Effects of local vibrations on muscle strength and roundhouse kick performance of taekwondo athletes

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

Mariana P Oliveira[ABCDE], Sara A Rodrigues[ABCDE], Leszek A Szmuchrowski [ADE], Maicon Rodrigues Albuquerque[CDE], Reginaldo Gonçalves[DE], Cristiano AG Flor[BD], Luiza F Vieira[BE], Marcos Drummond[BE], Márcio Prudêncio[DE] e Bruno P Couto[ABCDE]

Laboratório de Avaliação da Carga, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil

Received: 15 June 2016; **Accepted:** 21 October 2016; **Published online:** 30 January 2017

AoBID: 11202

Abstract

Background and Study Aim: Exercise with vibration exposure is a type of neuromuscular training that has been used with athletes and non-athletes. The vibration is used in the development of sports performance by applying only oscillatory movements in the human body or combining those oscillations with conventional strength training exercises. No studies were found that verified the effects of applying vibration on the performance of roundhouse kick. Thus, the aim of this study was the possibility of optimising performance of kick speed and maximal isometric strength through the application of mechanical vibrations.

Material and Methods: Ten taekwondo athletes (6 males and 4 females) with mean age 18.3 ±2.5 years, mean body mass 62.1 ±6.6 kg, mean height 173.3 ±7.0 cm and mean practice time 5.5 ±3.2 years volunteered to participate in this study. All the volunteers participated in two different sessions. In the sessions, they performed a warm-up, speed kick pre-test, maximal voluntary contraction (MVC) intervention (with or without vibration) and a speed kick post-test.

Results: No significant differences were found between pre-test and post-test (immediately, 3, 5 and 8 minutes after intervention) for speed kick. For the force recorded during MVC with local vibration (LV), a significant difference was found between moments, during and after vibration. The force produced during LV exposure was higher compared with after vibration. However no significant difference were found between the moments after and during LV compared to MVC without LV (in corresponded moments in the given range curve), in addition, the moment after LV was higher in MVC without LV. The impulse without vibration was significant higher than impulse with vibration.

Conclusions: These data suggest that training with the vibration parameters used in this present study was not able to increase the performance of speed kick (subacute) and maximal force (acute). In addition, reduced the maximal force subacutely and impulse acutely.

Key words: kick speed • mechanical vibration • sports training • strength training • maximal voluntary contraction

Conflict of interest: Authors have declared that no competing interest exists

Ethical approval: The study was approved by the Ethical Committee for Research at the Federal University of Minas Gerais, Brazil (49553815.4.0000.5149)

Provenance & peer review: Not commissioned; externally peer reviewed

Source of support: Fundação de Amparo à Pesquisa do est estado de Minas Gerais (FAPEMIG – Minas Gerais / Brazil) and the Pró-Reitoria de Pesquisa (PRPQ) [Research Pro- Rectory] from the Universidade Federal de Minas Gerais

Author's address: Bruno P Couto, Universidade Federal de Minas Gerais, Av. Antônio Carlos, 6627 Pampulha, Belo Horizonte, Minas Gerais, Brazil; e-mail: brunopena@yahoo.com.br

Roundhouse kick (*bandal tchagui*) – a type of kick executed to the chest that generally starts in the sagittal plane and finishes in the lateral plane.

Vibration – is a mechanical oscillation which usually is sinusoidal though others form of oscillations may be applied. In case of sinusoidal oscillations it is defined by frequency measured in the unit of hertz (Hz) and by amplitude. The number of Hz denotes number of cycles per seconds. Amplitude is a half difference between the maximum and the minimum of the oscillation [24].

Strength training – *noun* training that aims to build muscle strength, usually resistance training [25].

Stretch reflex – *noun* a reflex reaction of a muscle that contracts after being stretched [25].

Tonic – *adjective* relating to or affecting muscular tone or contraction [25].

Isometric – *adjective* **1.** involving equal measurement **2.** used for describing muscle contraction in which tension occurs with very little shortening of muscle fibres **3.** used for describing exercises in which the muscles are put under tension but not contracted [25].

Isometrics – *noun* a form of exercise in which the muscles are pushed against something fixed or against other muscles to strengthen them [25].

INTRODUCTION

Exercise with vibration exposure is a method of neuromuscular training that has been used both with athletes and non-athletes [1]. The vibration is used in the development of sports performance by applying only oscillatory movements in the human body or combining those oscillations with conventional strength training exercises.

Vibration exposure may be applied in two different ways: using local vibration (LV) or by whole body vibration (WBV). LV is normally applied perpendicularly to a muscle or tendon of the target muscle and indirectly through devices (dumbbells, bars and cables). In sports training, the most commonly used method is WBV, its application is performed indirectly, through vibration platforms. Tankisheva et al. [2] reported that when WBV is used, the vibration energy can be attenuated when transmitted through body tissues, especially for more distant muscles (e.g. upper body), because of the distance between the vibration source and the target muscle. On the other hand, during LV this attenuation is reduced by decreasing this distance between the vibration source and the target muscle and, therefore, optimizes the vibratory stimulus that reaches the muscles.

