether to include exercise while on the platform [32]. For this study, the frequency and the amplitude used were 30 Hz and 2.5 mm which was comfortable for the burned patient. Time is a very important variable that must be considered as it may have an impact on the neuromuscular system. If vibration stimulation is short, the testing of neuromuscular performance during or post vibration will be done in an unfatigued state [8], the time used for each stimulus in our study was 40 s in the first week and 75 s in the last week which was comfortable for burned patients, also patients position in our study was standing with bent knees (SWBK) creating a large physical demand on calf and quadriceps muscles with increased muscle activity under WBV.

It has been hypothesized that vibration training may improve muscle strength by facilitating neural control following tonic vibration reflex muscle activation i.e. increase in motor unit synchronization, co-contraction of the synergist

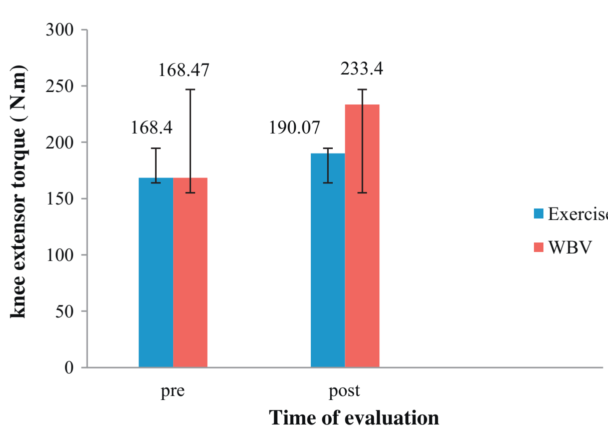


**Fig. 2 – Mean value for knee extensor torque for WBV and control group.**

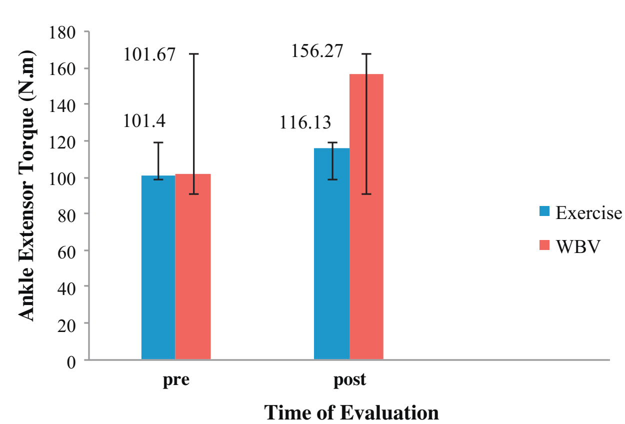


**Fig. 3 – Mean value for ankle planter flexor torque for WBV and control group.**

muscle, increased inhibition of the antagonist muscles, and increased ability of motor units to fire briefly at very high rates [33].

Also, it has been suggested that increased muscle strength may be caused largely by a neuromuscular activation linked to the TVR [18], although a number of articles point to other possible explanations. Issurin [34] reports that the cumulative effect of WBV stimulus improves monosynaptic stretch reflexes induced by afferent signals from muscle spindles, as well as reducing the inhibiting impact of Golgi tendon organs located at myotendinous junctions. Other possible causes may include a change in perceived exertion [35], improved motorneuron excitability [13,15,18], possible improvements in the anabolic hormone balance [36], and muscle hypertrophy could be an effect of long-term adaptation from vibration [8,37]

The early gains in force-generating capacity have been attributed to neural factors, probably related to an increase in sensitivity of the stretch reflex [14,18], stimulation of Ia-afferents via the muscle spindle, resulting in facilitating homonymous a-motor neurons. The responses may in turn trigger specific hormonal responses such as testosterone and growth hormone levels [18]. Recruitment thresholds of the motor units during vibration are lower compared to voluntary contractions, which may resulting in a more rapid activation of the high-threshold fast twitch motor units and consequently a greater training stimulus [15,29].

