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# Acute effects of whole-body vibration during dynamic lunge movement on jump and sprint performances

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**Abstract**

*Background and Study Aim* The aim of this study was to examine the acute effects of whole-body vibration applied to the dominant and non-dominant leg during repetitive lunge movements on jump and sprint performance.

*Material and Methods* Thirty-five male students from the Faculty of Sport Sciences voluntarily participated in the study. Participants performed squat jumps and countermovement jumps, and a 30-m sprint test on a non-motorized treadmill as pre- and post-tests. Participants were divided into the experimental group (n = 19, age: 22.0 ± 1.9 years, height: 177.7 ± 6.3 cm, body weight: 75.5 ± 12.6 kg) and the control group (n = 16, age: 21.9 ± 1.9 years, height: 173.4 ± 4.1 cm, body weight: 67.7 ± 7.1 kg). In the experimental group, a whole-body vibration of 50 Hz frequency and 4 mm amplitude was continuously applied to the dominant front leg. This was done on the whole-body vibration platform for 60 seconds throughout the repetitive lunge movement. At the end of the time, the leg was changed, and whole-body vibration was applied to the non-dominant leg using the same method. The control group performed the same movement without whole-body vibration. Pre- and post-test results were compared with an independent sample t-test within the group and a paired sample t-test between the groups. The statistical significance level was determined as $p \leqslant 0.05$.

*Results* The experimental group showed statistically significant pre-test and post-test differences in 30-m sprint power, non-dominant leg power, and non-dominant leg horizontal force parameters ($p < 0.05$, $p < 0.01$, and $p < 0.05$, respectively). It was determined that performing dynamic lunge movements with the dominant and non-dominant legs using whole-body vibration significantly increased mean power and non-dominant leg horizontal force.

*Conclusions* The acute effect on power, particularly on non-dominant leg power and non-dominant leg horizontal force during the 30-m sprint, was significant. This showed that whole-body vibration can be used as a short-term training method. In studies aiming to determine the acute and chronic effects of exercises with whole-body vibration on various performance parameters, it is important to focus on the frequency and amplitude differences in certain protocols.

**Keywords**: whole-body vibration, sprint, vertical force, horizontal force, power

## Introduction

In training science, whole-body vibration (WBV) during static or dynamic movements is frequently used as a training method to increase physical performance. It was first used for sports in Russia in the 1980s to give their Olympic team a competitive advantage by helping them speed up their recovery [1, 2]. Generally, WBV is applied before exercise on a special platform to prevent muscular fatigue [3]. It is performed at various amplitudes (1-10 mm) and frequencies (1-60 Hz) [4] in two ways: the athlete's whole body is on a platform, or vibration is applied to a part of their body [5]. With the increasing popularity of this novel approach in sports science, the aim is to enhance neuromuscular strength and power [6].

Low-frequency vibrations can simultaneously stimulate joints, tendons, and muscles [7]. Meanwhile, muscle spindles are stimulated through short and fast mechanical vibrations, creating a type of reflex response called a tonic vibration reflex. As a result of this reflex response, there is an increase in muscle tone [8]. When WBV is applied to the body, muscles and tendons, due to their flexible structure, act as spring-like elements in the release mechanism of stored energy [9]. Additionally, in WBV, the body's soft tissues, muscles, bones, and joints can tolerate, overcome, and absorb mechanical energy up to a certain point [10]. WBV causes reactive forces by transferring energy to the whole body


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or to a specific part of the body. These forces have the potential to be beneficial but also potentially harmful [11]. Based on this idea, it has been predicted that the use of WBV in training science may be beneficial for performance improvement [12, 13]. Repetitive muscle contractions performed with WBV for 20 seconds to 1 minute at a frequency of >20 Hz, combined with strength training, can improve maximal voluntary contraction [10]. This development is caused by motor unit synchronization and the firing of previously inactive motor units [2].