According to Cardinale and Bosco [5], an increase in muscle strength from mechanical vibration is purported to occur because of the TVR. The contractile response, which is investigated by means of electromyographic (EMG) activity, produces an involuntary component of force production. Bosco et al. [5] evaluated the influence of vibration on mechanical properties of elbow flexors in twelve elite boxing athletes. The results showed a significant acute increase in average power in the arm exposed to vibration. The EMG activity analysis showed a significant increase in neural activity during vibration exposure, compared with the recorded EMG activity before treatment. Similar Griffin et al. [6] also found a significant increase in strength and EMG activity of triceps for elbow extension when the vibration was applied. Bongiovanni and Hagbarth [7], Hazell et al. [8] found that muscle vibration provided acute increases in strength, EMG activity signals and the stimulation rate of motor units during maximal isometric contractions. However, Humphries et al. [9] applied vibration (50 Hz and 5 mm) in the belly of the rectus femoris during muscle contraction, did not find any change in muscle activation (EMG) and the force produced by maximal voluntary contraction (MVC).

There are three different responses to a training program: acute and subacute physiological responses and chronic adaptations. There are in the literature different explanations for the positive subacute effects induced by vibration exposure: increased proprioceptive feedback – increasing the sensitivity of muscles spindles [10]; increase in muscle temperature – increasing nerve conduction velocity [11] and the post-activation potentiation (PPA) – increasing the intracellular sensitivity Ca^{2+} due to prior muscle activation [12]. However, its effects on performance of some specific movements are still unknown [13].

According to Ogiso et al. [14], the mechanical response of stretch reflex depends on functional aspects relating to the motor task. In this way, probably the exercise performed during vibration exposed influences the response to this vibration stimulus. In addition, Rittweger [15] suppose that the complexity of the action may be influence the results of vibration exposure. The more complex action, smaller the effect of vibration to optimize performance. Therefore, it is still necessary to verify the effect of vibratory stimulation on the performance of specific techniques, such as taekwondo kick.

Taekwondo (TKD) is a Korean martial art sport, became a full-medal sport at the 2000 Summer Olympics in Sydney and has been an Olympic sport since then. Taekwondo can be characterized by short durations, high intensity and require specific fast, high and spinning kicks [16]. *Bandal chagui* (roundhouse kick) is the most used kick technique [17] and can be defined as a semi-circular kick performed with foot dorsum on the abdomen height of the opponent. This kick requires high precision and power of lower limbs muscles [18]. Because of its high velocity and impact force, during a competition, the opponents have less time to react and more likely to concede points. Therefore, the explosive turning kick is a principle focus of TKD training [19]. No studies were found that verified the effects of applying vibration on the performance of roundhouse kick.

Thus, the aim of this study was the acute and subacute effects of mechanical vibration on the roundhouse kick speed, muscle strength and impulse of lower limbs in taekwondo athletes. We set the following hypothesis: the athletes after the maximal isometric contraction performed with vibration, would produce a greater subacute performance in the kick speed and there would be an increase in acute and subacute maximal isometric strength.

MATERIALS AND METHODS

Participants

Ten taekwondo athletes (6 males and 4 females) with mean age 18.3 ±2.5 years, mean body mass 62.1 ±6.6 kg, mean height 173.3 ±7.0 cm and mean practice time 5.5 ±3.2 years volunteered to participate in this study.

Subjects were informed about the nature of this study and signed an informed consent form according to the International Review Board for the use of human subjects at research. All procedures were approved by the Ethical Committee for Research at the Federal University of Minas Gerais, Brazil (49553815.4.0000.5149).

Procedures and measures

Each subject visited the laboratory on two separate sessions: isometric intervention and isometric with vibration intervention - in a randomized order. In both sessions all the volunteers performed a warm-up, speed kick pre-test, isometric intervention or isometric with vibration intervention and a speed kick post-test (Figure 1).

Pre-test

After the warm-up (3 sets of 3 submaximal roundhouse kicks and an interval of 30 seconds between each set), all the athletes performed the speed kick pre-test composed of 3 maximal roundhouse kicks with an interval of 15 seconds between each repetition. There was a 1-minute recovery interval between the warm-up and the speed kick pre-test. To perform the roundhouse kick, the volunteer placed the foot that would kick on a contact mat. A taekwondo target pad was positioned at the optimum individual height and distance (Figure 2).

