Original Article

ACUTE EFFECTS OF LOCAL VIBRATION ON THE NEUROMUSCULAR RESPONSES

EFEITO AGUDO DA VIBRAÇÃO LOCAL SOBRE AS RESPOSTAS NEUROMUSCULARES

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ABSTRACT: The aim of this study was to evaluate acute neuromuscular responses to local vibrations (LV) exposure through monitoring of imposed acceleration. Nineteen healthy males (age = 22.43 ± 2.76 years; body mass = 76.4 ± 12.94 kg; height = 175 ± 6.76 cm) performed an elbow flexion isometric exercise (Scott bench) in two experimental conditions: simple isometric exercise (Control - CON) and vibrating isometric exercise (Local Vibration - LV; Frequency = 20.01 ± 0.13, displacement = 2 - 5 mm). Protocols consisted of 5 maximal voluntary contractions of 12 seconds each and five minutes of recovery between series with (LV) or without vibration (CON). During the exercise, individuals were seated on the bench with the dominant arm resting on the bench support at an approximate angle of 45º between shoulder flexion and the torso. Strength parameters (Rate of Force Development - RFD, p = .030; Peak Force - PF, p = .027; and Fatigue Index - FI, p = .001) significantly increased in LV compared to CON. For EMG parameters, significant changes were only observed for highest value of increase rate of the EMG signal - RER (p = .041), median frequency of EMG signal between peak force and force at the end of the isometric action - MFFbic (p = .045) (agonist) and root mean square of EMG signal of peak force at the end of the isometric action - RMSFtric (p <.001) (antagonist). The addition of local vibrations in resistance training induced an increase in maximal strength, explosive strength and reduced the capacity to sustain strength generation.

KEYWORDS: Biomechanics, Local vibrations, Maximal Strength, Resistance training, Electromyographic activity.

INTRODUCTION

In sport sciences, the first studies involving vibration were conducted as an alternative to conventional methods of improving strength and flexibility (ISSURIN; TENENBAUN, 1999). The most commonly used devices to provide vibrations are whole body vibration devices, combined with body bearing exercises without external loads (CARDINALE; BOSCO, 2003, HAAS et al., 2005; SPILIOPOLOU et al., 2013). On a smaller scale, it has been used to provide direct vibrations to a body segment. It is a vibration application system attached to cables and bars (ISSURIN; TENENBAUN, 1999; MORAS et al., 2009; FRIESENBICHLER; COZA; NIGG, 2012) or directly attached over the muscle tendon unit. These are classified as local vibration (LV, sinusoidal or random vibrations) devices (LUO; MCNAMARA; MORAN, 2008; LUO et al., 2009). Surprisingly, vibration has increasingly become importance over the past two decades in training programs, without a consensus on acute responses (RITTWEGER, 2010; FRISENBICHLER et al., 2012).

Mechanisms that explain human responses to vibration during exercise are not yet clearly understood (RITTWEGER, 2010; FRISENBICHLER et al., 2012). However, it has been suggested that the sinusoidal length change in the muscle tendon unit induced by vibration stimulates the afferent endings of muscle spindles combined with voluntary activation. Muscle spindle stimulation produces an excitatory effect on alpha motor neurons, leading to a reflex contraction of agonist muscles (BONGIOVANNI; HAGBARTH, 1990; RITTWEGER, 2010). As a result of exposure to vibration, the muscle tonic contraction is stimulated by a tonic vibration reflex and a concomitant inhibition of antagonist muscles (BONGIOVANNI; HAGBARTH, 1990; CARDINALE; BOSCO, 2003; RITTWEGER, 2010).

Additionally, it has been shown that LV is capable of amplifying the response of muscle spindle afferent endings in animal models (CORDO et al., 1996; FALLON; CARR; MORGAN, 2004), inducing an increase in the reflex response of a synergist muscle stretch (MARTINEZ et al., 2007).

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However, none of these studies directly investigated motor responses with this type of stimulation on human models (LUO; MCNAMARA; MORAN, 2008; LUO et al., 2009). Furthermore, it remains inconclusive whether adding LV produces any positive acute effect on neuromuscular performance (Electromyographic activity – EMG, and muscle strength) in resistance training. Little evidence of an acute performance improvement associated with vibration has been verified (LUO; MCNAMARA; MORAN, 2008; LUO et al., 2009; MARIN; RHEA, 2010).

