ABSTRACT

**Purpose:** The aim of the study was to investigate the origin and magnitude of neuromuscular fatigue induced by half-squat whole-body vibration.

**Methods:** Ten young, recreationally trained adults participated in six fatiguing protocols, each consisting of several sets of 30, 60 or 180 s static squatting superimposed with vibration (WBV$_{30}$, WBV$_{60}$, WBV$_{180}$) or without vibration (SHAM$_{30}$, SHAM$_{60}$, SHAM$_{180}$) for a total exercise exposure of 9-minutes in each trial. Maximum voluntary contraction (MVC), level of voluntary activation (%VA), single twitch peak torque (TW$_{PT}$), low- ($T_{20}$) and high-frequency ($T_{100}$) doublets, and low-to-high-frequency fatigue ratio ($T_{20/100}$) were assessed before, immediately after, 15 and 30 minutes after each fatiguing protocol.

GUIDELINES

**Study design:**

Each subject performed three different fatiguing exercises interventions with WBV and three exercise interventions in a SHAM condition without WBW (SHAM) to discriminate the effect of WBV. Each intervention contained a cumulative exercise period with a duration of 9 minutes divided into different sets (either 18 x 30 s or 9 x 60 s or 3 x 180 s), with 120 s rest between sets. Each intervention was randomly executed on different visits at the same day-time with at least 7 days rest in-between.
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Protocol status: Working
We use this protocol and it's working.

Created: Mar 26, 2020

Last Modified: Nov 03, 2020

PROTOCOL integer ID: 34853

Keywords: Level of voluntary activation, Maximum voluntary contraction, Whole body vibration, Double interpolated twitch technique, Doublets, high to low frequency ratio, neuromuscular fatigue, single twitch, double twitch, electrical stimulation.

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**Equipment**

**NAME**  
**TYPE**  
**BRAND**  
**SKU**  
**LINK**

**DS7A**  
HV Constant Current Stimulator  

Digitimer  
1  

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**Equipment**

**NAME**  
**TYPE**  
**BRAND**  
**SKU**  
**LINK**

10 mm Ag–AgCl electrode  
Type 0601000402  
Controle Graphique Medical  
1  

https://controle-graphique.fr/  
The picture is not the same as the electrode used

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**Equipment**

**NAME**  
**TYPE**  
**BRAND**  
**SKU**  
**SPECIFICATIONS**

ELECTRODES PERFORMANCE 50 X 100MM PIN  
Electrode  
Compex  
1

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protocols.io  
https://dx.doi.org/10.17504/protocols.io.beadjaa6  
Oct 3 2020
### Equipment

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<th>Type</th>
<th>Brand</th>
<th>SKU</th>
<th>Specifications</th>
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<td><strong>Isometric machine with force transducer</strong></td>
<td>Isometric dynamometer</td>
<td>Custom Made</td>
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<td>Force transducer (MES, Maribor, Slovenia) already used in (Tomazin et al. 2008; Garcia-Ramos et al. 2016)</td>
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<td><strong>Galileo Fit</strong></td>
<td>Whole body vibration platform - WBV</td>
<td>Novotec Medical GmbH</td>
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### Equipment calibration

1. We calibrated the
prior to each measuring session.
The signal of the dynamometer was connected to

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**Equipment**

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<tr>
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**PowerLab 16/35 (PL3516)**

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<td>DAQ - data acquisition hardware</td>
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<td>ADInstruments</td>
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**Software**

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<th>Name</th>
<th>OS</th>
<th>Developer</th>
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<td>LabChart</td>
<td>Windows XP</td>
<td>ADInstruments Australia</td>
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</table>

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protocols.io | https://dx.doi.org/10.17504/protocols.io.beadja6

Oct 3 2020
The same machine has been used in several other studies:

**CITATION**


[LINK](https://doi.org/10.1007/s00421-008-0685-y)

**CITATION**


[LINK](https://doi.org/10.1515/hukin-2015-0152)

We calibrated the force transducer, by hanging a 20 kg weight. We read the Voltage transformation to calculate the exerted torque.

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**Pre experiment procedures**

1. We invited the subject to seat on the Isometric dynamometer in order to adjust the seating position and lever arm. The subject was positioned in an upright sitting position, the trunk at 100° leaning against the backrest of the isometric dynamometer, fixed by straps over the pelvis and a horizontal pad over the distal third of the thigh. The knee joint axis was aligned with the mechanical axis of the dynamometer. The shin pad was placed just above the medial malleolus. The right knee joint was fixed at a 60° angle (0° = full extension).