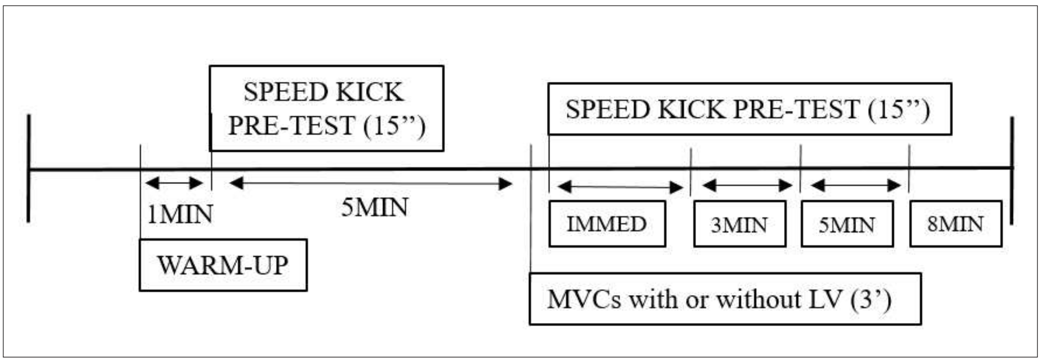

Figure 1. Study Design

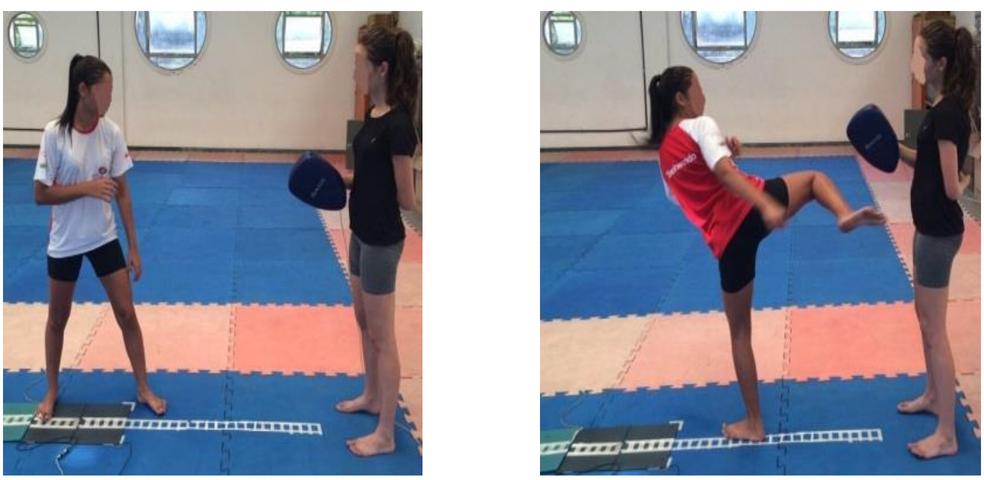

Figure 2. Roundhouse kick test.

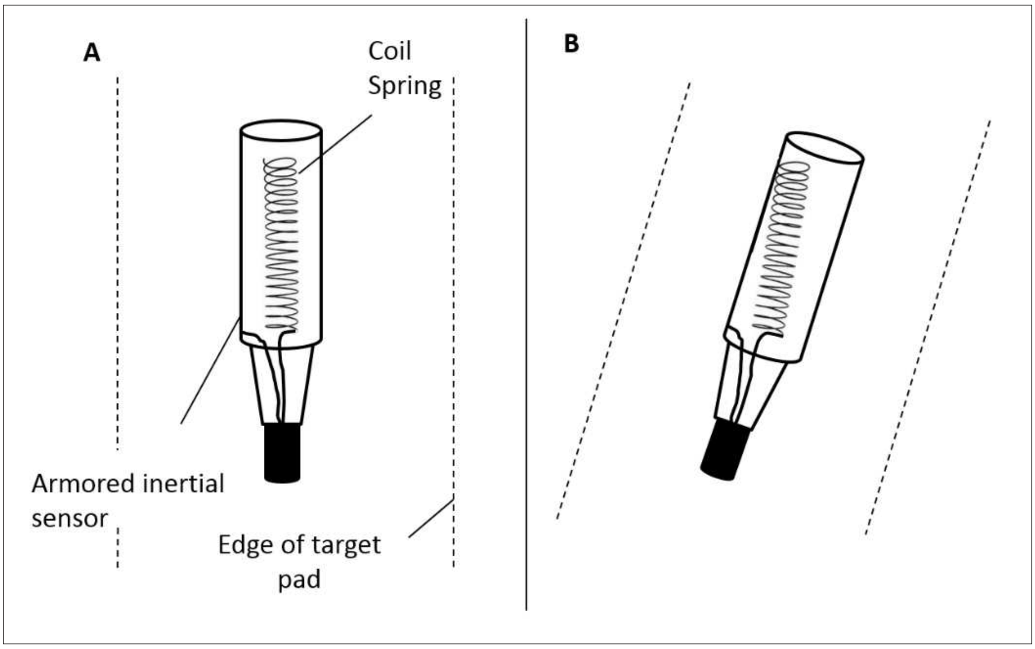

Figure 3. Coupled inertial sensor inside the target pad: (A) – before the kick contact; (B) – after the kick contact (closed electronic circuit between the coil spring and the armoured inertial sensor).

The athletes were also instructed to perform the movement as quick as possible. An inertial sensor was coupled to the target pad for measuring the movement time, which corresponded to the loss of contact of the kicking foot to the mat until contact with the target pad. At the end of each kick, the volunteer received as feedback the performance achieved during the attempt. For the roundhouse kick test, it was used a contact mat fixed to the ground. The contact mat was connected to a computer containing the Multisprint Full program version 3.5.7 (Hidrofit Ltd., Brazil). The mat fixed to the floor was marked with the length of centimetres, so the initial position for all kicks were the same, and to keep the distance between the mat and the target pad also the same during the test. An armoured inertial sensor was inside to a specific taekwondo target pad (Figure 3).