Thus, the aim of this study was to evaluate acute neuromuscular responses to LV exposure through monitoring of imposed acceleration. It was hypothesized that vibration should positively affect the muscle function.

MATERIAL AND METHODS

Sample

The study included 19 male healthy volunteers (22.43 ± 2.76 years; 76.4 ± 12.94 kg; 175 ± 6.76 cm). After the necessary explanation, volunteers signed a written consent. The study was approved by the local ethics committee and conducted in accordance with the declaration of Helsinki. The sample calculation resulted on a minimum of 17 volunteers. The sample size was determined considering a 95% significance level ($p<0.05$) and a statistical power of 90%.

Experiment protocol

The exercise was a dominant limb elbow flexor exercise of muscles' maximal isometric action on a Scott bench (Figure 1A). During the exercise, individuals were seated on the bench with the dominant arm resting on the bench support at an approximate angle of 45º between shoulder flexion and the torso (ISSURIN; TENENBAUN, 1999). The radio-ulnar joint remained in supination and the elbow remained flexed at about 90º. To provide wrist stability during the exercise, volunteers used orthosis in the dominant member.

During sessions, the contralateral limb remained stretched on the bench in order to activate the manual trigger, and synchronize EMG and muscle strength. For the fixation and stabilization of the elbow, the bench had a workpiece support that was adjustable to the upper limb dimensions. It was located in the central portion of the seat support's rubber plate. The bench also had angle adjustment and holder slipping.

Then, after familiarization to the exercise, the subjects were submitted to tests using a strong verbal encouragement. Five to seven days of interval were applied among sessions, which were always conducted at the same day time. At the beginning of the sessions, volunteers performed a warm-up exercise consisting of a light jogging activity (5 minutes) followed by a 5-minute exercise for the upper limbs on a cycle ergometer (Maxx®, Hidrofit, Belo Horizonte, Brazil).

Protocols consisted of 5 maximal voluntary contractions of 12 seconds each and five minutes of recovery between series with (LV) or without vibration (CON). In the LV exercise, LV with a frequency range of 17-23 Hz and 2-5 mm peak-to-peak displacement were applied (LUO; MCNAMARA; MORAN, 2008; MARIN; RHEA, 2010). During each muscle action, individuals were asked to activate the trigger button to synchronize strength and EMG data immediately after performing the exercise.

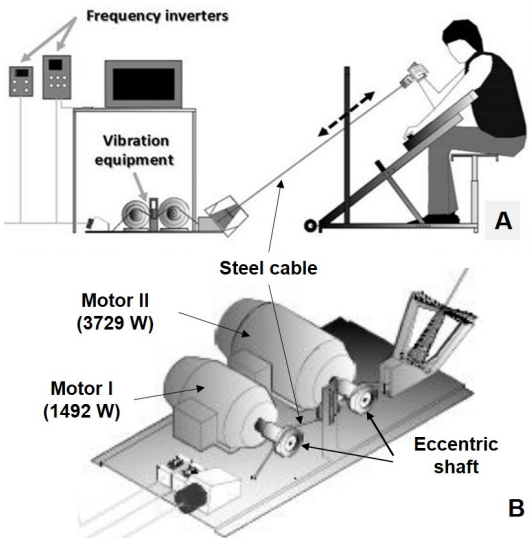

Figure 1. (A) Elbow flexion isometric exercise, (B) Equipment for application of vibration.

Equipment for application of vibration

The equipment (Figures 1A and 1B) consisted of two independent systems working together. The first system consists of an induction motor and a frequency converter (IP55, 1,492 W, 1,740 rpm and CFW08, respectively; WEG®, Jaragua do Sul, Brazil) connected to an eccentric shaft (2 mm) pulling or pushing a piece with a bearing adjacent to a steel cable (Figure 1). The motor's rotation speed was determined by the man-machine interface of the converter (constant speed of 1,200 rpm).