In the study [14], WBV training was applied to trained and untrained individuals at different exercise intensities (20, 35, 50 Hz and 3 mm amplitude) to determine its acute effect on the lower extremities. Following this, squat jump (SJ) and countermovement jump (CMJ) were tested. Improvement was observed in both groups at a frequency of 50 Hz, whereas no improvement was seen at frequencies of 20 and 35 Hz. Consequently, it was concluded that working with 50 Hz is necessary to determine the effects of traditional explosive strength training. This conclusion was supported by Feland et al.'s [15] study, which found that WBV, including 10 intervals (26 Hz and 3.6 mm) of 60 seconds in a half squat followed by 60 seconds of rest, had no effect on CMJ.

Involuntary contractions can be increased with vibration training [16]. WBV training increased the activation of the leg muscles (rectus femoris, vastus lateralis, vastus medialis, and gastrocnemius) [4]. Peak power values increased after concentric contractions due to squat training performed with vibration [3]. Since CMJ increased after WBV training, WBV training could be a potential warm-up exercise to enhance CMJ [17]. Dallas et al. [18] also found an increase in SJ and CMJ with WBV training.

Studies have shown that WBV training has positive effects on performance [6, 18, 19, 20], but there are also studies indicating that it has negative or no effects [11, 21, 22]. It is believed that new studies using WBV at different frequencies, various body positions, and movements are needed to obtain more detailed information about the effects of WBV applications.

Although many studies [6, 23, 24, 25] have examined the acute effects of WBV during dynamic movements on SJ and CMJ heights and sprint time, the varying results regarding SJ and CMJ jump heights and sprint time are attributed to differences in vibration parameters. These parameters include amplitudes between 0.83-4.00 mm, frequencies between 20-50 Hz, application times between 20-90 seconds, repetitions between 1-10, and movement variabilities. Based on these studies, determining the specific effects of WBV on the dominant leg (DL) and non-dominant leg (NDL) during dynamic lunge movements, particularly for leg muscle performance improvement, will inform new training protocols for jumping and sprinting. It will also guide future studies on the chronic effects of WBV. Therefore, the aim of this study was to examine the acute effects of WBV applied to the DL and then the NDL during repetitive lunge movements on jump and sprint performances.

## Material and Methods

*Participants*

Forty male students from the Faculty of Sports Sciences, aged between 18 and 22, participated in this study. These students had no experience with WBV training and were physically active at an easy-to-medium level (⩽3 aerobic sessions per week). G*Power 3.1.9.7 analysis indicated that a minimum of 38 participants (19 in each group) was necessary for the study. The analysis was based on a required power (1- β) of .80, a type I error or alpha level, α = .05, and an effect size (d) of .80. The study utilized a non-crossover experimental design, with subjects randomly divided into two groups: the experimental group (EG) (n = 19, age: 22.0 ± 1.9 years, height: 177.7 ± 6.3 cm, body weight: 75.5 ± 12.6 kg) and the control group (CG) (n = 16, age: 21.9 ± 1.9 years, height: 173.4 ± 4.1 cm, body weight: 67.7 ± 7.1 kg).

Two participants from the EG and three participants from the CG were excluded from the study due to missing values. Participants were free to discontinue the study at any time. They were asked to maintain their normal dietary intake, avoid any strenuous exercise in the 48 hours before the experimental sessions, and abstain from smoking, alcohol, and caffeine consumption for 24 hours before all tests. Participants were randomly assigned to the test protocols.

Written informed consent was obtained from the participants in accordance with the principles of the Helsinki Declaration after the procedures and potential risks had been explained to them. Ethical Committee approval (Code number: Istanbul Nisantasi University n.2022/24) was also obtained.

*Research Design*

Participants were assigned to the measurement and testing protocols using a simple random method. Each participant performed a 30-m sprint on a non-motorized treadmill and jump tests before and after the vibration applied during repetitive lunge movements with the DL and then the NDL. Before starting the measurements and tests, each device was calibrated. Each participant underwent tests and the vibration protocol for trial and familiarization 3-7 days before the study. The "Waterloo Footedness Questionnaire-Revised" by Elias and Bryden [26], adapted to Turkish by Özsu [27], was used to determine the DL and NDL.

