

Acute Effects of Loaded and Unloaded Whole-Body Vibration on Vertical Jump Performance in Karate Athletes

by

Haris Pojskic^{1,*}, Željko Zombra^{2,3}, Jad Adrian Washif⁴, Jeffrey Pagaduan⁵

We investigated the acute effects of different whole-body vibration (WBV) interventions on the jump height of highly trained karate practitioners. Fifteen male karate club athletes (age: 20.0 ± 3.8 years; stature: 177.3 ± 4.7 cm; body mass: 76.9 ± 11.2 kg; % body fat: 9.2 ± 4.3) performed six randomized interventions: [a] static half-squat (SHS); [b] SHS with external loads at 30% of the body weight (SHS + 30%BW); [c] WBV at frequency (f) 25 Hz, and 2 mm amplitude (A) (WBV 25/2); [d] WBV 25/2 with external loads of 30% of the body weight (WBV 25/2 + 30% BW); [e] WBV at f = 50 Hz, and A = 4 mm (WBV 50/4), and [f] WBV 50/4 with external loads of 30% of the body weight (WBV 50/4 + 30% BW). Each intervention was performed for 5 sets at 60 s/set, with a rest interval of 30 s between sets. Countermovement jump (CMJ) data were collected at 2, 4, 6, 8 and 10 min after each preconditioning intervention. Two-way repeated-measures ANOVA revealed a non-significant main effect of intervention [$F(5, 10) = 1.44, \eta^2 = 0.42, p = 0.29$] and a significant main effect of the rest interval [$F(4, 11) = 3.51, \eta^2 = 0.56, p = 0.04$] on CMJ height. A rest interval of 4 min resulted in significantly higher CMJ values than a rest interval of 2 min ($p = 0.031$). In conclusion, utilizing a 4-min rest interval irrespective of the intervention schemes may have potential for enhancing jumping performance among highly trained karate athletes.

Keywords: martial arts; countermovement jump; explosive power; isometric contraction; postactivation potentiation enhancement

Introduction

Explosive power is an important component in karate performance, especially in “kumite”, which is a free form of fighting (Roschel et al., 2009). Efficient karate punching, kicking and rapid movements are manifestations of well-developed muscular power (Martínez de Quel et al., 2020), facilitated by a good warm-up. A typical karate warm-up consists of an aerobic activity followed by dynamic and passive stretching exercises. Recently, there has been increasing interest in designing warm-up strategies to elicit power. Among these is whole-body vibration (WBV).

Several mechanisms are believed to enhance performance from WBV (Bullock et al., 2008; Dallas et al., 2023; Pojskic et al., 2015). WBV can produce a sine wave motion from the vibration’s acceleration (intensity), amplitude, and frequency, which prompts muscles and tendons to cyclically lengthen and shorten, resulting in a rapid and energy-efficient warm-up effect (Washif, 2019). Thus, WBV is thought to produce compensatory muscular contractions from mechanical vibrations via stimulation of primary endings of muscle spindles and activation of alpha-motor neurons, resulting in higher power output (Cardinale and Bosco, 2003; Di Iorio et al., 2012). Furthermore, WBV has also been demonstrated to

¹ Department of Sports Science, Faculty of Social Sciences, Linnaeus University, Kalmar, Sweden.

² Institute for Kinesiology, Lukavac, Bosnia and Herzegovina.

³ Faculty of Physical Education and Sports, University of Tuzla, Bosnia and Herzegovina.

⁴ Sports Performance Division, Institut Sukan Negara Malaysia (National Sports Institute of Malaysia), Kuala Lumpur, Malaysia.

⁵ Faculty of Physical Culture, Palacký University Olomouc, Olomouc, Czech Republic.

* Correspondence: haris.pojskic@lnu.se

improve intra- and intermuscular coordination, as well as motor unit recruitment and synchronization (Cardinale and Lim, 2003). Additionally, WBV is also linked to post-activation potentiation enhancement (PAPE), which is a combination of various physiological conduits contributing to increased muscle output from preload stimulation (Berriel et al., 2022; Blazevich and Babault, 2019; Garbisu-Hualde et al., 2023; Krzysztolik and Wilk, 2020). With these characteristics, WBV appears to be a promising approach to optimize the warm-up.

Different mechanical stimuli exist in WBV. Researchers suggested WBV set-up with amplitudes between 4 mm and 10 mm, exposure duration from 30 s to 4 min, a work-to-rest ratio of 1:1 to 1:3, and rest intervals from 0 to 15 min to elicit positive benefits (Dabbs et al., 2012; Dallas et al., 2015). Furthermore, when applying 50 Hz of frequency, a 4 mm to 6 mm amplitude is recommended (Dabbs et al., 2012; Dallas et al., 2015). However, for highly trained individuals, additional external loads may be necessary during WBV to further optimize force production (Pojskic et al., 2015; Rønnestad, 2009). For example, previous studies indicated that an additional external load of 30% of the body weight under WBV posted superior gains in the countermovement jump, speed and agility compared to unloaded WBV, loaded non-WBV and unloaded non-WBV interventions in well-trained college soccer players (Pojskic et al., 2015).