The second system consists of an induction motor controlled by an inverter (IP55, 3,729 Watts, 1,800 rpm and CFW09, respectively; WEG®, Jaragua do Sul, Santa Catarina, Brazil), also coupled to an eccentric shaft (Figure 1B, 3 mm). To determine the motor's speed range, a signal was generated from 0 to + 5V with the software LabView® (National Instruments, Austin, Texas, USA). It used the analog output of a data acquisition card (NI-DAQ I/O USB6009®, National Instruments, Austin, Texas, USA) for analog inputs of the reference motor speed of the inverter, where it was amplified with a scale from 0 to + 10V.

A sinusoidal signal of 0.1 Hz, combined with a uniform white noise proportional to the motor's speed range of 1,020 at 1,380 rpm (17 – 23 Hz), was emitted. The generated signal was proportional to the desired frequency of the vibration exercises. The combined shaft's motion tensed the cable, producing a displacement (mm) conditioned by its eccentricity level.

Data Analysis

EMG measurement

To obtain the electromyographic signal, a skin shaving and the placement of electrodes on the biceps and triceps brachii (lateral portion) muscles was performed (MISCHI; CARDINALE, 2009). After warming up exercises, collection sites were marked and the electrodes were placed. During experimentation, the volunteers were asked to maintain the markings of collecting sites on the skin. Circular Ag/AgCl electrodes were used with a 10 mm diameter, 3M®, model 2223BRQ, with bipolar configuration and a 20-mm inter-electrode distance from center to center.

EMG signals were differentially amplified (total amplification gain = 2,000 times, input impedance = 109 Ω, common rejection module = > 100 dB, noise ratio <3 μV RMS), with a data acquisition system with eight EMG830C channels (EMG System do Brasil®, São José dos Campos, Brazil). Both EMG and muscle strength were recorded during the sessions and during the pre-exercise period at a 1 kHz sampling frequency.

The EMG was smoothed with an analog filter at a 20-500 Hz band pass. In all experimental conditions, EMG had the main band of vibration and its harmonics were rejected by Chebishev filters (zero lag, second order, reject ranges 17-23 Hz, 39-41 Hz, 59-61 Hz and 79-81Hz), according to Fratini et al. (2009). The EMG onset was determined by the threshold method using the mobile signal obtained by calculating the square root mean square (RMS), where this was the first sample where the following conditions were met: (I) the RMS value of the instantaneous sample should be higher than the baseline value plus 0.5% of the peak RMS; and (II) the mean value of RMS obtained from the next 50ms window (from i to i + 50ms, where "i" is the sample number) is higher than the baseline value plus 1% of the peak RMS (Fig. 2B). The developed algorithm detected the threshold automatically starting the tracking through the onset of EMG, 10 samples before the visual onset of RMS curve obtained by the same evaluator. For the calculation of the variables, the initial 10 seconds of the 12 seconds of contraction were used.

The RMS was determined with a mobile windowing of 512 ms [from (i - 512ms) to i for each i, where "i" is the value of EMG instantaneous sample] for the full EMG signal from each muscle. This curve was used to calculate the RMS peak (RMSbic and RMStric), which is the RMS peak between EMG onset and sample peak force. Between the force peak and the end of the contraction (10 s), the value of RMS (RMSFbic and RMSFtric) was determined. Abbreviations are listed in Table 1.

The Rate of EMG Rise (RER) of the biceps was obtained by plotting the derivation (ΔEMG/ΔTime) of the continuous EMG curve with a mobile windowing of 50 ms [ΔTime: n - (n - 50ms) for each 'n' sample of the EMG signal] from the EMG onset to the end of the duration of the contraction (AAGAARD et al., 2002). In the frequency spectrum analysis, a fast Fourier transform was applied to the filtered EMG with a mobile windowing of 512 ms. Then, the peak median frequency from the EMG onset to peak force (MFbic and MFtric) and the median frequency from the EMG signal to the end of the contraction (MFFbic and MFFtric) were quantified.

Table 1. Abbreviations.