The sensor, in its interior, has a mass in the form of coil spring. When the foot loses contact with the mat on the floor, it opens an electric circuit, and when the foot makes contact with the target pad, it closes the electric circuit. The variable obtained in the roundhouse kick test was kick time. The volunteers were instructed to kick as fast as possible, with the preferred member, the taekwondo target pad was positioned at the height of the iliac crest of the individual, and the kick should be performed as soon as allowed. The horizontal distance, defined by the length of lower limbs plus the volunteer basis size, and the height of the iliac crest of the individual were used to calculate the hypotenuse, through the Pythagorean Theorem (Figure 4) [20]. The hypotenuse was considered as the distance between the initial position of the kicking foot and the target pad. As this distance represents the displacement, it was used to calculate the kick speed:

$$KS = \sqrt{(HD^2 + HC^2)} / KT$$

Since KS is the kick speed, in m/s, HD the horizontal distance, in meters, HC the height of the iliac crest of the individual, in meters, and KT the kick time in seconds.

Isometric Intervention

Each volunteer executed four MVCs with 3min rest between each MVC. The MVCs were performed in a specific kick position (Figure 5). To that end, each volunteer tried to perform a roundhouse kick and then maintained the contraction against an insurmountable resistance with a duration of 8 seconds, starting from the moment when the volunteer reached the peak strength. At the isometric with vibration intervention, the first MVC was performed without vibration; this

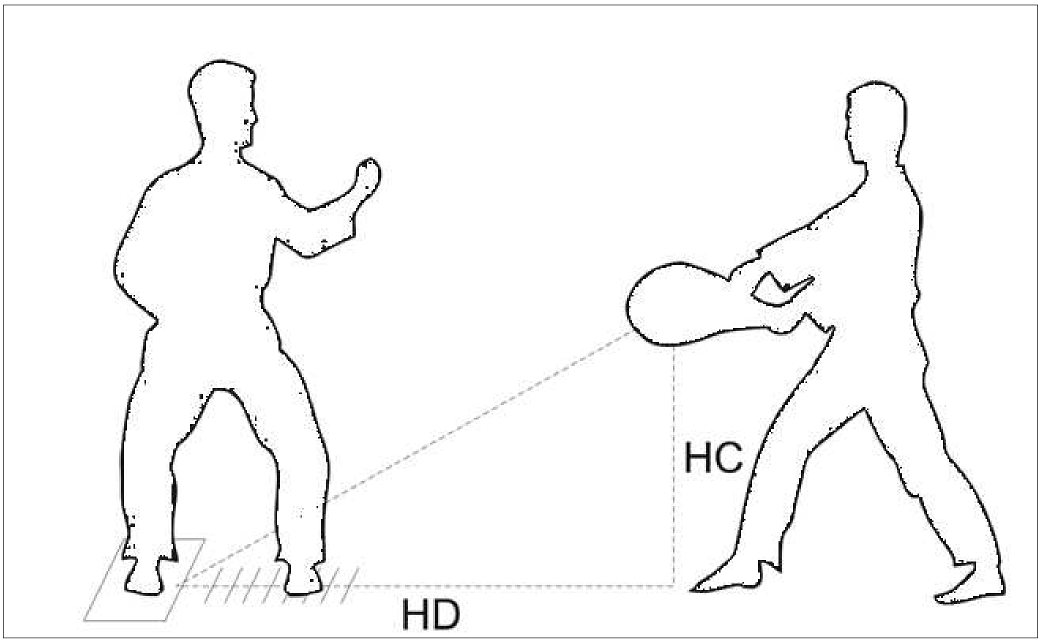

Figure 4. Roundhouse kick (model of the test and measurement criteria).

was to verify if the volunteers were in the same recovery condition. Subsequently, the mechanical vibration was superimposed during the last 3 MVCs. The sinusoidal LV was applied through a steel cable in the direction of the resultant muscle forces' vector addition [21]. The steel cable was attached to the athlete's back foot. The athlete was placed with their back to the engine and forced to flex the hip and extend the knee while grasping the railing in front of them. The vibration stimulus were applied during the 6 seconds of the MVC.

To the application of LV, it was used a motor, three-phase induction, brand WEG (IP55 model, 2 CV power, frequency 60Hz and speed 3400 rpm) coupled to an eccentric shaft. A cable passes through this eccentric shaft, which transmitted vibration to the athlete's ankle. Values of maximal force and impulse (force versus time curve area) were obtained using a force cell by JBA(Zb Staniak, Poland) connected to an amplifier of signals (WTM 005–2T/2P, Jaroslaw Doliriski Systemy Mikroprocesorowe, Poland). The amplifier itself was connected to a computer with a MAX (version 5.1, JBA) interface that enables analysis of the strength curve as a function of time (frequency of data input: 1000 Hz). The measurements obtained in this study were impulse (MVC with and without vibration), maximal force: MVCs with vibration (1^{st} moment – before vibration - 2^{nd} moment – during vibration – 3^{rd} moment – after vibration) (Figure 6). And MVCs without vibration - three corresponding moments of the MVCs with vibration (1^{st} moment - peak strength - 2^{nd} - highest force value registered in the range of 6 seconds, after reached the peak strength - 3^{rd} moment - highest force value after the 6 seconds). The strength variables were calculated using the software Dasylab (11.0). It was considered the highest value of force registered in the given range curve analysis.