The participants warmed up for 10 minutes in their sportswear, which included jogging, stretching, and exercise movements. As pre-tests, they performed two 30-m sprint tests with 3-minute intervals and vertical jump tests consisting of SJ and CMJ after 90 seconds of passive rest, as stated by Kacoglu and Kale [28]. Each jump test was performed twice with 30 seconds of passive rest between attempts. Each participant rested passively between the two jump tests. Before the post-tests, during the repetitive dynamic lunges, the DL and then the NDL were placed on the vibration platform, and the vibration was applied to the sole of the foot for 1 minute each, totaling 2 minutes in the EG. The CG performed the same lunges without WBV. The two 30-m sprint and jump tests were repeated with the same protocols after a 90-second passive rest following the dynamic lunges.

*Body Weight and Height Measurements*

Body weight was measured using an electronic laboratory scale (Seca, Vogel & Halke, Hamburg) with an accuracy of 0.1 kg, and height was measured using a wall-mounted stadiometer (Holtain, UK) with an accuracy of 0.01 mm, according to Lohman et al. [29].

*Sprint Test*

Subjects participated in a 2x30 m sprint test with a 3-minute interval on a non-motorized computer-assisted treadmill (Woodway Force 3.0, Woodway Inc., USA) after a 10-minute warm-up consisting of light running, stretching, and mobility exercises. Before testing, the horizontal force (HF) strain gauge was adjusted parallel to the treadmill at waist level. The best 30 m sprint result was statistically analyzed. Thirty-meter sprint speed was calculated using the mean velocity (Vmean) formula: Vmean = distance (d) / time (t), expressed in $m{\cdot}s^{-1}$. During the 30 m sprint, HF and vertical force (VF) data were recorded to a computer at 200 Hz.

Mean HF ($HF_{mean}$) was calculated with 30 m sprint total HF/30m sprint total stride number formula in terms of Newton. Mean VF ($VF_{mean}$) was calculated with 30 m sprint total VF/30m sprint total stride number formula in terms of Newton. Same calculation method was used for all other sprint parameters of both legs that are mean stride frequency ($SF_{mean}$), mean stride length ($SL_{mean}$), mean work ($W_{mean}$) and mean power ($P_{mean}$), and also DL and NDL that are dominant leg SF ($SF_{DL}$), non-dominant leg ($SF_{NDL}$), dominant leg SL ($SL_{DL}$), non-dominant leg SL ($SL_{NDL}$), dominant leg HF ($HF_{DL}$), non-dominant leg HF ($HF_{NDL}$), dominant leg VF ($VF_{DL}$), non-dominant leg VF ($VF_{NDL}$), dominant leg W ($W_{DL}$), non-dominant leg W ($W_{NDL}$), dominant leg P ($P_{DL}$), non-dominant leg P ($P_{NDL}$).

*Jump Tests*

SJ and CMJ tests were performed using the OptoJump™ (Microgate, Bolzano, Italy), which records with 1 ms accuracy. One of the two parallel bars of the device, placed on the ground and connected to the computer via a data-transmitting cable, served as the transmitter unit emitting infrared light 0.003 m above the ground. The other bar functioned as the receiver unit. Each participant performed the SJ and CMJ after taking a fixed position for jumping between these two parallel bars. When the participant's feet interrupted the infrared light during the jump, the timer on the unit was triggered and stopped when the feet returned to the starting position after the jump. The time between taking off from the ground and landing back on the ground after the jump was considered the flight time.

The flight time of the SJ and CMJ was transferred to the computer, and the jump heights were calculated using the OptoJump™ software. After each jump test, participants rested for 60 seconds. For each jump test, two trials were performed with 30-second rest breaks, and the highest jump height was used for statistical evaluation. As suggested by Bosco and Komi [30], the SJ was performed on the ground between two parallel bars, with feet shoulder-width apart, eyes focused forward, hands on the waist, and jumping vertically from a ~90° fixed squat position. The CMJ was performed on the ground between the same two parallel bars, with feet shoulder-width apart, eyes focused forward, hands on the waist, squatting from the standing position to a ~90° squat position as quickly as possible, and then jumping vertically.

