



Original Article

A prophylactic effect of local vibration on quadriceps muscle fatigue in non-athletic males: a randomized controlled trial study

KHADIJEH OTADI, PhD^{1)*}, MEHRI GHASEMI, PhD²⁾, SHOHREH JALAEI, PhD¹⁾,
HOSSEIN BAGHERI, PhD¹⁾, MORTEZA AZIZIAN¹⁾, SAEID EMAMDOOST³⁾, HADI SARAFRAZ, PhD¹⁾,
MUSTAPH SEPAHVAND, MSc¹⁾

¹⁾ Department of Physiotherapy, School of Rehabilitation, Tehran University of Medical Sciences: Tehran, Iran

²⁾ Department of Physiotherapy, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Iran

³⁾ Department of Physiology, Tehran University of Medical Sciences, Iran

Abstract. [Purpose] This study was conducted to investigate the immediate prophylactic effects of local vibration on quadriceps muscle fatigue in young non-athletic males. [Participants and Methods] Thirty healthy young males were randomly assigned to vibration and sham control groups. Participants in the local vibration group received a single session vibration (2 minutes, 30 Hz). They also in the control group received a 2-minute vibration, while the vibration system was off. MVC, RMS and median frequency of EMG findings and time to reach fatigue were measured. [Results] Time to reach fatigue and MVC in the local vibration group was significantly high than those in the sham control group. [Conclusion] It seems that the prior local muscle vibration may be useful to attenuate some signs and symptoms of muscle fatigue.

Keywords: Fatigue, Vibration, Muscles

(This article was submitted Sep. 23, 2018, and was accepted Dec. 10, 2018)

INTRODUCTION

Muscle fatigue is the decline in ability of a muscle to generate force or power. It can be associated with reduced muscle strength, performance and consequently lower extremity injuries¹⁾. In most cases, muscle fatigue is experienced during sport and exercise activities, but is also increasingly observed as a secondary outcome in various diseases and health conditions during performance of daily activities²⁾.

Quadriceps muscle fatigue can alter gait parameters, and the most injuries occurred when the participants are tired. Therefore, clinically, fatigue prevention is preferable and more important, since it reduces the cost of treatment, time lost from or during training or rehabilitation, and the probability of persisting further injury. It also allows continuation of exercise^{3, 4)}.

There are different types of modalities and exercise therapy aiming at reducing or preventing fatigue such as massage, low level laser therapy, electrical stimulation and stretching⁵⁾.

Vibration is one of the new modalities to recover from or prevent fatigue. There are two shapes of vibration stimulation: whole body vibration and local muscle vibration.

Previous investigations reported controversial effectiveness of whole body vibration on the peak force of quadriceps muscle, recovery from muscle fatigue, flexibility, strength profile of knee flexors, hamstring/quadriceps strength ratio and recovery of muscle damage^{6–10)}.

*Corresponding author. Khadijeh Otadi (E-mail: k_otadi@sina.tums.ac.ir)

©2019 The Society of Physical Therapy Science. Published by IPEC Inc.



This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial No Derivatives (by-nc-nd) License. (CC-BY-NC-ND 4.0: <https://creativecommons.org/licenses/by-nc-nd/4.0/>)

Another shape of vibration is local muscle vibration (LMV), indicating some interesting aspects differentiating it from whole-body vibration. Local vibration can directly provide muscle mechanical pressures and increase local circulation, having the same effect as massage¹¹). The local vibration makes it possible to use very precise vibratory stimulus without propagation of mechanical signals through biological tissues and distortion of the applied signal.

Another advantage of LMV is portable-accessible with cheaper price for patient or athletes; likewise, LMV is user friendly, since patients can use it at home.

Limited studies^{12, 13}) have assessed the effect of local vibration on muscles. These studies demonstrated that LMV induced significantly higher muscle activity than no vibration (NV) condition, and LMV could affect motor performance as well as acceleratory recovery of muscle neural activation. It can also prevent inflammation, increases ROM, has positive effects on muscle function and contributes to clinical improvement of patients^{7, 10, 14-16}).

Although there seems to be more positive than negative results for vibration in recovery and performance, it remains unclear whether vibration would be a useful recovery modality used to enhance performance and alleviate fatigue after exercise. Likewise, the preventive effect of LMV on fatigue is unclear. Furthermore, the present study aimed to investigate prophylactic effects of local vibration on the quadriceps muscle fatigue.