Rest intervals also affect performance with WBV. Sale (2004) suggests that rest intervals should reach a balance between allowing the individual to fully recover from fatigue, and ensuring that the acute potentiating effects on neuromuscular function, induced by the loading stimulus, are not yet diminished. There exists a lack of consensus about the most appropriate time of rest following a single session of WBV exercises, as evidenced by conflicting findings reported in different studies (Adams et al., 2009; Bedient et al., 2009; Cochrane and Booker, 2014; Dabbs et al., 2011; Dallas et al., 2015; Kostrzewa et al., 2020). Those studies have documented the positive impact of WBV on the vertical jump height within time intervals ranging from 0 to 15 min.

Athletes and coaches constantly attempt to find ways to improve performance from a warm-up (Washif, 2019). At present, a limited

number of studies have attempted to assess vibration frequency, amplitude, and the external load in WBV (Naclerio et al., 2014). To the best of the researchers' knowledge, no investigations on warm-up settings employing loaded and unloaded WBV in karate practitioners have been conducted. WBV as a warm-up in karate might be an effective strategy to increase leg power to improve vertical jump height. Therefore, the purpose of this study was to examine the effects of loaded and unloaded WBV schemes with varying rest intervals (2, 4, 6, 8 and 10 min) on countermovement jump (CMJ) performance. We hypothesized that WBV with an additional load would generate the highest gains in CMJ performance compared to the results of the other preconditioning protocols.

Methods

Participants

Fifteen highly trained male karate practitioners (age: 20.0 ± 3.8 years; stature: 177.3 ± 4.7 cm; body mass: 76.9 ± 11.2 kg; % body fat: 9.23 ± 4.3) from several karate clubs volunteered to participate in the study. All had no history of musculoskeletal injuries within 6 months prior to data collection. They competed at the international ($n = 7$) and national ($n = 8$) levels and had 10.2 ± 3.2 years of training and 8.2 ± 3.1 years of competitive experience. According to their coaches, they trained 7.5 h a week (5 sessions of 1.5 h each) on tatami to improve technical and tactical skills, and 3 h a week (2 sessions of 1.5 h each) in a weight room to develop strength, power, and endurance. A light meal was allowed to be consumed >3 h before the beginning of testing sessions. To maintain hydration status and avoid excessive dehydration, athletes were allowed to drink the appropriate amount of water during testing sessions (Chryssanthopoulos et al., 2023). They were encouraged to avoid strenuous activity, tobacco, alcohol consumption, and caffeine intake 48 h prior to the testing sessions. Non-complying athletes, including those who reported having sleep deprivation, were excluded. Prior to data collection, all athletes were informed about the potential benefits and risks associated with the study. They all provided written informed consent. This study was approved by the Institutional Review Board of the Faculty of Physical Education and Sports, University of Tuzla (02/11-2370/13-5.5.) with procedures conforming to the principles of

the Declaration of Helsinki on human experimentation.

Design and Procedures

This cross-sectional study investigated the effects of acute loaded and unloaded WBV on CMJ performance. Participants were exposed to various loaded and unloaded warm-up schemes in randomized order. Post-intervention CMJs at different time points were gathered to identify an appropriate rest interval between stimulus and performance. All participants in the current study visited the Exercise Science Laboratory for 7 sessions between 8 a.m. and 10 a.m., separated by 48 h. The first session was assigned for the measurement of stature, body mass, and body fat content. A handheld stadiometer (Astra scale 27310, Gima, Italy) was used to assess stature at nearest 1 cm. A bioelectric body composition analyzer (Tanita TBF-300 increments 0.1%; Tanita, Tokyo, Japan) was utilized to evaluate body mass and body fat content. Testing equipment and experimental procedure familiarization were also conducted during that session. Then, participants underwent randomization to determine the order of schemes in the next 6 sessions. All randomized interventions were preceded by a 5-min warm-up on a cycle ergometer at 125 W and 70–75 rpm (Life Fitness, USA).

Warm-up schemes involved the following: (i) a static half squat (SHS); (ii) a SHS with an additional external load of 30% of the body weight (SHS + 30%BW); (iii) whole-body vibration at $f = 25$ Hz, $A = 2$ mm (WBV 25/2); (iv) WBV 25/2 with an additional external load of 30% of the body weight (WBV 25/2 + 30% BW); (v) whole-body vibration at $f = 50$ Hz, $A = 4$ mm (WBV 50/4); and (vi) WBV 50/4 with an additional external load of 30% of the body weight (WBV 50/4 + 30% BW). All interventions were carried out 5 times for 60 s for a total of 5 min, with a rest interval of 30 s between sets. Participants stepped off the platform (POWRX® Vibration Plate Pro Evolution 2.7, Germany) and stood for 30 s during rest in WBV schemes. The squat pattern followed a 100-degree knee flexion measurement with feet slightly wider than shoulder width apart. For loaded schemes, an Olympic bar and an appropriate set of weights were applied to achieve extra 30% of the BW.