*WBV*

First, the mat on the WBV device (Power Plate, pro5, AIRdaptive, London, UK) was removed to prevent it from absorbing the vibration. Each participant in the EG was prepared according to Kale [31]: without shoes, with hands on the waist and torso upright, standing on the phalanges of the DL. After positioning their knees in a flexed position between approximately 110-130°, a repetitive dynamic lunge movement was performed, extending until the knees reached 180°. During the repetitive dynamic lunge movement, WBV was applied to the DL for 1 minute at a frequency of 50 Hz and an amplitude of 4 mm. To ensure the foot on the WBV device maintained a 90° joint angle, each participant placed their other foot on a stand of the same height outside the WBV device. Immediately after this period, the leg was changed, and WBV was applied to the NDL using the same method.

*Statistical Analyses*

Data analysis was conducted using Jamovi (2.3.28.0, Stats Open Now). All pre-test parameters of the participants were determined to be normally distributed by Skewness-Kurtosis analysis, and they were divided into two groups, EG and CG, using a simple random method. The same statistical analyses showed that the pre-test parameters of EG and CG were normally distributed. Pre-test jump and 30 m sprint parameters related to the NDL and DL were normally distributed, except for $HF_{NDL}$ and $HF_{DL}$. Specifically, pre-test parameters were normally distributed except for $HF_{DL}$ in EG and $HF_{NDL}$ in CG. Pre- and post-test results between the groups were compared using an independent sample t-test. Pre- and post-test results within the groups were compared using a paired sample t-test. The Mann-Whitney U test was used for pre-test and post-test comparisons between the two groups for $HF_{NDL}$ and $HF_{NDL}$, which did not show normal distributions in the pre-tests, and the Wilcoxon Signed Rank test was used for pre- and post-test comparisons within the two groups. Statistical significance was determined by an alpha level of $p \leqslant 0.05$. Cohen's d effect size (ES) was calculated from the mean and standard deviation and classified as: trivial (<0.20), small (0.20 to 0.49), medium (0.50 to 0.79), or large (⩾0.80) as described by Wassertheil and Cohen [32].

## Results

All results are presented in Tables 1, 2, 3, 4, and 5.

There were no significant statistical pre- and post-test differences between and within 2 groups in SJ and CMJ parameters (Table 1).

As seen in Table 2, there were statistically significant differences in the VF and P parameters between the groups in the 30 m sprint pre-tests [ES: 0.89 (large), $p < 0.01$ and ES: 0.76 (moderate), $p < 0.05$, respectively]. In the post-tests, statistically significant differences were also found between the groups in the same parameters [ES: 1.0 (large), $p < 0.01$ and ES: 0.88 (large), $p < 0.05$, respectively]. In pre- and post-test comparisons within the groups, only the P parameter showed a statistically significant difference in the EG [ES: 0.52 (moderate), $p < 0.05$].

As seen in Table 3, the non-parametric comparisons between groups for the HF parameter, which did not show a normal distribution in the 30 m sprint, revealed significant differences in the pre-tests [ES: 0.49 (low), $p < 0.01$] and in the post-tests [ES: 1.14 (large), $p < 0.001$]. There were no statistically significant pre- and post-test differences within the two groups for the HF parameter.

Table 4 showed that there were significant statistical pre-test differences in $VF_{NDL}$, $VF_{DL}$, and $P_{DL}$ between EG and CG ($p < 0.01$, $p < 0.05$, and $p < 0.01$, respectively). $VF_{NDL}$, $VF_{DL}$, $P_{NDL}$, and $P_{DL}$ had significant post-test differences between EG and CG ($p < 0.05$, $p < 0.01$, $p < 0.05$, and $p < 0.05$, respectively). Pre-test and post-test $P_{BOB}$ comparisons within the groups demonstrated a statistically significant difference in EG ($p < 0.01$).

As seen in Table 5, there was no statistically significant $HF_{NDL}$ difference in the pre-test in the non-parametric comparisons between groups, but there was a statistically significant difference in the post-test comparison [ES: 0.41 (small), $p < 0.05$]. In non-parametric comparisons of $HF_{DL}$ between groups, a statistically significant difference was found in the pre-tests [ES: 0.61 (medium), $p < 0.01$] and in the post-tests [ES: 0.43 (low), $p < 0.05$]. $HF_{NDL}$ showed a statistically significant difference in EG [ES: -0.71 (medium), $p < 0.01$] for pre-test and post-test non-parametric comparisons within the groups.