Post-test

The athletes performed speed kick test composed of 3 maximal roundhouse kicks with an interval of 15 seconds between each repetition in each moment - immediately, 3, 5 and 8 minutes- after the last MVC of each session with vibration (repeated measurements). The comparison between the pre-test and post-test values of kick speed was performed to verify the subacute effects of the isometric intervention with and without vibration in the roundhouse kick speed.

Statistical analysis

The normality of all data was verified using the Shapiro-Wilk test. A Paired Student's t-test was

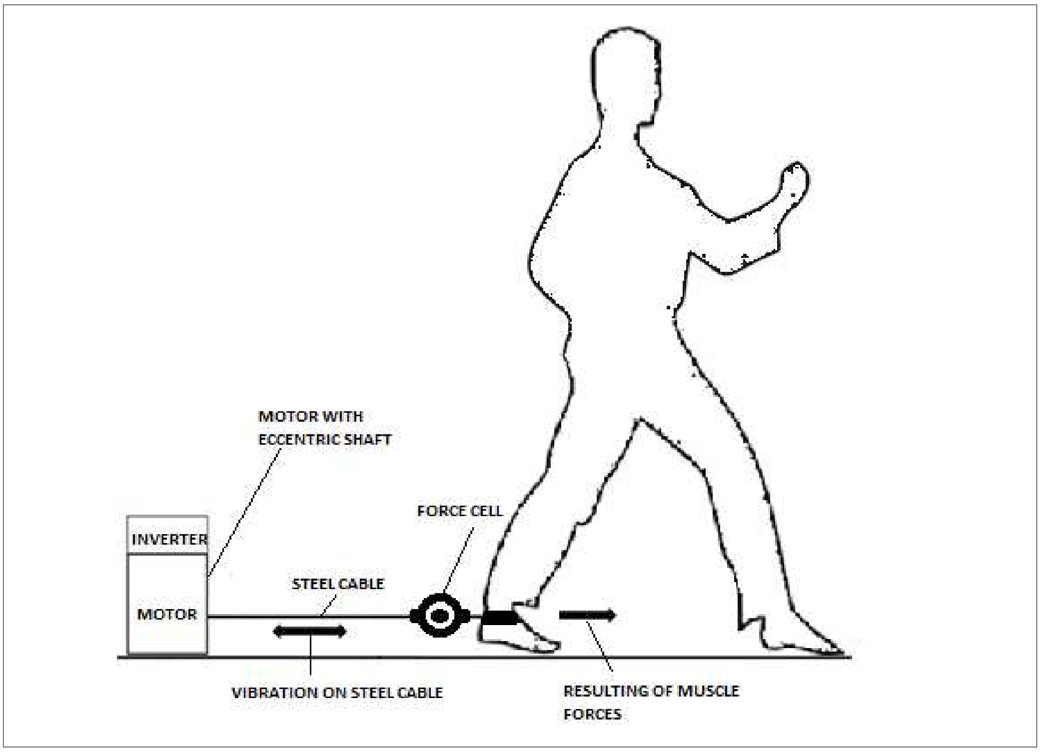

Figure 5. Intervention: MVC (with and without vibration) position.

done to compare the impulse during MVC with and without vibration. The Shapiro-wilk test and Paired Student's t-test was performed using SPSS (version 20.0). To compare the results of kick speed and force along the MVC, Two-way ANOVA (interventions vs. time) with repeated measures with post hoc LSD (vibration) and with post hoc Scott-Knott (time) was implemented using Sisvar (version 5.6) software. For the data analysis, the mean of the three MVCs (maximal force and impulse) and the mean of the three kicks were used. The significance level was set at $p<0.05$.

RESULTS

Concerning the results from kick speed, no significant differences were found between the repeated measurements, pre-test, immediately after, three, five and eight minutes MVC with LV ($F_{(1,5)}= 0.366$, $p = 0.832$) and MVC without LV ($F_{(1,5)}= 0.0364$, $p = 0.991$) and between interventions (MVC's without or with vibration exposure) for kick speed ($F_{(1,5)}= 0.117$, $p = 0.9764$). Figure 7 shows the repeated measurements values of speed kick with and without vibration.

No significant differences were found between the maximal force values obtained during the first MVC in the first (713.83 ± 164.8) and second session (607.11 ± 122.8) ($p = 0.293$). All the volunteers were under the same recovery conditions between sessions.

The impulse without vibration was significant higher than the impulse with vibration ($p = 0.001$). For the force recorded during MVC with LV, a significant difference was found between moments, 1st, 2nd and 3rd ($F_{(1,9)}= 15.143$, $p = 0.0000$). The force produced in the MVC during LV exposure was higher compared with 1st and 3rd moment (before and after vibration). There were no significant difference between moments (1st,2nd and 3rd) in MVCs without LV ($F_{(1,9)}= 2.363$, $p = 0.101$) and between MVC with and without vibration in the 1st moment ($F_{(1,9)}= 3.254$, $p = 0.0769$) and 2nd moment ($F_{(1,9)}= 1.708$, $p = 0.197$). However, the force produced in the MVC without the application of LV, 3rd moment, were higher than MVC with LV ($F_{(1,9)}= 4.850$, $p = 0.0320$).