Abbreviations	Meaning
RMS	root mean square
PF (N)	value of highest force during action;
FI (%)	difference between PF and force at the end of the contraction divided by PF and multiplied by 100;
RFD ($N.s^{-1}$)	highest production of force rate with a time window of 50 ms (RFD = max(d(f(t))/dt), where f(t) = Force signal);
A_{RMS} ($m.s^{-2}$)	RMS acceleration (wrist joint);
A_{peak} ($m.s^{-2}$)	peak acceleration (wrist joint);
f_{Peak} (Hz)	peak of vibration frequency;
RER (µV/s)	highest value of increase rate of the EMG signal (RER = max(d(e(t))/dt), where e(t) = EMG signal);
RMSbic (µV)	highest activation value between EMG onset and force peak;
RMSFbic(µV)	root mean square of EMG signal of peak force at the end of the isometric action;
MFbic (Hz)	highest value of mean frequency between EMG onset and peak force;
MFFbic (Hz)	median frequency of EMG signal between peak force and force at the end of the isometric action;
RMStric (µV)	highest activation value between EMG onset and peak force;
RMSFtric(µV)	root mean square of EMG signal of force peak and at the end of the isometric action during fatigue;
MFtric (Hz)	highest value of median frequency between EMG onset and peak force;
MFFtric (Hz)	median frequency during EMG signal at the end of the isometric action.

Force measurement

To obtain force data, a tensile and a compression load cell (previously calibrated) with capacity of 2,000 N was used connected to a lever. The force signal in all experimental conditions had the main range of vibration and the noise rejected by a Chebishev filter (zero lag, second order, reject range 17-23 Hz). Then, it was softened with a Butterworth digital filter (zero lag, fourth-order, low-pass, with a cutoff frequency of 8 Hz). Mean values of five contractions were used to calculate the variables.

To determine force variables, the onset was initially quantified. It was defined as the point at which the force curve exceeds the baseline value 2.5% over the filtered signal of the peak force (PF). The Rate of force development (Rate of Force Development = ΔForce/ΔTime) was determined using the same procedure used to calculate RER. Rate of force development (RFD) is a neuromuscular capability to develop the highest possible strength per unit of time. For the smoothing of the data, a Butterworth low-pass filter (zero-lag, second-order, with a cutoff frequency of 6 Hz) was applied. The fatigue index (FI) was determined by the percentage of difference from peak force to force in the 10th second of sustained contraction. Abbreviations are listed in Table 1.

Acceleration measurement

To measure and control the magnitude of vibration imposed on the volunteers, at the beginning of the exercises, the orthosis of the dominant limb (wrist joint) was fixed to a biaxial accelerometer (“x” - anteroposterior axis, aligned to the direction of vibration and muscle action; and “y” – mediolateral axis, not used in the analysis) connected to a data acquisition system, with a data sampling rate of 1 kHz (ME6000T8 Biomonitor System, eight channels, MEGA Electronics, Kuopio, Finland). The orthosis was used to provide stability for the wrist joint.

Accelerometry data were filtered with a Butterworth filter (fourth order, reject range of 59-61 Hz). The peak acceleration ($A_{peak} = A_{RMS}*\sqrt{2}$) and the RMS acceleration ($A_{RMS} = \sqrt{1/n*\Sigma x_i^2}$) of only one of the axis ("x" axis) were determined in the first six seconds. The fast Fourier transform was applied to verify the peak of vibration frequency (f_{peak}). For data analysis, the software Matlab® version 7.9 (Mathworks, Natick, USA), was used.

Statistical Analysis

Previously, the assumptions of normality using the Shapiro-Wilk test and homoscedasticity using the Bartlett test were verified for all variables. When any of the assumptions was violated, a logarithmic transformation was performed and the normality and homoscedasticity tests were performed again. To verify the differences between

groups for acute responses (strength and electromyography of biceps and triceps), a one-way ANOVA in blocks was applied. Vibration magnitude variables (mean acceleration, peak acceleration and peak frequency) were described as mean and standard deviation. The significance level was set at $p < 0.05$. For the statistical analysis, we used the "R" statistical software, version 3.12.