PARTICIPANTS AND METHODS

This study was a semi-experimental sham-controlled cross-over randomized trial, registered in Iranian Registry clinical trial (IRCT) with the number 20090228001719N7. A total of 30 healthy non-athletic young males without any problem in lower limb volunteered to participate in this experiment (age 21 ± 9 years, height 175 ± 0.1 cm, weight 72.5 ± 8 kg). Participants with neuromuscular pathology, lower leg injury and cardiovascular diseases were excluded. Written informed consent was obtained from all participants prior to their participation, and protocol was approved by Tehran University of Medical Sciences Ethics Committee with a code of 34556.

Thirty participants was determined based on pilots study, and then were randomly assigned into two groups (LMV and control groups). Fix bike for 5 minutes was used to warm up the participants. Then participant sit on the chair to start the test. For each person, the chair was adjusted so that the individuals could sit in the middle of the chair with 90° knee flexed, and dynamometer pedal was placed at 3 cm above the lateral malleolus.

First, the maximum voluntary contraction (MVC) was measured in three repetitions and maximum value was recorded. Electromyography electrodes and myometer electrodes (Biometrics Ltd., UK) connected to the dynamometer were closed to the leg. In the vibration group, the participants were asked to exert maximum isometric force of quadriceps muscle to reach fatigue. Vibration began for 30 s after completion of the pre-intervention measurements.

LMV was applied by a handheld mechanical vibration generator (Thrive, 717A, Japan). No pressure was applied on the head of the vibrator (5 cm in diameter). Previous studies have demonstrated beneficial effects of vibration in preventing or treating DOMS vibration at 50 Hz frequency for 2 minutes on the middle line of dominant side quadriceps^{7, 14}).

When the participants were tested in control group, the hand held vibrator was turned off.

MVC was calculated in before and immediately after LMV or Sham vibration intervention. And likewise during intervention RMS and median frequency and time to reach fatigue was calculated.

Randomized group allocation was determined by using unmarked envelopes in clinic to achieve simple randomization. There were 30 envelopes, 15 of which contained the word "LMV" on 15 of which contained the word "sham-LMV". Therefore in the first part of the study fifteen participants were randomly assigned to LMV and fifteen participants were randomly assigned to the sham vibration. Then, in the second part of the study, they went through a wash-out period. Finally, in the third part of the study, those who received LMV at first received the sham vibration while those who received the sham vibration at first received LMV, which is the cross-over part.

Experiment was done on biomechanics lab in Shahid Beheshti University of Medical Sciences.

MVC was recorded by dynamometer, and root mean square and median frequency (RMS, MF) and time to reach fatigued were recorded by electromyography (Data Log, Biometrics Ltd, UK). Two double differential bar electrodes were positioned over each of the superficial muscles of the quadriceps according to Fry (2014)⁸).

The participants were verbally encouraged to perform maximal voluntary contraction of quadriceps muscle to extend the knee.

Peak force of quadriceps muscle, median frequency, and RMS were measured during inducing muscle fatigue to reach fatigue point. Fatigue was defined as a reduction in the force production of $\geq 50\%$ of the peak force compared to the baseline pre-fatigue activity¹⁷).

The same method was applied in the sham control group, while the LMV machine was turned off.

Statistical analysis was performed using Statistical Package for Social Sciences, version 16.0 (SPSS, Chicago, IL, USA). Data were analyzed using paired t-test, and the effect size as well as power was sorted out by repeated measurement ANOVA. Significance was accepted for values of $p < 0.05$ in all analysis.

Table 1. Mean \pm SD of outcome measures (MF, RMS) in the two groups

	Vastus medialis			Rectus femoris			Vastus lateralis		
	Control	Vib	p value	Control	Vib	p value	Control	Vib	p value
RMS (mv)	0.063 \pm 0.03	0.068 \pm 0.04	p=0.08, ES=0.07	0.041 \pm 0.02	0.048 \pm 0.03	p=0.07 ES= 0.1	0.081 \pm 0.03	0.082 \pm 0.03	p=0.1 ES=0.02
MF (h)	64.7 \pm 8.4	65.5 \pm 10.03	p>0.05 ES=0.04	62.3 \pm 6.3	63.4 \pm 6.7	p>0.05 ES=0.08	64.9 \pm 5.3	64.6 \pm 5.1	p>0.05 ES=0.03
Time (ms)	24.82 \pm 1.03	26.8 \pm 1.03	p value=0.006* ES=0.7						

mv: micro volt; h: hertz; ms: mili second; ES: Effect Size.