CMJ data were collected at 2, 4, 6, 8 and 10 min after each conditioning stimulus. At each time

point, athletes performed two CMJs, separated by a 5-s rest interval. Participants were seated during the recovery periods. During the CMJ, participants started in an upright position with hands akimbo, to avoid arm swings throughout the vertical jump. A rapid downward movement (approximately semi-squat level) was then executed, and followed by an upward maximal jump. Athletes were instructed to land at the same starting spot, while bending the knees upon ground contact to reduce mechanical stress (Pojskic et al., 2022; Washif and Kok, 2022). The CMJ was conducted using commercial equipment (Optojump System, Microgate, Bolzano, Italy), with the best trial used for further analysis. The experimental protocol is displayed in Figure 1.

Statistical Analysis

All analyses were performed using commercial software SPSS® 24.0 for Windows (IBM Statistics, Chicago, IL) with alpha threshold set at 0.05. Data are presented with the means as well as standard deviations (Table 1). The Shapiro-Wilk test was used to verify data normality. A two-way repeated-measures ANOVA with six interventions \times five recovery intervals (6 \times 5) was carried out to determine any significant differences in vertical jump performance across the interventions and recovery intervals. The Mauchly's test was utilized to examine the sphericity of the data (Field, 2009). Eta squared (η^2) was used to estimate the effect size. The Bonferroni correction was applied to assess the significance of the post hoc pairwise comparisons. To calculate the smallest worthwhile change (SWC) considering CMJ height, average between-subject standard deviation (SD) of the all warm-up schemes was multiplied by 0.2, which represents the typical small effect (Pyne et al., 2005). Before the commencement of the study, sample size was determined using G-Power software (version 3.1.9.2; Heinrich Heine University Dusseldorf, Dusseldorf, Germany). For repeated measures ANOVA (p value of 0.05, effect size of 0.30, five measurements and power of 0.80), the program estimated 15 subjects ($df = 13$) as an appropriate sample size.

Results

The sphericity assumption in the Mauchly's test for CMJ data was fulfilled. Two-way repeated-measures ANOVA revealed a non-

significant main effect of interventions on CMJ performance [$F(5, 10) = 1.44$, $\eta^2 = 0.42$, $p = 0.29$] (Table 1). There was a significant effect of rest intervals on CMJ performance [$F(4, 11) = 3.51$, $\eta^2 = 0.56$, $p = 0.044$] (Table 1). Post hoc tests showed that a rest interval of 4 min displayed significantly higher CMJ values than a rest interval of 2 min [mean difference = 0.60 cm (CI95% 0.04–1.13 cm),

$p=0.031$], while there were no other significant differences across the other rest intervals. However, the calculated SWC ($SD \times 0.2$) was $5.5 \times 0.2 = 1.10$ cm, which is higher than observed CMJ height mean difference. There were no significant interactions among the interventions and rest intervals.

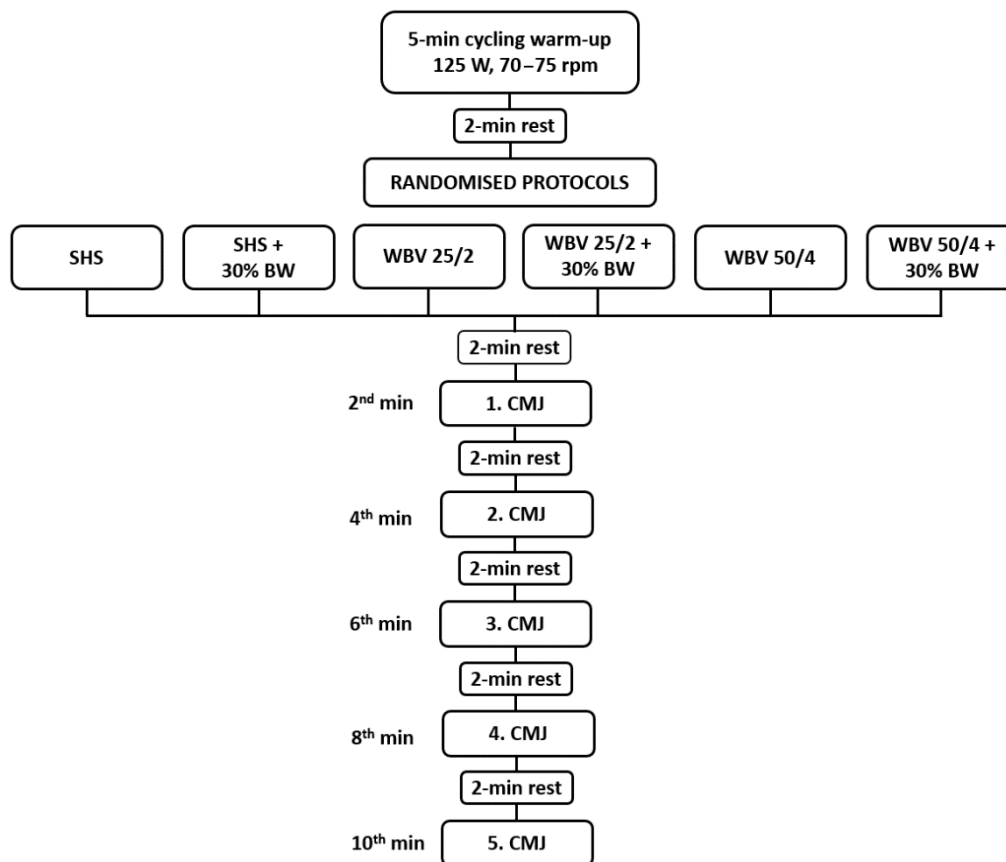


Figure 1. Experimental protocol.