RESULTS

Table 2 shows mean acceleration and f_{peak} values collected during the exercises. The LV exercise had mean acceleration values close to 4 g (g = 9.81 $m.s^{-2}$) and a peak of approximately 10 g. Meanwhile, as expected, the control group showed acceleration values below 1 g. Strength parameters (RFD, $F_{1,36} = 4.535$, $p = .030$; PF, $F_{1,36} = 5.932$, $p = .027$; and FI, $F_{1,36} = 15.158$, $p = .001$) significantly increased in LV compared to CON (Figure 2 and Table 2).

Table 2. Strength parameters and magnitude of vibration (mean ± standard deviation) during exercises. The asterisk (*) indicates differences between groups ($p<0.05$).

Variables	Control	LV
PF (N)	170.53±21.5	183.76±20.7*
FI (%)	14.46±4.8	19.3±5.51*
RFD ($N.s^{-1}$)	629.65±188.76	774.35±192.06*
A_{RMS} ($m.s^{-2}$)	0.64 ± 0.29	35.86 ± 4.81
A_{peak} ($m.s^{-2}$)	3.83 ± 2.6	99.46 ± 15.49
f_{Peak} (Hz)	12.52 ± 3.06	20.01 ± 0.13

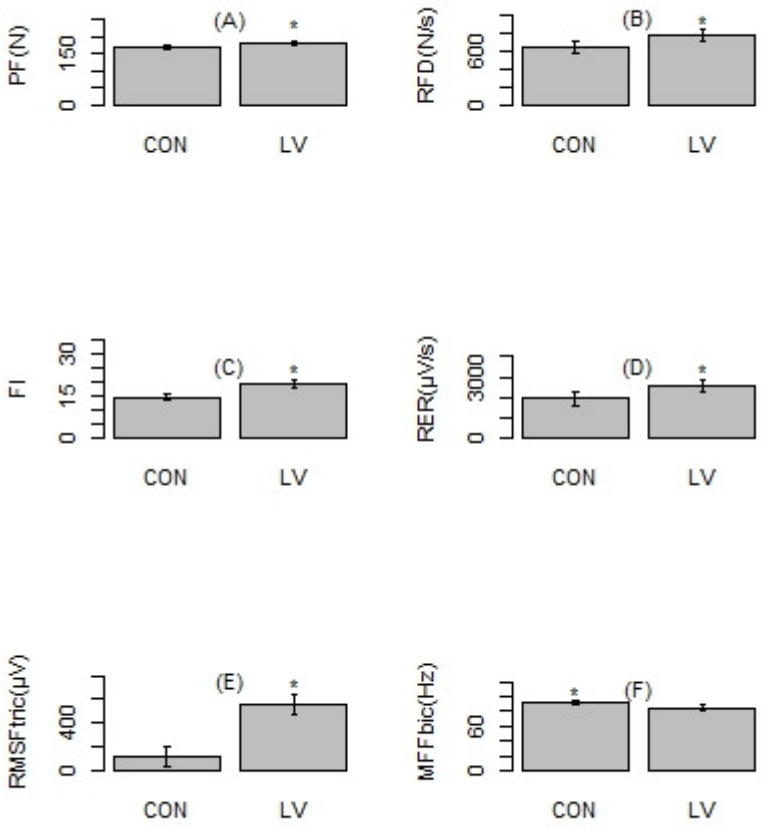

Figure 2. Mean values for (A) PF (N), (B) RFD (N/s), (C) FI (%), (D) RER (µV/s); (E) RMSFtric; (F) MFFbic (Hz). The asterisk (*) indicate diferences ($p<0.05$).

For agonist EMG parameters, significant changes were only observed for RER in time ($F_{1,36}$ = 4.812, p = .041) and MFFbic in frequency ($F_{1,36}$ = 4.242, p = .045). On the other hand, a change was only observed for the RMSFtric variable in time ($F_{1,36}$ = 30.677, p<.001) for antagonist EMG parameters. The other analyzed parameters showed no change among groups (RMSbic, $F_{1,36}$ = .020 , p = .882; RMSFbic, $F_{1,36}$ = .018, p = .895; MFbic, $F_{1,36}$ = 2.537, p = .129; RMStric, $F_{1,36}$ = 0.372, p = .546; MFtric, $F_{1,36}$ = .016, p = .901; MFFtric, $F_{1,36}$ = .320, p = .578). Table 3 and Figure 2 show values obtained for groups.