## Discussion

The aim of this study was to examine the acute effects of vibration applied to the DL and then the NDL during repetitive lunge movements on jump and sprint performances. In the literature, only one study [30] investigated the acute effects of dynamic lunge movement with NDL WBV (4 mm, 50 Hz, 60 s) on sprinting and jumping in 38 physically active males who exercised at least three times a week from the Faculty of Sports Sciences. In the study by [30], there was an acute statistical decrease ($p < 0.05$) in the performance of 30 m sprints, SJ, and CMJ after dynamic lunge movement performed with WBV only on the NDL. In contrast, the current study found no decrease in these variables after the lunge movement performed with WBV on both the DL and NDL.

**Table 1.** Mean ± SD values and pre- and post-test comparisons of jump parameters for DG (n= 19) and CG (n= 16)

| Parameters | Group | Pre | Post | ES [95% CI] | Inference |
|---|---|---|---|---|---|
| SJ (cm) | EG | 35.4 ± 7.4 | 35.9 ± 8.2 | 0.22 [-0.67, 0.23] | Small |
| | CG | 32.5 ± 4.5 | 32.8 ± 4.4 | 0.16 [-0.65, 0.32] | Trivial |
| | ES [95% CI] | 0.35 [-0.15, 0.85] | 0.39 [-0.12, 0.89] | | |
| | Inference | Small | Small | | |
| CMJ (cm) | EG | 38.3 ± 7.8 | 38.4 ± 8.4 | 0.04 [-0.49, 0.40] | Trivial |
| | CG | 35.01 ± 4.4 | 35.5 ± 4.3 | 0.36 [-0.86, 0.14] | Small |
| | ES [95% CI] | 0.33 [-0.17, 0.83] | 0.33 [-0.18, 0.83] | | |
| | Inference | Small | Small | | |

SJ: Squat jump; CMJ: Countermovement jump; EG: Experimental group; CG: Control group; Mean ± Sd: Mean ± Standard deviation; ES [%95 CI]: Effect size [95% Confidence interval].

**Table 2.** Mean ± SD values and pre- and post-test comparisons of 30 m sprint parameters for DG (n= 19) and CG (n= 16)

| Parameters | Group | Pre | Post | ES [95% CI] | Inference |
|---|---|---|---|---|---|
| t (s) | EG | 6.43 ±1.6 | 6.47 ± 1.6 | 0.12 [-0.57, 0.32] | Trivial |
| | CG | 5.51 ±1.6 | 5.59 ± 1.78 | 0.22 [-0.72, 0.27] | Small |
| | ES [95% CI] | 0.56 [-0.13, 1.24] | 0.52 [-0.17, 1.19] | | |
| | Inference | Moderate | Moderate | | |
| TS (number) | EG | 36.05 ± 5.38 | 36.57 ± 6.34 | 0.12 [-0.57, 0.32] | Trivial |
| | CG | 38.62 ± 5.78 | 39.37 ± 5.14 | 0.13 [-0.62, 0.36] | Trivial |
| | ES [95% CI] | 0.46 [-1.13, 0.22] | 0.47 [-1.15, 0.21] | | |
| | Inference | Small | Small | | |
| SF (Hz) | EG | 5.99 ± 1.22 | 6.21 ± 1.09 | 0.24 [-0.69, 0.21] | Small |
| | CG | 6.38 ± 1.10 | 6.52 ± 0.86 | 0.14 [-0.63, 0.34] | Trivial |
| | ES [95% CI] | 0.32 [-0.99, 0.35] | 0.31 [-0.98, 0.36] | | |
| | Inference | Small | Small | | |
| SL (m) | EG | 0.85 ± 0.12 | 0.84 ± .14 | 0.06 [-0.39, 0.51] | Trivial |
| | CG | 0.79 ± 0.12 | 0.77 ± .10 | 0.17 [-0.32, 0.66] | Trivial |
| | ES [95% CI] | 0.46 [-0.22, 1.13] | 0.54 [-0.14, 1.23] | | |
| | Inference | Small | Moderate | | |
| VF (N) | EG | 786.1 ± 153.1 | 796.7 ± 158.7 | 0.30 [-0.76, 0.15] | Small |
| | CG | 673 ± 84.3¥¥ | 665.7 ± 85.5¥¥ | 0.15 [-0.34, 0.64] | Trivial |
| | ES [95% CI] | 0.89 [0.15, 1.6] | 1.00 [0.25, 1.70] | | |
| | Inference | Large | Large | | |
| P (W) | EG | 725.7 ± 96.6 | 761 ± 133.9* | 0.52 [-0.99, -0.03] | Moderate |
| | CG | 664.2 ± 54.8¥ | 663.7 ± 71.9¥ | 0.01 [-0.47, 0.50] | Trivial |
| | ES [95% CI] | 0.76 [0.04, 1.46] | 0.88 [0.14, 1.59] | | |
| | Inference | Moderate | Large | | |