CMJ: Countermovement

jump, rpm: revolutions per minute, WBV: whole-body vibration, SHS: standing in a static half squat position, SHS + 30% BW: SHS with an additional load of 30% of the body weight, WBV 25/2: WBV at $f = 25$ Hz, $A = 2$ mm, WBV 25/2 + 30% BW: WBV 25/2 with an additional load of 30% of the body weight, WBV 50/4: WBV at $f = 50$ Hz, $A = 4$ mm, WBV 50/4 + 30% BW: WBV 50/4 with an additional load of 30% of the body weight.

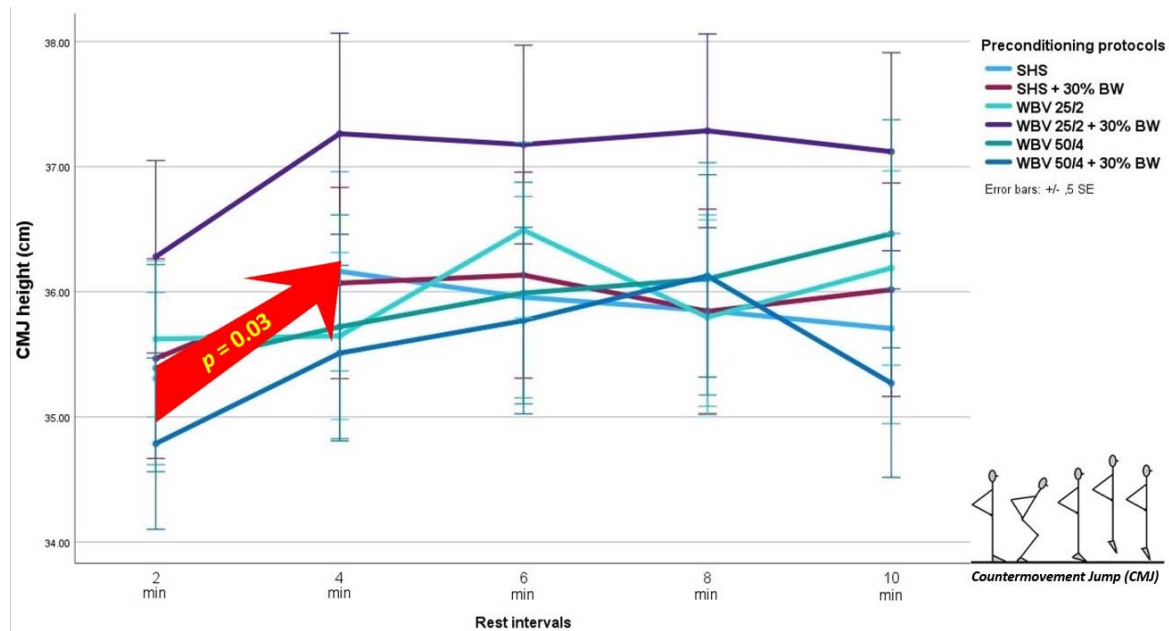


Figure 2. Multiple comparison of different loaded and unloaded whole-body vibration (WBV) and low intensity intermittent isometric interventions at various recovery intervals on countermovement jump (CMJ) height.

SHS: standing in a static half squat position; SHS + 30% BW: SHS with an additional load of 30% of the body weight, WBV 25/2: WBV at $f = 25$ Hz, $A = 2$ mm, WBV 25/2 + 30% BW: WBV 25/2 with an additional load of 30% of the body weight, WBV 50/4: WBV at $f = 50$ Hz, $A = 4$ mm, WBV 50/4 + 30% BW: WBV 50/4 with an additional load of 30% of the body weight. The red arrow shows significant improvement in CMJ height after 4-min recovery compared to 2-min recovery ($p = 0.03$).

Table 1. Descriptive variables (means \pm SD) of countermovement jump (CMJ) height (cm) after different conditioning interventions and recovery intervals.

Recovery intervals	PRECONDITIONING INTERVENTIONS						Average
	SHS	SHS + 30% BW	WBV 25/2	WBV 25/2 + 30% BW	WBV 50/4	WBV 50/4 + 30% BW	
2 min	35.3 \pm 5.3	35.5 \pm 6.2	35.6 \pm 4.8	36.3 \pm 6.0	35.4 \pm 6.4	34.8 \pm 5.3	35.5 \pm 5.4
4 min	36.2 \pm 6.2	36.1 \pm 5.9	35.6 \pm 5.2	37.3 \pm 6.2	35.7 \pm 6.9	35.5 \pm 5.4	36.1 \pm 5.8*
6 min	35.9 \pm 6.2	36.1 \pm 6.4	36.5 \pm 5.4	37.2 \pm 6.1	36.0 \pm 6.9	35.8 \pm 5.8	36.3 \pm 6.0
8 min	35.8 \pm 5.9	35.8 \pm 6.3	35.8 \pm 6.0	37.3 \pm 6.0	36.1 \pm 7.2	36.1 \pm 6.3	36.2 \pm 6.1
10 min	35.7 \pm 5.9	36.0 \pm 6.6	36.2 \pm 6.0	37.1 \pm 6.1	36.5 \pm 7.1	35.3 \pm 5.8	36.1 \pm 6.0
Average	35.8 \pm 5.8	35.9 \pm 6.1	35.9 \pm 5.4	37.1 \pm 5.9	35.9 \pm 6.7	35.5 \pm 5.6	36.0 \pm 5.7