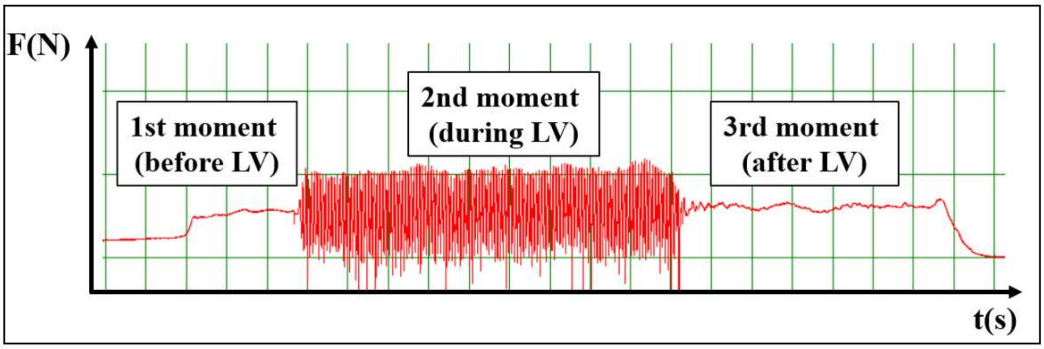

Figure 6. Maximal force along the MVC with vibration (1st, 2nd and 3rd moment).

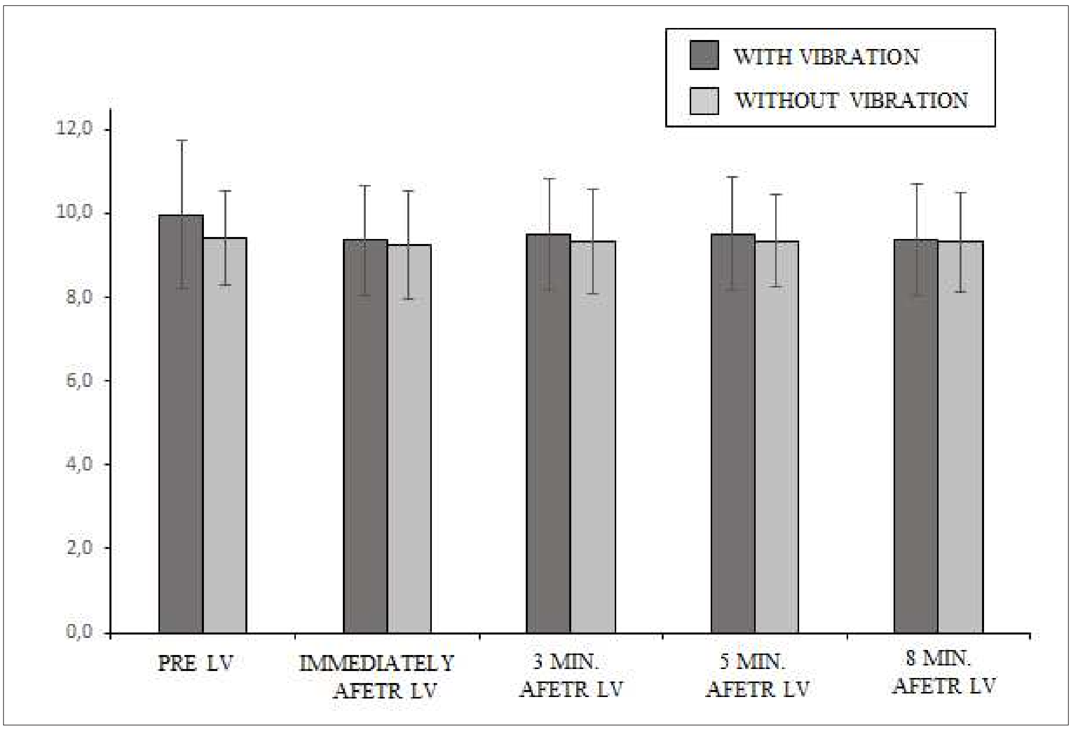

Figure 7. Kick speed (m/s) before and after MVC's without and with vibration exposure.

DISCUSSION

The principal issue of the present study is related to the possibility of optimizing the performance of kick speed through the application of mechanical vibrations. Based on the results, the hypotheses have not been confirmed. No statistical differences were found between the values of kick speed at the pre-test and post-test (immediately, 3, 5 and 8 minutes after intervention) in the isometric and isometric combined with vibration intervention.

Considering both intervention characteristics used in this present study, it is possible that the magnitude of the stimulus was not sufficient to produce effects on speed of specific techniques. According to Rittweger et al. [1] depending on the frequency of vibration, the mechanical vibration can be specific training of type of type II muscle fibres. Additionally, athletes can be more sensitives to acute vibration effects compare to non-athletic people. Nevertheless, the complexity of the action maybe influence the effects of vibration exposure. The more complex action, smaller the effect of vibration to optimize performance [15]. Rittweger [15] suggests that power gains obtained with vibrations intervention were not observed in sprint running. Rittweger [15] suggests that power gains obtained with vibrations intervention were not observed in sprint run, because, sprint run is a more complex task than vertical jump and involves other factors, such as

Table 1. shows mean ± Standard Deviation values for impulse during MVC and maximal force in moment 1st and 2nd moment.