EG: Experimental group; CG: Control group; Mean ± Sd: Mean ± Standard deviation; ES [%95 CI]: Effect size [95% Confidence interval]; t: time; TS: Total stride; SF: Stride frequency; SL: Stride length; HF: Horizontal force; VF: Vertical force; P: Power; *: p<0.05 within the groups; ¥: p<0.05 between the groups; ¥¥: p<0.01 between the groups.

**Table 3.** Mean ± SD values and pre- and post-test non-parametric comparisons of HF parameters in 30 m sprint test for DG (n= 19) and CG (n= 16)

| Parameters | Group | Pre | Post | ES | Inference |
|---|---|---|---|---|---|
| HF (N) | **EG** | 153.4 ± 8.61 | 160.1 ± 15.9 | -0.58 | Moderate |
| | **CG** | 145.7 ±6.12¥¥ | 145.7 ±6.80¥¥¥ | 0.07 | Trivial |
| | **ES** | 0.49 | 1.14 | | |
| | **Inference** | Small | Large | | |

EG: Experimental group; CG: Control group; Mean ± Sd: Mean ± Standard deviation; ES [%95 CI]: Effect size [95% Confidence interval]; HF: Horizontal force; ¥¥: p<0.01 between the groups; ¥¥¥: p<0.001 between the groups.

Many studies have investigated the effects of WBV on increasing muscle activity in both acute and chronic conditions, particularly in vertical jump [33, 34], CMJ [14, 17, 34, 35], power and gross motor learning [36], and squats [37, 38, 39]. The main factors contributing to the varying results in the acute and chronic effects of WBV exercises on performance parameters include amplitude and frequency intervals, type of WBV, application procedures, training volume and intensity, exercise protocols, and participant characteristics [35].

The study by [36] stated that WBV combined

**Table 4.** Mean ± SD values and pre- and post-test non-parametric comparisons of 30 m sprint DL and NDL parameters for DG (n= 19) and CG (n= 16)