Legend: WBV = whole-body vibration; SHS = standing in a static half squat position; SHS + 30% BW = SHS with an additional load of 30% of the body weight; WBV 25/2 = WBV at $f = 25$ Hz, $A = 2$ mm; WBV 25/2 + 30% BW = WBV 25/2 with an additional load of 30% of the body weight; WBV 50/4 = WBV at $f = 50$ Hz, $A = 4$ mm; WBV 50/4 + 30% BW = WBV 50/4 with an additional load of 30% of the body weight. * statistically significant difference in CMJ height between 2- and 4-min recovery intervals ($p = 0.03$).

Discussion

The purpose of this study was to determine the effects of loaded and unloaded WBV interventions on CMJ height among highly trained karate practitioners. The results indicated non-significant CMJ differences among the WBV interventions employed. However, there was a significant main effect of the rest interval on CMJ performance. Specifically, a rest interval of 4 min resulted in significantly higher CMJ values than a rest interval of 2 min.

In the current study, there were no significant differences in the CMJ observed across intervention schemes. The effect of WBV in athletes may be influenced by individual background, such as the performance level (Washif et al., 2019). Even though participants in our study were individuals with extensive training experience in karate, accustomed to explosive lower body movements such as jumping activities (Ravier et al., 2009), they had a lower CMJ height compared to other international karate athletes. For instance, Loturco et al. (2014) reported CMJ height of 43.2 ± 5.3 cm in a sample of nineteen Brazilian professional karate practitioners, which is approximately 5 cm higher than in the current cohort. However, it is possible that athletes in the current study achieved an optimal state of motor neuron excitability and reflex sensitivity, leading to a reduction in vibration sensitivity (Bullock et al., 2008; Hortobágyi et al., 2015). It is known that lower-level athletes are more responsive and have a greater degree of improvement in jumping performance when exposed to WBV, compared to elite-level and well-trained athletes with comparable training experience (Washif et al., 2019). Consistently, the efficacy of WBV for increasing jumping performance has been demonstrated in recreationally trained men (Turner et al., 2011) and 'competitive' and lower-level athletes (Dallas et al., 2015; Washif, 2019). Therefore, additional research is needed to explore alternative WBV schemes that can be beneficial in elite karate athletes.

The external loading in WBV carried out in this study was not influential to generating enhancement in jump performance. For example, a WBV 50/4 at 30% BW (i.e., high frequency vibration and external loads) protocol resulted in the lowest CMJ values compared to other groups. This contradicted previous studies that noted

improvement in performance with external loads under WBV (Naclerio et al., 2014; Pojskic et al., 2015; Rønnestad, 2009). Researchers suggest employing WBV with 30 Hz with an amplitude of 4 to 10 mm to elicit benefits in WBV (Dabbs et al., 2012; Washif et al., 2019). A noticeable outcome utilizing a low vibration frequency and amplitude (i.e., 25 Hz, 2 mm) WBV 25/2 + 30% BW protocol was identified in this study, which somewhat coincides with the previous recommendation. It seems that PAPE occurred at different times, highlighting the need for individuality when using loaded WBV. Therefore, it is necessary for coaches and athletes to determine the optimal loading stimulus on a case-by-case basis for designing WBV-based warm-up strategies.

On the other hand, the current study demonstrated an improvement in performance with 4-min recovery duration compared with that of 2-min duration. These data imply that, regardless of vibration stimuli, loaded or unloaded conditions, adequate recovery duration (i.e., 4 min) after the stimulus is more important in maximizing vertical jump performance. For example, Armstrong et al. (2010) discovered a substantial improvement in CMJ performance at the 5th min and the 10th min after different WBV stimuli among untrained participants. Similarly, Adams et al. (2009) observed that a 1- to 5-min interval after WBV was optimum for improving performance. However, McBride et al. (2010) and Dallas et al. (2023) showed that the effect of WBV might last up to 8 min following WBV, which partly supports the current study findings. Interestingly, several authors (Avelar et al., 2014; Washif, 2019) found PAPE effects immediately after the intervention, which might be explained by other factors, such as the influence of athleticism (Washif, 2019). In this study, it seems that a 4-min rest was sufficient to allow recovery from WBV, thereby increasing jump performance. However, it must be acknowledged that the mean difference in CMJ height between the rest intervals of 2 and 4 minutes was lower (i.e., 0.60 cm) than the obtained SWC (i.e., 1.10 cm) and as such it might be questionable how significant it is in practical settings. Nevertheless, the study's findings suggest a distinct efficacy range for using WBV to enhance CMJ height. However, further research is needed to identify the exact mechanisms contributing to the enhancement in leg power resulting from a rest

interval after WBV exposure.