*p<0.05.

Table 2. Mean \pm SD Maximum Voluntary Contraction (micro volt): MVC

	Control	Vib
Pre-test	156.5 \pm 41.04	156.3 \pm 40.1
Post-test	156.7 \pm 41.3	157.8 \pm 40.4
p value	p>0.05	p<0.05*

RESULTS

We didn't have dropped participant, therefore all participants continued the experimental procedures to end. So the 30 participants were used for the final analysis. Table 1 displays the mean values for the outcome measures. Paired t-test revealed a significant difference in MVC in the vibration group in pre to post-test (p<0.05), but not in the control group (Table 2). Changes in MVC showed a significant difference (p<0.03) between the two groups at the end of fatigue activity, but not at first. Effect size was 0.35 and power 0.12. Significant difference was found between the vibration and control groups in time to reach fatigue (p=0.006). No significant difference existed between the two groups in RMS and MF.

DISCUSSION

The current randomized controlled trial aimed to examine prophylactic effects of local vibration on quadriceps muscle fatigue. It was found that two-minute vibration improved the MVC of Quadriceps muscle in the LMV group compared to the sham group. RMS, MF and time to reach fatigue were different between the LMV and sham control groups in favor of fatigue prevention in the LMV group. However only significant difference (p=0.006) was found in time to reach fatigue parameter in comparison the LMV group with sham group.

The findings of this study are in line with results of those studies reporting that vibration improved voluntary muscle activation or peak isometric torque of knee extensors, muscle activation during maximal isometric knee extensor force production, or maximal rate of force rise and the muscle performance^{7, 15, 18}. Some studies reported that vibration did not affect either MVC of quadriceps or decrease of muscle weakness^{8, 19}.

Previous studies reported that vibration was highly effective for muscle damage recovery, acceleration of muscle neural activation recovery^{7, 13, 20}; however, some studies have reported that vibration has a negative effect on muscle fatigue or muscle weakness^{6, 21}.

One study has indicated a significant increase of RMS after WBV compared to the sham control group¹⁸. This controversial result may be due to different cases, setting and sample size. In this study RMS measures in the LMV group were more than those in the sham control group without significance; therefore, we think that larger sample size induces significant results.

Significant increase of MVC in the LMV group without significance in EMG finding may be owing to more involvement of type II muscle fiber in the LMV group. It seems that local vibration has more affects on type II muscle fiber than type I. This result is in line with Benedeti's report about increase of type II muscle fiber recruitment in the local vibration group compared to the sham control group¹⁶.

Considering the longer time to reach fatigue in the LMV group, we can state that recruitment of type I muscle fiber was more than that in the control group.

In this respect, different settings had optimal effects on prevention and prolongation to reach fatigue. Regarding the small effect size, it seems that an increase in sample size may yield promising results.

Another possible explanation is that the participants might need a longer period of vibration to obtain significant prophylactic effects on muscle fatigue. One major limitation of our results was the young healthy participants. Therefore, we cannot

generalize these data and results to other pathological situation or different ages. In conclusion these results suggest that a single session of local muscle vibration was effective in improving of MVC and increasing of time to reach fatigue.

Funding

This paper was supported by Tehran University of Medical Sciences, Tehran, Iran.

Conflict of interest

None.