	Maximal force		
Maximal force (MF)	**1st moment**	**2nd moment**	**3rd moment**
MF without LV (N)	541.6±99.4	646.8±130.6	628.4±151.2**
MF with LV (N)	452.0±65.7	711.7±128.9≠	512.5±119.9
Impulse			
Impulse without LV (N.s)	250.7* ± 53.7		
Impulse with LV (N.s)	210.1±41.0		

Legend: Maximal force (MF) in moment 1st, 2nd and 3rd moments without and with local vibration (LV).

*Significate difference between impulse without vibration and with vibration (p=0.001). ** Significate difference between MF without LV and MF with LV. ≠ Significate difference between 1st, 2nd and 3rd moment in MF with LV (p=0.0000).

reaction time, motor patterns and tendon force transmission that are not improved by vibration training. This explanation can justify the results found in the present study; kick speed is a complexity motor task. Supporting our results, Couto et al. [13] and Cochrane et al. [11], did not find positive effects of vibration exposed on the speed on a run protocol. Moreover, Bogaerts et al. [4] found no significant increases in speed of knee extension after a WBV protocol.

Most of the previous studies, which have investigated the effect of vibration in the lower limbs, evaluate using performance on the vertical jumps. The vertical jump constitute the most common method of assessing the power of lower limbs in athletes [22]. Despite being a universal method of assessing the power of lower limbs, it is not a specific test to evaluate the physical condition of taekwondo athletes [23]. Furthermore, is a simpler test compared to the kick technique. For this reason, it is expected different results to speed kick, compared with the results reported in the literature for vertical jumps. Moreover, contrasting to the type of vibration used in these previous studies (WBV), this study applied LV simultaneously with the isometric action, producing consecutive movements opposite to the muscular action. Still discussing the speed kick results, it is also important to know that the pre-test was conducted after a warm-up and the post-test performed immediately after the isometric vibration intervention, consequently, the athletes were probably fatigued. During the post-test, conducted 3, 5 and 8 minutes perhaps they were potentiated, nevertheless already without the warming effect. So, this condition is maybe equating the results from pre and during the repeated measure in the post-test.

Our results revealed no difference between maximal forces registered in the 1st and 2nd moments of MVCs with and without vibration and values of 3rd moment were higher in MVC without LV. We investigated the effects of isometric with and without vibration on the impulse, as well. The impulse without vibration was significant higher than the impulse with vibration (p = 0.001).

An explanation for these results maybe be related to the intervention used - vibrations characteristics (frequency, amplitude and exposure time) and the technique performed to superimpose LV, as already presented. Additionally, although the volunteers were athletes and had a high level of familiarity with the kick technique, they had no experience with isometric training combined with vibration application. Therefore, perhaps, the volunteers had to create strategies to maintain balance/stability during MVC, which may have induced a reduction in mean values of force (impulse). As well, although the MVC with and without vibration have a similar condition, what actually happens is that during the concentric phase of return to the isometric position, the force production tends to reduce with vibration exposure. In other words during the application of vibration what happens are successive eccentric-concentric actions, these sequences of muscular actions cause cycles of increased (eccentric) force production and subsequent abrupt (concentric) force drop, which probably generate, on average, lower values of force.

As observed, the exposure to vibration had a significant reduction of the impulse compared to MVC without vibration and did not produce acute increases in maximal force. In addition, the subacute effect usually founded after the application of mechanical vibration

[11,21], also, was not observed in this present study. Therefore, maybe for strength capability, training with this procedure (e.g. LV, 26Hz and MVC position) adopted is not useful for Taekwondo athletes.

Another point to discuss is the vibration transmission characteristics. In general, the transmission of vibration is attenuated when propagated through the body [2], and this attenuation depends on the joints angles. Although vibration has been applied direct to the ankle, we speculated that the joints angles of MVC position - specifically ankle and knee - may have attenuated the vibration transmission and for this reason, the acceleration that reached the target muscle group (e.g. knee extensors and hip flexors) was probably less than the real acceleration that was generated by the vibration source.

The influence of vibration stimulus on sports performance depend on many factors such as, the characteristics of the training protocol (exercise, characteristic of vibratory stimulus, muscle action, exposure time and interval between the application the application of vibration and data collection), as also the samples of characteristics (trained, not trained, elderly, etc.). According to Luo et al. [24] trained individuals have higher acute effects to vibration training compared with untrained subjects. The volunteers recruited for this present study were national taekwondo athletes, so it was expected that they respond acutely and subacutely to the vibration stimulus. However, this hypothesis was not confirmed. The principal issue discussed in the present study has related the importance to understanding the stimulus performed. If the objective of the training is, generate PPA or to train on the PPA effects, the stimulus proposed here was not suitable. Nevertheless, if the intention is to use the mechanical vibration as an additional resource to conventional strength training, the coach need to know clearly about what kind of stimulus he intends to apply. If the impulse is important, use this type of vibration is not adequate. If the objective is to diversify the stimulus for maximal force, perhaps, the application of this type of vibration becomes an interesting training resource.

CONCLUSION

These data suggest that training with vibrations at a frequency of 26 Hz, amplitude at 6mm, directed to the resulting muscle forces, was not able to increase the performance of speed kick (subacute), maximal force and impulse (acute). In addition, reduced the maximal force subacutely.