This study has several limitations. First, the study was conducted under acute conditions, which reduces its applicability in long-term settings. Second, interpretation of the results may be limited to the participants or comparable cohort athletes. Additionally, the warm-up protocols employed did not include baseline measurements, which are crucial to elucidate information regarding PAPE. Moreover, the performance of multiple jumps with 2-min rest intervals might influence the CMJ outcomes of this study. Exploring multiple jumps at longer rest intervals (e.g., 5 min) may potentially reduce

residual effects. Future studies addressing these limitations are warranted.

In conclusion, utilizing a 4-min rest interval irrespective of the preconditioning schemes may have potential for enhancing jumping performance among highly trained karate practitioners. Both the loaded and unloaded WBV and non-WBV schemes used in the current study appear to produce similar effects, regardless of the vibration (amplitude, frequency, etc.) and load variables. As a final note, to optimize the effectiveness of warm-ups and introduce training variety, it is advisable for coaches and athletes to consider implementing the vibration stimulus employed with a 4-min recovery period.

Author Contributions: Conceptualization: H.P. and Ž.Z.; methodology: H.P., Ž.Z. and J.P.; software: H.P. and J.P.; validation: H.P., J.A.W. and J.P.; formal analysis: H.P. and J.P.; investigation: H.P. and Ž.Z.; resources: H.P. and Ž.Z.; data curation: H.P. and Ž.Z.; writing—original draft preparation: H.P., Ž.Z., J.A.W. and J.P.; writing—review & editing: H.P., Ž.Z., J.A.W. and J.P.; visualization: H.P.; supervision: H.P.; project administration: H.P. All authors have read and agreed to the published version of the manuscript.

ORCID iD:

Haris Pojskic: 0000-0002-9554-1234

Željko Zombra: 0009-0000-7050-4712

Jad Adrian Washif: 0000-0001-8543-4489

Jeffrey Pagaduan: 0000-0003-1435-7636

Funding Information: This research received no external funding.

Institutional Review Board Statement: This study was conducted following the principles of the Declaration of Helsinki, and approved by the Institutional Review Board of the Faculty of Physical Education and Sports, University of Tuzla (protocol code 02/11-2370/13-5.5. / 2013/03/18).

Informed Consent: Informed consent was obtained from all participants included in the study.

Conflicts of Interest: No potential conflict of interest were reported by the authors.

Acknowledgements: The researchers would like to thank the subjects for their kind cooperation during experimentation sessions.

Received: 23 June 2023

Accepted: 20 September 2023

References

- Adams, J. B., Edwards, D., Serravite, D. H., Bedient, A. M., Huntsman, E., Jacobs, K. A., Del Rossi, G., Roos, B. A., & Signorile, J. F. (2009). Optimal frequency, displacement, duration, and recovery patterns to maximize power output following acute whole-body vibration. *Journal of Strength and Conditioning Research*, 23(1), 237–245. <https://doi:10.1519/JSC.0b013e3181876830>