Table 3. EMG parameters for time and frequency during exercises. The asterisk (*) indicates differences between groups (p<0.05).

Variables	Control	LV
RER (µV/s)	1,921.47±976.88	2,585.16±1,591.55*
RMSbic (µV)	1,131.11±443.38	1,115.57±359.52
RMSFbic (µV)	906.68±384.47	893.98±291.99
MFbic (Hz)	118.58±14.76	112.68±11.3
MFFbic (Hz)	91.48±12.28	85.38±10.97*
RMStric (µV)	153.4±61.86	185.65±110.71
RMSFtric (µV)	114.66±53.95	555.25±324.71*
MFtric (Hz)	128.14±17.52	129.5±24.14
MFFtric (Hz)	88.15±11.16	86.75±14.85

DISCUSSION

In order to evaluate acute neuromuscular responses to exposure to vibration, it was hypothesized that adding LV would interfere on the muscle function. Results found in this study were in line with that hypothesis, since adding LV had a positive influence on strength response and electromyographic activity.

The increase in explosive strength can be explained by an involuntary stretching reflex action concomitant to the voluntary activation. Vibratory stimulation may have led to an increased muscle spindle firing frequency, leading to a reflex contraction. An increased RFD can be understood as a motor recruitment acceleration evidenced by RER, since there was no change in agonist and antagonist median frequencies (MFbic and MFtric). The increase found for the use of LV corroborates the results found by Issurin and Tenenbaun (1999), who also used vibrations in the opposite direction to muscle's shortening.

Another possible explanation for the improved strength performance could be related to tonic vibration reflex. However, this seems unlikely, since the appearance of tonic vibration reflex has been verified by a direct stimulation of relaxed muscles, and not by contraction, as in the current experiment. Furthermore, the appearance of tonic vibration reflex has been showed only after 30 seconds of exposure to vibration, a time higher than the adopted 12 seconds of stimulation (BONGIOVANNI; HAGBARTH, 1990; RITTWEGER, 2010).

Both maximum strength and explosive strength may have been changed by at least one of contractile or elastic mechanisms during the sustained contraction. Torque applied to the direction opposite to muscle's shortening induces fast and small muscle tendon unit stretches (SILVA; COUTO; SZMUCHROWSKI, 2008). Stretching during strength development may lead to an abrupt increase of muscle tendon unit rigidity, consequently increasing the strength response (MONROY; LAPPIN; NISHIKAWA, 2007; EDMAN, 2012). Furthermore, muscle tendon unit in series and parallel elastic components can be deformed, and part of the kinetic energy of vibration can be stored in the form of elastic potential energy. Stored energy may help to produce a restorative momentum during contraction (RITTWEGER, 2010).

However, Friesenbichler; Coza and Nigg (2012) found a decrease in torque peak and an increase in agonist EMG (displacement = 6 ± 2.2 mm, frequency = 20 - 45Hz), suggesting that indirect vibratory stimulation is a factor that enhances strength training. From the results of our study, it was evidenced that a local vibration stimulus may enhance strength performance. However, the maximum displacement adopted in the study conducted by Friesenbichler; Coza and Nigg (2012) was higher than that of this study and all studies that used LV (ISSURIN; TENENBAUN, 1999; LUO; MCNAMARA; MORAN, 2008; LUO et al., 2009; MISCHI; CARDINALE, 2009; MARIN; RHEA, 2010). Furthermore, as the protocol was performed in only one day, intervals

may have been insufficient for a recovery (2 minutes between series and 5 minutes between conditions).

The association of local vibratory stimulation and exercise produced a decreased ability to sustain production of strength compared to the control group. This result corroborates reports according to which an acute exposure to local sinusoidal vibration has reduced exhaustion times in isometric actions (SAMUELSON; JORFEDT; AHLBORG, 1989) and repetitions of dynamic actions, accelerating the increase in lactate concentration (COUTO et al., 2013).