ACKNOWLEDGEMENTS

Fundação de Amparo à Pesquisa do est estado de Minas Gerais (FAPEMIG – Minas Gerais / Brazil) and the Pró-Reitoria de Pesquisa (PRPQ) [Research Pro- Rectory] from the Universidade Federal de Minas Gerais.

REFERENCES

1. Rittweger J, Beller G, Felsenberg D. Acute physiological effects of exhaustive whole-body vibration exercise in man. Clinical Physiology 2000; 20(2): 134-142
2. Tankisheva E, Jonkers I, Boonen S et al. Transmission of Whole-Body Vibration and Its Effect on Muscle Activation. J. Strength Cond. Res 2013; 27(9): 2533-2541
3. Pollock RD, Woledge RC, Mills KR et al. Muscle activity and acceleration during whole body vibration: Effect of frequency and amplitude. Clin Biomech 2010; 25(8): 840-846
4. Bogaerts A, Delecluse C, Claessens AL et al. Impact of Whole-Body Vibration Training Versus Fitness Training on Muscle Strength and Muscle Mass in Older Men: A 1-Year Randomized Controlled Trial. Journals Gerontol A Biol Sci Med Sci 2007; 62(6): 630-635
5. Bosco C, Cardinale M, Tsarpela O. Influence of vibration on mechanical power and electromyogram activity in human arm flexor muscles. Eur J Appl Physiol Occup Physiol 1999; 79(4): 306-311
6. Griffin L, Garland SJ, Ivanova T et al. Muscle vibration sustains motor unit firing rate during submaximal isometric fatigue in humans. J Physiol 2001; 535(Pt 3): 929-936
7. Bongiovanni LG, Hagbarth KE. Tonic vibration reflexes elicited during fatigue from aximal voluntary contractions in man. J Physiol 1990; 423: 1-14
8. Hazell TJ, Jakobi JM, Kenno KA. The effects of whole-body vibration on upper-and lower-body EMG during static and dynamic contractions. Appl Physiol Nutr Metab 2007; 32(6): 1156-1163
9. Humphries B, Warman G, Purton J et al. The Influence of Vibration on Muscle Activation and Rate of Force Development during Maximal Isometric Contractions. J Sports Sci Med 2004; 3(1): 16-22
10. Marín PJ, Bunker D, Rhea MR et al. Neuromuscular Activity During Whole-Body Vibration of Different Amplitudes and Footwear Conditions: Implications for Prescription of Vibratory Stimulation. J Strength Cond Res 2009; 23(8): 2311-2316
11. Cochrane DJ. Does Muscular Force of the Upper Body Increase Following Acute, Direct Vibration? Int J Sports Med 2016; 37(7): 547-551
12. Cochrane DJ, Stannard SR, Firth EC, et al. Acute whole-body vibration elicits post-activation potentiation. Eur J Appl Physiol 2009; 108(2): 311-319

13. Couto BP, Costa GAS, Barbosa MP et al. Efeito da aplicação de vibração mecânica sobre a impulsão vertical. Mot Rev Educ Física 2012; 414-422 [in Portuguese]

14. Ogiso K, McBride JM, Finni T et al. Stretch-reflex mechanical response to varying types of previous muscle activities. J Electromyogr Kinesiol 2002; 12(1): 27-36

15. Rittweger J. Vibration as an exercise modality: how it may work, and what its potential might be. Eur J Appl Physiol 2010; 108(5): 877-904

16. Marković G, Mišigoj-Duraković M, Trninić S. Fitness profile of elite Croatian female taekwondo athletes. Coll Antropol 2005; 29(1): 93-99

17. Kwok HHM. Discrepancies in fighting strategies between Taekwondo medalists and non-medalists. J Hum Sport Exerc 2012; 7(4): 806-814

18. Kazemi M, Perri G, Soave D. A profile of 2008 Olympic Taekwondo competitors. The J Can Chiropr Assoc 2010; 54(4): 243-249

19. Jakubiak N, Saunders DH. The feasibility and efficacy of elastic resistance training for improving the velocity of the Olympic Taekwondo turning kick. J Strength Cond Res 2008; 22(4): 1194-1197

20. O Goulart KN, Corgosinho RF, Rodrigues SA et al. Correlation between roundhouse kick and countermovement jump performance. Arch Budo 2016; 12: 125-131

21. Couto BP, Silva HR, Barbosa MP et al. Chronic effects of different frequencies of local vibrations. Int J Sports Med 2012; 33(2): 123-129

22. Markovic G, Dizdar D, Jukic I et al. Reliability and factorial validity of squat and countermovement jump tests. J Strength Cond Res 2004;18(3): 551-555

23. Drummond MD, Szmuchrowski LA, Goulart KN et al. Effect of strength training on regional hypertrophy of the elbow flexor muscles. Muscle Nerve 2016; 54(4): 750-755

24. Luo J, McNamara B, Moran K. The Use of Vibration Training to Enhance Muscle Strength and Power. Sport Med 2005; 35(1): 23-41

25. Dictionary of Sport and Exercise Science. Over 5,000 Terms Clearly Defined. London: A & B Black; 2006

Cite this article as: Oliveira MP, Rodrigues SA, Vieira LF et al. Effects of local vibrations on muscle strength and roundhouse kick performance of taekwondo athletes. Arch Budo 2017; 13: 23-33