- Armstrong, W. J., Grinnell, D. C., & Warren G. S. (2010). The acute effect of whole-body vibration on the vertical jump height. *Journal of Strength and Conditioning Research*, 24(10), 2835–2839. <https://doi:10.1519/JSC.0b013e3181e271cc>
- Avelar, N. C., Salvado, F. S., Ribeiro, V. G., Vianna, D. M., Costa, S. J., Gripp, F., Coimbra, C. C., & Lacerda, A. C. (2014). Whole body vibration and post-activation potentiation: a study with repeated measures. *International Journal of Sports Medicine*, 35(8), 651–657. <https://doi:10.1055/s-0033-1354360>
- Bedient, A. M., Adams, J. B., Edwards, D., Serviette, D., Huntsman, E., Mow, S. E., Roos, B. A., & Signorile, J. F. (2009). Displacement and frequency for maximizing power output resulting from a bout of whole-body vibration. *Journal of Strength and Conditioning Research*, 23(6), 1683–1687. <https://doi:10.1519/JSC.0b013e3181b45bdc>
- Berriel, G. P., Cardoso, A. S., Costa, R. R., Rosa, R. G., Oliveira, H. B., Krueel, L. F. M., & Peyré-Tartaruga, L. A. (2022). Effects of Postactivation Performance Enhancement on The Vertical Jump in High-Level Volleyball Athletes. *Journal of Human Kinetics*, 82, 145–153. <https://doi.org/10.2478/hukin-2022-0041>
- Blazevich, A. J., & Babault, N. Post-activation Potentiation Versus Post-activation Performance Enhancement in Humans: Historical Perspective, Underlying Mechanisms, and Current Issues. (2019). *Frontiers in Physiology*, 10, 1359. <https://doi.org/10.3389/fphys.2019.01359>
- Bullock, N., Martin, D. T., Ross, A., Rosemond, C. D., Jordan, M. J., & Marino, F. E. (2008). Acute effect of whole-body vibration on sprint and jumping performance in elite skeleton athletes. *Journal of Strength and Conditioning Research*, 22(4), 1371–1374. <https://doi:10.1519/JSC.0b013e31816a44b5>
- Cardinale, M., & Lim, J. (2003). Electromyography activity of vastus lateralis muscle during whole body vibration of different frequencies. *Journal of Strength and Conditioning Research*, 17(3), 621–624.
- Cardinale, M., & Bosco, C. (2003). The use of vibration as an exercise intervention. *Exercise and Sport Sciences Reviews*, 31(1), 3–7.
- Chryssanthopoulos, C., Dallas, G., Arnaoutis, G., Ragkousi, E. C., Kapodistria, G., Lambropoulos, I., Papassotiriou, I., Philippou, A., Maridaki, M. & Theos, A., (2023). Young Artistic Gymnasts Drink Ad Libitum Only Half of Their Fluid Lost during Training, but More Fluid Intake Does Not Influence Performance. *Nutrients*, 15(12), 2667. <https://doi.org/10.3390/nu15122667>
- Cochrane, D. J., & Booker, H. (2014). Does Acute Vibration Exercise Enhance Horizontal Jump Performance? *Journal of Sports Science and Medicine*, 13(2), 315–20.
- Dabbs, N. C., Muñoz, C. X., Tran, T. T., Brown, L. E., & Bottaro, M. (2011). Effect of different rest intervals after whole-body vibration on vertical jump performance. *Journal of Strength and Conditioning Research*, 25(3), 662–7. <https://doi:10.1519/JSC.0b013e318207eafc>
- Dabbs, N., Tran, T. T., Garner, J. C., & Brown, L. E. (2012). Brief review: using whole-body vibration to increase acute power and vertical jump performance. *Strength and Conditioning Journal*, 34(5), 78–84. <https://doi:10.1519/SSC.0b013e31826daf9c>
- Dallas, G., Colson, S., Pappas, P., Dallas, C. & Paradisis, G. (2023). Whole body vibration and drop jumps induces post-activation performance enhancement. *Human Movement*, 24(2), 78–84. <https://doi.org/10.5114/hm.2023.117211>
- Dallas, G., Paradisis, G., Kirialanis, P., Mellos, V., Argitaki, P. & Smirniotou, A. (2015). The acute effects of different training loads of whole body vibration on flexibility and explosive strength of lower limbs in divers. *Biology of Sport*, 32(3), 235–241. <https://doi.org/10.5604/20831862.1163373>
- Di Iorio, F., Cesarelli, M., Bifulco, P., Fratini, A., Roveda, E., & Ruffo, M. (2012). The Effect of Whole Body Vibration on Oxygen Uptake and Electromyographic Signal of the Rectus Femoris Muscle during Static and Dynamic Squat. *Journal of Exercise Physiology Online*, 15(5), 18–31.
- Garbisu-Hualde, A., Gutierrez, L., & Santos-Concejero, J. (2023). Post-Activation Performance Enhancement as a Strategy to Improve Bench Press Performance to Volitional Failure. *Journal of Human Kinetics*, 88, 199–206. <https://doi.org/10.5114/jhk/162958>
- Gouvêa, A. L., Fernandes, I. A., César, E. P., Silva, W. A., & Gomes P. S. (2013). The effects of rest intervals on jumping performance: a meta-analysis on post-activation potentiation studies. *Journal of Sports Science*, 31(5), 459–67. <https://doi.org/10.1080/02640414.2012.738924>
- Hodgson, M., Docherty, D., & Robbins, D. (2005). Post activation Potentiation. *Sports Medicine*, 38, 585–595.