2. Femoral nerve stimulation electrode placement

We invited the participants to flex their hip from in a seated position, while we palpated the iliac fossa.
and placed the electrode (cathode) into the femoral triangle.

A larger self-adhesive electrode placed over the gluteal fold served as an anode.
Femoral nerve test stimulation

Electrical impulses (single, square wave, 1-ms duration) elicited by a high voltage constant current electrical stimulator were used to trigger the muscle response, which was detected as a change in knee extensors torque.

4.1 We elicited several impulses (3 in average, max 6) at a fixed intensity of 20 mA at a frequency of 0.1 Hz and slightly moving the cathode in order to find the spot which produced the highest response (highest torque).
Warm-up

5 00:06:00 warm-up routine consisting of bench stepping (20 cm high) at a frequency of 0.5 Hz with a leg exchange each minute

6 00:02:00 rest

Pre experiment procedure

7 The stimulation intensity to elicit the maximum knee extensor isometric twitch was determined in each subject after Warm-up (starting from 10 mA) progressively increasing the stimulation intensity by 10 mA until no further increase in torque was observed despite further increment in current. The current at maximal twitch torque was additionally increased by a factor of 1.5 to obtain a supra-maximal stimulus. This intensity was maintained for the entire visit.

PRE - assessment (t0)
8.1 Maximal voluntary contraction with double twitch interpolated techniques

Subjects were asked to perform a 5 s maximal isometric voluntary (MVC) knee extension.

The signal was smoothed using a 0.5 s window moving average filter and peak torque (MVC) was retained for analysis. The double twitch interpolated technique.
was performed by superimposing a 100 Hz doublet on the isometric plateau (T\textsubscript{MVC}). A second analogous stimulation (T\textsubscript{100}) on the relaxed muscle followed after 3 s.

The ratio of the amplitude of the T\textsubscript{MVC} over T\textsubscript{100} was then calculated to obtain the level of voluntary activation (\%VA):

\[
\%VA = (1 - \frac{T\text{MVC} - MVC}{T\text{100}}) \times 100
\]

8.2 **High- and low-frequency doublets**

The torque change induced by the paired high- (100 Hz, i.e. 10 ms interstimulus interval) and low-frequency (20 Hz, i.e. 50 ms interstimulus interval) supramaximal electrical stimuli were analyzed.

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**CITATION**


**CITATION**


**LINK**

https://doi.org/10.1152/japplphysiol.01051.2007
The following parameters were obtained: peak torque from 100 Hz doublet ($T_{100}$), peak torque from 20 Hz doublet ($T_{20}$) and the low- to the high-frequency ratio ($T_{20}/T_{100}$) was calculated using the following formula:

$$ T_{20}/100 = \frac{T_{20}}{T_{100}} \times 100 $$

This ratio was then used as a surrogate of low- to high-frequency tetanic stimulation.

8.3 Single twitch

The torque change induced by the single supramaximal femoral nerve stimuli was analysed.

The following parameters were obtained: 1) the maximum torque value ($TW_{PT}$);
which was switched on (or off for SHAM conditions) at a frequency of \(26 \text{ Hz}\). Subjects were instructed to maintain a half-squat position with their knees flexed at an angle of 60°. Subjects stood with their feet 40 cm apart where the tilting platform reaches peak-to-peak displacement amplitude of 5 mm.

CITATION


LINK

https://doi.org/10.1007/s00421-012-2402-0

POST assessments - \((t_f)\)

10 Repetition assessment procedure

POST 15 assessments - \((t_{f15})\)

11 Repetition assessment procedure
A two-way factorial ANOVA was conducted in 

Software

R programming language

The R Foundation

Comprehensive R Archive Network

with the

Software

afex: Analysis of Factorial Experiments

Henrik Singmann

https://cran.r-project.org/web/packages/afex/index.html

to compare the main effects of time and trial and the interaction effect of time \times trial. Generalized eta squared (\eta^2) effect sizes were calculated for the ANOVA main and interaction effects.
The *emmeans* package (Lenth et al. 2018) was used to perform follow-up post hoc analysis. Planned comparisons were performed using Sidak corrected linear contrasts comparing. Statistical significance was set at $p < 0.05$. Standardized changes in the mean of each measure were used to assess magnitudes of effects and were calculated using Cohen’s $d$ and interpreted using thresholds of 0.2, 0.5, 0.8 for small, moderate and large, respectively (Batterham and Hopkins 2006). An effect size of $\pm 0.2$ was considered the smallest worthwhile effect with an effect size of $< 0.2$ considered to be trivial. The effect was considered unclear if its 95% confidence interval overlapped the thresholds for small positive and small negative effects.