Despite the increasing scientific interest, the results of WBV interventions on muscular performance differ between studies. Two recent systematic reviews highlighted that gender, age, training status, and exercise protocol are moderators of the response to vibration exercise for strength and power development [5,6]. The type of vibrating platform also seems to affect the training results. For chronic adaptations, like those investigated in our study, synchronous (vertical) platforms have been suggested to elicit a larger treatment effect than alternating (oscillating) platforms [5,6]. Vibration frequencies between 35 and 40 Hz and peak-to peak displacements from 8 to 10 mm have shown to be the most effective for long-term strength and power adaptations [5,6].

A number of studies [13,14,38–40] have shown that WBV exercise resulted in improved muscle strength that was comparable to gains with moderate resistance training. In a placebo-controlled study [13] knee extensor strength improvements following WBV were associated with reflex muscle activity and not the body-weight exercises .The current study also demonstrated improvements in knee extensor strength following WBV, yet these gains were significantly larger than those for a group performing the same exercises without vibration. Results of our study were compared with moderately trained young men or recreationally resistance-trained men because there was lack of studies conducted on non-healthy subjects and this comparison was limited.

In a study with similar aim to ours, three groups of moderately trained young men performed a 9-week program of resistance training, WBV or a simultaneous combination of both [41]. Authors found that maximal isometric voluntary contraction (MVC) equally increased when using resistance training or the combination protocol. The training protocol used our study comprised six sets per session, 30 s vibration sets, 20–25 Hz and 4 mm. The presence (or absence) of vibration was the only difference between combined and resistance training group [41].

Neurological adaptations, which encompass learning and coordination among others, may make their greatest contribution during the early stages of a training program [42]. In non-athletic subjects like those in our study, the potential for neural adaptations may be even higher compared to well-trained athletes [43].

Muscle performance improved in elderly people by 18% after two months of whole body vibration training [44] and the vertical jump height increased by 8.5% after four months of whole body vibration training [27] also after three months of whole body vibration training, isometric and dynamic knee extensor strength improved by 16.6% and 9.0% respectively, whereas an equal number of moderate resistance training sessions induced similar gain 14.4% and 7.0% respectively [13].

De Ruiter et al. [45] conclude that discrepancies among studies often are linked to differences in whole body vibration protocols and methods and total period of the study. Our study applied on burned patients who have definite decrease in muscle strength [1–3] so the gain in muscle strength in burned patients was greater and acceptable. These findings stimulate a growing interest in the potential of whole body vibration training to improve lower limb muscle strength after thermal burn.

Finally, the addition of WBV to home based physical therapy during 8 weeks, in adult with healed thermal burn, result in a larger muscular strength improvement compared to an identical exercise program performed in absence of vibration this improvement relate to decrease skeletal muscle strength after burn and the beneficial effect of loaded WBV training program.

This study has several limitations. The relatively small number of participants might limit the generalization of the study results; large sample size based on power analysis has been required. The relative short period for follow up. Another concern is that subjects were recruited from the only one regional burn centre. During the study, the patients attended three sessions each week. Such a schedule was determined based on the assumption that outpatients would be less inclined to attend more frequent sessions. This limits the generalization of our results to intervention programmes that have a different schedule, such as four times a week. And possibly the fact that the evaluator of the final outcomes was not completely blind of patient groups, was considered another limitation of the study.

## 6. Conclusion

The results of the current study demonstrated that exercise program plus WBV training program for 8-weeks produced a significant improvement in plantar-flexor and knee extensors strength for adult with thermal burn. Following the training period, improvements in planter flexor torque more than quadriceps and showed significant differences between the WBV group and control group. Finally, the strength gains following vibration training appear to be WBV used as one of physical therapy methods for burned patient rehabilitation.

## Conflict of interest

None.

## Practical applications

Vibrations exercise has been shown to be effective in enhancing leg muscle strength in burned patients, and this new technique could be used separately or in combination with conventional strength-training routines for burn patient's rehabilitation. Vibration stimuli are similar to the ones experienced during plyometric exercise and place less stress on joints due to the reduced impact load and this was accepted for burned patients. Different vibration exercise protocols are needed for skeletal muscle training in different pathological conditions.

## Clinical messages

Whole body vibration protocol in combination with a proper physical therapy exercise program improve leg muscle strength in subjects with thermal burn.

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