REFERENCES

- 1) Barry BK, Enoka RM: The neurobiology of muscle fatigue: 15 years later. *Integr Comp Biol*, 2007, 47: 465–473. [[Medline](#)] [[CrossRef](#)]
- 2) Rimmer JH, Schiller W, Chen MD: Effects of disability-associated low energy expenditure deconditioning syndrome. *Exerc Sport Sci Rev*, 2012, 40: 22–29. [[Medline](#)] [[CrossRef](#)]
- 3) Pinsault N, Vuillerme N: Differential postural effects of plantar-flexor muscle fatigue under normal, altered and improved vestibular and neck somatosensory conditions. *Exp Brain Res*, 2008, 191: 99–107. [[Medline](#)] [[CrossRef](#)]
- 4) Kavanagh JJ, Morrison S, Barrett RS: Lumbar and cervical erector spinae fatigue elicit compensatory postural responses to assist in maintaining head stability during walking. *J Appl Physiol* 1985, 2006, 101: 1118–1126. [[Medline](#)] [[CrossRef](#)]
- 5) Dos Reis FA, da Silva BA, Laraia EM, et al.: Effects of pre- or post-exercise low-level laser therapy (830 nm) on skeletal muscle fatigue and biochemical markers of recovery in humans: double-blind placebo-controlled trial. *Photomed Laser Surg*, 2014, 32: 106–112. [[Medline](#)] [[CrossRef](#)]
- 6) Kim JY, Kang DH, Lee JH, et al.: The effects of pre-exercise vibration stimulation on the exercise-induced muscle damage. *J Phys Ther Sci*, 2017, 29: 119–122. [[Medline](#)] [[CrossRef](#)]
- 7) Ansari NN, Naghdi S, Karimi-Zarchi H, et al.: A randomized controlled pilot study to investigate the effect of whole-body vibration on lower-extremity fatigue. *J Sport Rehabil*, 2017, 26: 339–346. [[Medline](#)] [[CrossRef](#)]
- 8) Bakhtiary AH, Safavi-Farokhi Z, Aminian-Far A: Influence of vibration on delayed onset of muscle soreness following eccentric exercise. *Br J Sports Med*, 2007, 41: 145–148. [[Medline](#)] [[CrossRef](#)]
- 9) Fry A, Folland JP: Prolonged infrapatellar tendon vibration does not influence quadriceps maximal or explosive isometric force production in man. *Eur J Appl Physiol*, 2014, 114: 1757–1766. [[Medline](#)] [[CrossRef](#)]
- 10) Kararantou K, Gerodimos V, Dipla K, et al.: Whole-body vibration training improves flexibility, strength profile of knee flexors, and hamstrings-to-quadriceps strength ratio in females. *J Sci Med Sport*, 2013, 16: 477–481. [[Medline](#)] [[CrossRef](#)]
- 11) Imtiyaz S, Veqar Z, Shareef MY: To compare the effect of vibration therapy and massage in prevention of Delayed Onset Muscle Soreness (DOMS). *J Clin Diagn Res*, 2014, 8: 133–136. [[Medline](#)]
- 12) Yildirim A: Acute effects of local vibration on muscle performance at different durations and frequencies. Middle East Technical University. 2010.
- 13) Poenaru D, Cinteza D, Petrusca I, et al.: Local application of vibration in motor rehabilitation—scientific and practical considerations. *Maedica (Buchar)*, 2016, 11: 227–231. [[Medline](#)]
- 14) Broadbent S, Rousseau JJ, Thorp RM, et al.: Vibration therapy reduces plasma IL6 and muscle soreness after downhill running. *Br J Sports Med*, 2010, 44: 888–894. [[Medline](#)] [[CrossRef](#)]
- 15) Lau WY, Nosaka K: Effect of vibration treatment on symptoms associated with eccentric exercise-induced muscle damage. *Am J Phys Med Rehabil*, 2011, 90: 648–657. [[Medline](#)] [[CrossRef](#)]
- 16) Benedetti MG, Boccia G, Cavazzuti L, et al.: Localized muscle vibration reverses quadriceps muscle hypotrophy and improves physical function: a clinical and electrophysiological study. *Int J Rehabil Res*, 2017, 40: 339–346. [[Medline](#)] [[CrossRef](#)]
- 17) Wojtys EM, Wylie BB, Huston LJ: The effects of muscle fatigue on neuromuscular function and anterior tibial translation in healthy knees. *Am J Sports Med*, 1996, 24: 615–621. [[Medline](#)] [[CrossRef](#)]
- 18) Pamukoff DN, Ryan ED, Blackburn JT: The acute effects of local muscle vibration frequency on peak torque, rate of torque development, and EMG activity. *J Electromyogr Kinesiol*, 2014, 24: 888–894. [[Medline](#)] [[CrossRef](#)]
- 19) Mohammadi S, Bakhtiary A, Tabesh H, et al.: Effect of local quadriceps vibration on the treatment of knee osteoarthritis symptoms. *Majallah-i Ilmi-i Danish-gah-i Ulum-i Pizishki-i Rafsanjan*, 2013, 12: 279–290.
- 20) Kamandani R, Ghazalian F, Ebrahim K, et al.: The effect of acute vibration training on delayed onset muscle soreness in young non-athlete women. *Health Scope*. 2013, 2: 119–124. [[CrossRef](#)]
- 21) Abbasi E, Kahrizi S, Razi M, et al.: The effect of whole-body vibration training on the lower extremity muscles' electromyographic activities in patients with knee osteoarthritis. *Med J Islam Repub Iran*, 2017, 31: 107. [[Medline](#)]