



Original Article

The effects of whole-body vibration exercise on isokinetic muscular function of the knee and jump performance depending on squatting position

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Abstract. [Purpose] The purpose of this study was to investigate the effects of whole-body vibration exercise (WBVE) on isokinetic muscular function of the knee and jump performance depending on different squatting positions. [Subjects] The subjects were 12 healthy adult men who did not exercise regularly between the ages of 27 and 34. [Methods] WBVE was performed with high squat position (SP), middle SP, and low SP. Before and after the intervention, isokinetic muscular function of the knees and jump performance were measured. [Results] Knee flexion peak torque at 60°/s and total work at 180°/s were significantly increased after implementing WBVE. Jump height also significantly increased after completing the exercise at all positions in comparison with the pre-exercise programs. [Conclusion] The results of this study suggest that SP during WBVE is an important factor stimulating positive effects on muscular function.

Key words: Whole-body vibration exercise, Squatting position, Muscular function

(This article was submitted Sep. 10, 2015, and was accepted Oct. 14, 2015)

INTRODUCTION

Muscular strength and power are important factors in neuromuscular control^{1, 2}). Neuromuscular control can be defined as an interaction between the nervous and musculoskeletal systems to produce a desired effect or response to a stimulus³). Enhancements of several factors such as muscular strength, power, and endurance are directly related to the improvement in an athletes' exercise performance. Recently, various kinds of training methods have been implemented in order to improve the muscular power of sports players; plyometric training has been a typical intervention for enhancing the muscular function⁴), power⁵), and running performance ability⁶). However, it might cause musculoskeletal injuries at landing phase^{7, 8}). In this sense, whole-body vibration exercise (WBVE), regarded as a neuromuscular training method utilizing a moderate vibration stimulus to improve muscular strength and power^{9–12}), has become a practical exercise intervention for athletes. The potential factors expected from WBVE are vibration type, frequency, body position, and additional load¹³). Among these, a change in the body position through different knee bending angles^{14, 15}) might be one of the most crucial factors that can augment muscular function with WBVE. However, previous studies have not suggested the optimal squatting position that can maximize the effect of WBVE, and explained the interrelationship between the optimum knee angle during a squat and WBVE. Accordingly, the primary objective of this study was to validate the optimal squatting position that maximizes muscular function when WBVE is performed with a certain vibration frequency, and for a certain time duration.

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Table 1. Differences in isokinetic muscular function of the knee and jump performance according to the squatting position

		Pre-intervention	HS (170°)	MS (125°)	LS (90°)	Comparison
60°/sec	Extension	518.3 ± 68.9	542.2 ± 56.3	537.0 ± 5.5	550.3 ± 67.8*	A < D
(Nm)	Flexion*	339.0 ± 50.5	392.2 ± 49.9	387.8 ± 47.8	412.3 ± 61.9	A < B,C,D
180°/s	total work* (J)	2,188.7 ± 346.6	2,728.0 ± 478.2	2,787.0 ± 444.0	2,685.9 ± 432.9	A < B,C,D
	Jump height* (cm)	49.16 ± 2.8	50.59 ± 3.4	51.04 ± 3.76	51.32 ± 3.6	A < B,C,D

All variables are mean ± standard deviation. s: second.

*a significant difference between the interventions ($p < 0.05$).

A: Pre-intervention, B: HS, C: MS, D: LS

SUBJECTS AND METHODS

12 subjects (men, aged 26 ± 1.9 years, height 175.91 ± 7.3 cm, weight 74.4 ± 10.88 kg) who did not exercise regularly participated in this study. The participants were explained the procedures and the purpose of the study, and were requested to submit a written consent form. This study was approved by the University of Sunmoon Research Ethics Review Committee (SYUIRB 2010-007, 27 February 2015) according to the Declaration of Helsinki.

The protocol of this study for assessing the vibration frequency and time is based on a previous study conducted by Bosco¹⁴, and interventions for the different squatting positions are adopted from studies conducted by Deleclus¹⁵ and Jacobs¹⁶. In addition, this study defined the squatting position according to the knee and hip angle as lower squatting position (LS) (90°), middle squatting position (MS) (140°), and high squatting position (HS) (170°).

WBVE was performed at 26 Hz frequency with 5 sets of exercise in one minute. After resting for 6 minutes, another session of 5 sets was conducted in one minute. All participants implemented the exercise program without wearing shoes and socks in order to eliminate additional effects like cushion of the shoes. Moreover, all measurements in this study were performed by the same tester, and the measurement schedules were planned with at least one-week interval after a certain session to minimize the learning effect.

Data from knee isokinetic muscular function test were evaluated with an isokinetic dynamometer, BTE PrimusRS system (BTE Technologies Inc., USA), and jump performance variables were measured with G-jump (BTS bioengineering, Italy). WBVE equipment (Galileo 2000, Novotec Medical, Germany) was used to determine the effects of the exercise program.

Statistical analysis was performed using SPSS/PC 18.0 statistical program for mean and standard deviations. Analysis of variance (ANOVA) was performed for repeated measurements to analyze the differences in knee isokinetic muscular function and jump performance depending on the squatting position. Moreover, the post-hoc test with least significance difference (LSD) was used in this study. Statistical significance level (α) for data analysis was set at $p < 0.05$.

RESULTS

In Table 1, the difference in isokinetic muscular function of the knee and jump performance depending on the squatting position, and the knee angles for each squatting position (HS, MS, and LS) are represented. Significant difference was seen in the knee flexor strength at 60°/s and knee muscle endurance at 180°/s after WBVE intervention in all squatting positions ($p < 0.05$). For the knee extensor strength at 60°/sec, among the squatting positions significant difference was seen only for LS. In addition, jump height was significantly increased in all squatting positions ($p < 0.05$).

DISCUSSION

In this study, it can be said that WBVE might have provided an external stimulus for improving muscular strength, power, and performance for sports players during the time period. The present study shows that isokinetic muscular functions such as muscular strength and endurance had significantly increased in all squatting positions with WBVE when compared to pre-exercise state. This implies that primary endings of the muscle spindle are stimulated by the vibrations, which excites the motor neurons causing contraction of motor units, resulting in tonic contraction of the muscle known as tonic vibration reflex^{15, 17}, and greater training effects are stimulated by increased motor unit recruitment as an effect of the tonic vibration reflex¹⁸. It is thought that the results of this study demonstrate the improvement in muscular functions by increasing the co-contraction ability of the synergist muscles. In addition, it is noteworthy that the muscular function in LS (90° knee angle) was significantly better than the pre-intervention state. Although no significant difference was found among the squatting positions, LS with WBVE might be able to maximize the neuromuscular exercise effect in terms of amplifying the sensitivity of the muscle spindle. It can be said that the stimulated spindle of vastus medialis and lateralis and its muscular power are the optimum results of WBVE with LS. These aspects could increase the tonic vibration reflex, and, as a result, the exercise ability such as jump performance was better in LS in comparison with other squatting positions (MS and HS). In other words, when applying WBVE with squatting position, the knee angle is one of the most important factors when it comes to consider-

ing the optimal exercise effect. More importantly, WBVE might be able to offer positive training effects to the sports players hoping to improve their muscular power and endurance within a short period, as shown in this study, when time or exercise methods are lacking. In conclusion, this study suggests that WBVE at 26 Hz vibration frequency with 90° angle of hip and knee might be a feasible exercise intervention for sports players; however, other combinations between the knee angle and vibration frequency for an optimal exercise effect should be considered in future studies.

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