- Hortobágyi, T., Lesinski, M., Fernandez-del-Olmo, M., & Granacher, U. (2015). Small and inconsistent effects of whole body vibration on athletic performance: a systematic review and meta-analysis. *European Journal of Applied Physiology*, 115, 1605–1625. <https://doi.org/10.1007/s00421-015-3194-9>
- Kostrzewa, M., Laskowski, R., Wilk, M., Błach, W., IgnatjeVa, A., Nitychoruk, M. (2020). Significant Predictors of Sports Performance in Elite Men Judo Athletes Based on Multidimensional Regression Models. *International Journal of Environmental Research and Public Health* 17(21), 8192. <https://doi.org/10.3390/ijerph17218192>
- Krzysztofik, M., & Wilk, M. (2020). The effects of plyometric conditioning on post-activation bench press performance. *Journal of Human Kinetics*, 74, 99–108. <https://doi.org/10.2478/hukin-2020-0017>
- Loturco, I., Artioli, G. G., Kobal, R., Gil, S., & Franchini, E. (2014). Predicting punching acceleration from selected strength and power variables in elite karate athletes: a multiple regression analysis. *Journal of Strength and Conditioning Research*, 28(7), 1826–1832. <https://doi.org/10.1519/JSC.0000000000000329>
- Lowery R., Duncan N. M., Loenneke J. P., Sikorski E. M., Naimo M. A., Brown L. E., Wilson F. G., & Wilson J. M. (2012). The effects of potentiating stimuli intensity under varying rest periods on vertical jump performance and power. *Journal of Strength and Conditioning Research*, 26, 3320–3325. <https://doi.org/10.1519/JSC.0b013e318270fc56>
- Martínez de Quel, Ó., Ara, I., Izquierdo, M., & Ayán, C. (2020). Does Physical Fitness Predict Future Karate Success? A Study in Young Female Karatekas. *International Journal of Sports Physiology and Performance*, 15(6), 868–873. <https://doi.org/10.1123/ijsp.2019-0435>
- McBride, J. M., Nuzzo, J. L., Dayne, A. M., Israetel, M. A., Nieman, D. C., & Triplett, N. T. (2010). Effect of an acute bout of whole body vibration exercise on muscle force output and motor neuron excitability. *Journal of Strength and Conditioning Research*, 24(1), 184–189. <https://doi.org/10.1519/JSC.0b013e31819b79cf>
- Naclerio, F., Faigenbaum, A.D., Larumbe-Zabala, E., Ratamess, N. A., Kang, J., Friedman, P., & Ross, R. E. (2014). Effectiveness of different postactivation potentiation protocols with and without whole body vibration on jumping performance in college athletes. *Journal of Strength and Conditioning Research*, 28(1), 232–239. <https://doi.org/10.1519/JSC.0b013e318295d7fb>
- Pojkic, H., Papa, E. V., Wu, S. S. X. & Pagaduan, J. (2022). Validity, reliability, and usefulness of jump performance from a low-cost contact mat. *Journal of Human Sport and Exercise*, 17(2), 261–271. <https://doi.org/10.14198/jhse.2022.172.03>
- Pojkic, H., Pagaduan, J., Uzicanin, E., Babajic, F., Muratovic, M., & Tomljanovic, M. (2015). Acute effects of loaded whole body vibration training on performance. *Asian Journal of Sports Medicine*, 6(1), e24054. <https://doi.org/10.5812/asjms.24054>
- Pojkic, H., Pagaduan, J. C., Babajic, F., Uzicanin, E., Muratovic, M., & Tomljanovic, M. (2015). Acute effects of prolonged intermittent low-intensity isometric warm-up schemes on jump, sprint, and agility performance in collegiate soccer players. *Biology of Sport*, 32(2), 129–134. <https://doi.org/10.5604/20831862.1140427>
- Pyne, D., Hopkins, W., Batterham, A., Gleeson, M. & Fricker, P. (2005). Characterising the individual performance responses to mild illness in international swimmers. *British Journal of Sports Medicine*, 39(10), 752–756. <http://dx.doi.org/10.1136/bjms.2004.017475>
- Ravier, G., Dugué, B., Grappe, F., & Rouillon, J. D. (2009). Impressive anaerobic adaptations in elite karate athletes due to few intensive intermittent sessions added to regular karate training. *Scandinavian Journal of Medicine and Science in Sports*, 19(5), 687–94. <https://doi.org/10.1111/j.1600-0838.2008.00807.x>
- Robbins, D. W. & Docherty, D. (2005). Effect of loading on enhancement of power performance over three consecutive trials. *Journal of Strength and Conditioning Research*, 19(4), 898–902.
- Rønnestad, B. R. (2009). Acute effects of various whole-body vibration frequencies on lower- body power in trained and untrained subjects. *Journal of Strength and Conditioning Research*, 23(4), 1309–1315. <https://doi.org/10.1519/JSC.0b013e318199d720>
- Roschel H., Batista M, Monteiro R., Bertuzzi R. C., Barroso R., Loturco I., Ugrinowitsch C., Tricoli V., & Franchini E. (2009). Association between neuromuscular tests and kumite performance on the Brazilian Karate national team. *Journal of Sports Science and Medicine*, 8(CSSI 3), 20–24.

- Sale, D. (2004). Postactivation potentiation: role in performance. *British Journal of Sports Medicine*, 38(4), 386–387. <http://dx.doi.org/10.1136/bjism.2002.003392>
- Tsolakis, C., Bogdanis, G. C., Nikolaou, A., & Zacharogiannis, E. (2011). Influence of type of muscle contraction and gender on postactivation potentiation of upper and lower limb explosive performance in elite fencers. *Journal of Sports Science and Medicine*, 10(3), 577–583.
- Turner, A. P., Sanderson, M. F., & Attwood, L. A. (2011). The acute effect of different frequencies of whole-body vibration on countermovement jump performance. *Journal of Strength and Conditioning Research*, 25(6), 1592–1597. <https://doi.org/10.1519/JSC.0b013e3181df7fac>
- Washif, J. A. (2019). Does whole-body vibration potentiate reactive strength performance in sprinters? *Journal of Australian Strength and Conditioning*, 27(07), 14–22.
- Washif, J. A., & Kok, L. Y. (2022). Relationships between vertical jump metrics and sprint performance, and qualities that distinguish between faster and slower sprinters. *Journal of Science in Sport and Exercise*, 4(2), 135–44. <https://doi.org/10.1007/s42978-021-00122-4>
- Xenofondos, A., Laparadis, K., Kyranoudis, A., Galazoulas, C., Bassa, E., & Kotzamanidis, C. (2010). Postactivation-potentiation: factors affecting it and the effect on performance. *Journal of Physical Education and Sport*, 28, 32–38.