The A_{peak} represents the maximum capacity of the equipment in to offer acceleration to the body segment in a vibration cycle, resultant from higher frequency and vibration displacement imposed by the equipment. Thus, A_{peak} is sporadic large loads provided by the vibration equipment. On the other hand, the A_{RMS} is the mean acceleration over the entire cycle of vibration reaching the segment. The A_{RMS} is proportional to a_{peak}, f_{peak} and oscillatory displacement (RITTWEGER, 2010).

Possibly, the abrupt acceleration variation observed by high A_{peak} values (Table 2) may have triggered strength inhibition by a reflex of Golgi tendon organ, leading to an increased mechanical compliance of muscle tendon unit elastic components (ZATSIORSKY; PRILUTSKY, 2012). Supporting this argument, this study has shown a slight reduction of motor units stimulation frequency (MFFbic). On the other hand, a higher and faster initial MU's recruitment (ISSURIN; TENENBAUN, 1999) may also explain reduction of strength through a reduction of the agonist motor units firing frequency during fatigue.

In addition, results of this study did not indicated an antagonist EMG change due to a reciprocal inhibition mechanism, as has been proposed. Conversely, the triceps co-contraction may have been mediated by the golgi tendon organ reflex, which was evidenced by an increase in antagonist EMG during fatigue (RMSFtric) (ZATSIORSKY; PRILUTSKY, 2012). Furthermore, this increase may be possibly explained as a response to the fast and varied stretches imposed by variation of vibration parameters as a measure to increase elbow joint stiffness and assist in stabilizing the performance of the exercise under a fatigue condition. In this case, the inhibitory interneurons involved in stretch reflex receive excitatory and inhibitory signals from the main central descending pathways, regulating the stiffness of the elbow joint by co-contraction according to muscle action requirements (KANDELL et al., 2013).

Although the volunteers were instructed not to perform shoulder translation movements, this movement was not mechanically limited to the anteroposterior direction. This may constitute a limitation of this study. Finally, more studies with representative samples considering athletes are necessary.

The assumed displacement was determined according to the eccentricity axis of the device, which might be different from that imposed on the body part in contact with the device and the targeted muscle. In addition, the elucidation of how and frequency parameters and displacement interact, affecting the magnitude of neuromuscular responses such as the dose-response relation, needs further research. In order to guide the application of vibration to training, comparisons between whole body vibration and local vibration devices with the same magnitude of acceleration and weight are recommended.

CONCLUSIONS

The LV (oscillation in frequency and displacement) induced an acute increase of maximum and explosive strength, and decreased the capacity to sustain production of strength (Mean acceleration $\approx$ 4 g), thus increasing training unit effectiveness.

The improvement of maximum strength was probably mediated by contractile factors related to the increase in muscle tendon unit rigidity and/or the use of elastic energy. However, the increase in explosive strength was possibly explained not only by contractile factors, but also by a motor unit recruitment acceleration via stretch reflex.

The reduced ability to sustain production of strength was possibly due to a decrease in the motor unit firing frequency and a high motor recruitment demand.

RESUMO: O objetivo deste estudo foi avaliar as respostas neuromusculares durante o exercício com a variação dos parâmetros de vibração local. Foram recrutados 19 indivíduos saudáveis do gênero masculino (idade = 22,43 ± 2,76 anos; massa corporal = 76,4 ± 12,94 kg; altura = 175 ± 6,76 cm) que executaram o exercício isométrico em duas situações experimentais: somente o exercício isométrico (Controle); exercício com a adição de vibrações locais (LV; Frequência = 20 ± 3Hz, Deslocamento = 2 - 5 mm). Os parâmetros de força foram significativamente aumentados no tratamento LV

comparados ao tratamento controle (RFD, p = ,030; PF, p = ,027; and FI, p = ,001). Para os parâmetros de atividade eletromiográfica, foram observadas alterações significativas para a RER (p = ,041), MFFbic (p = ,045) no músculo bíceps braquial (agonista) e RMSFtric (p <.001) no músculo tríceps braquial (antagonista). A adição de vibrações locais no treinamento contra – resistência, induziu um aumento da força máxima, força explosiva e uma redução da capacidade de sustentar a produção de força.

PALAVRAS-CHAVE: Biomecânica. Vibrações locais. Força máxima. Treinamento contra – resistência Atividade eletromiográfica.

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