| Parameters | Group | Pre | Post | ES [95% CI] | Inference |
|---|---|---|---|---|---|
| $SF_{NDL}$ (Hz) | EG | 6.05 ± 1.14 | 6.23 ± 1.10 | 0.25 [-0.70, 0.20] | Small |
| | CG | 6.36 ± 1.15 | 6.44 ± .90 | 0.08 [-0.57, 0.40] | Trivial |
| | ES [95% CI] | 0.27 [-0.40, 0.93] | 0.20 [-0.46, 0.86] | | |
| | Inference | Small | Small | | |
| $SF_{DL}$ (Hz) | EG | 6.20 ± 1.10 | 6.18 ± 1.13 | 0.02 [-0.42, 0.47] | Trivial |
| | CG | 6.39 ± 1.09 | 6.59 ± .92 | 0.17 [-0.66, 0.31] | Trivial |
| | ES [95% CI] | 0.17 [-0.49, 0.84] | 0.39 [-0.29, 0.60] | | |
| | Inference | Trivial | Small | | |
| $SL_{NDL}$ (m) | EG | 0.83 ± 0.12 | 0.82 ± 0.13 | 0.11 [-0.33, 0.56] | Trivial |
| | CG | 0.78 ± 0.12 | 0.76 ± 0.11 | 0.16 [-0.33, 0.65] | Trivial |
| | ES [95% CI] | 0.35 [-1.02, 0,32] | 0.42 [-1.09, 0.26] | | |
| | Inference | Small | Small | | |
| $SL_{DL}$ (m) | EG | 0.83 ± 0.14 | 0.83 ± 0.14 | 0.01 [-0.43, 0.46] | Trivial |
| | CG | 0.78 ± 0.12 | 0.75 ± 0.10 | 0.23 [-0.26, 0.72 ] | Small |
| | ES [95% CI] | 0.43 [-1.10, 0.25] | 0.63 [-1.33, 0.07] | | |
| | Inference | Small | Moderate | | |
| $VF_{NDL}$ (N) | EG | 758 ± 178 | 806 ± 206 | 0.30 [-0.76, 0.15] | Small |
| | CG | 577 ± 140¥¥ | 666 ± 136¥ | 0.49 [-10.1, 0.03] | Small |
| | ES [95% CI] | 1.11 [-1.87, -0.32] | 0.78 [-1.49, -0.05] | | |
| | Inference | Large | Moderate | | |
| $VF_{DL}$ (N) | EG | 865 ± 160 | 826 ± 173 | 0.22 [-0.23, 0.68] | Small |
| | CG | 749 ± 145¥ | 664 ± 131¥¥ | 0.51 [-0.01, 0.20] | Moderate |
| | ES [95% CI] | 0.75 [-1.46, -0.02] | 1.03 [-1.78, -0.26] | | |
| | Inference | Moderate | Large | | |
| $P_{NDL}$ (W) | EG | 701 ± 106 | 773 ± 162** | 0.66 [-1.15, -0.15] | Moderate |
| | CG | 669 ± 87 | 670 ± 97¥ | 0.01 [-0.50, 0.47] | Trivial |
| | ES [95% CI] | 0.32 [-0.99, 0.35] | 0.74 [-1.45, -0.01] | | |
| | Inference | Small | Moderate | | |
| $P_{DL}$ (W) | EG | 750 ± 97 | 748 ± 149 | 0.01 [-0.43, 0.46] | Trivial |
| | CG | 659 ± 100¥¥ | 656 ± 80¥ | 0.02 [-0.46, 0.51] | Trivial |
| | ES [95% CI] | .92 [-1.65, -0.16] | 0.75 [-1.45, -0.02] | | |
| | Inference | Large | Moderate | | |

EG: Experimental group; CG: Control group; Mean ± Sd: Mean ± Standard deviation; ES [%95 CI]: Effect size [95% Confidence interval]; SFNDL: Non-dominant leg stride frequency; SFDL: Dominant leg stride frequency; SLNDL: Non-dominant leg stride length; SLDL: Dominant leg stride length; HFNDL: Non-dominant leg horizontal force; HFDL: Dominant leg horizontal force; VFNDL: Non-dominant leg vertical force; VFDL: Dominant leg vertical force; PNDL: Non-dominant leg power; PDL: Dominant leg power; **: p<0.01 within the groups; ¥ p<0.05 between the groups; ¥¥: p<0.01 between the groups.

with isometric squats is sufficient to induce post-activation potentiation (PAP), as indicated by a significant increase in maximal voluntary contraction (MVC) peak force immediately post-exercise. These results were supported by [40], which found that WBV causes a decrease in the excitation threshold of the central and peripheral nervous system, increasing the preferential recruitment of fast-twitch fibers. However, it was explained that the mechanism for this increase in peak force is unclear, as no changes in muscle activation or motor neuron excitability were observed. Another study [41] speculated that WBV for more than 1 minute may cause fatigue due to excessive contraction of the extrafusal fibers caused by constant muscle spindle firing, whereas WBV up to 1 minute may stimulate the gamma

Table 5. Mean ± SD values and pre- and post-test non-parametric comparisons of HFNDL and HFDL parameters in 30 m sprint test for DG (n= 19) and CG (n= 16)

| Parameters | Group | Pre | Post | ES | Inference |
|---|---|---|---|---|---|
| $HF_{NDL}$ (N) | EG | 148 ± 11 | 163 ± 21** | -0.71 | Moderate |
| | CG | 147 ± 15 | 147 ± 15¥ | 0.03 | Trivial |
| | EB | 0.09 | 0.41 | | |
| | Inference | Trivial | Small | | |
| $HF_{DL}$ (N) | EG | 158 ± 11 | 157 ± 24 | 0.19 | Trivial |
| | CG | 145 ± 18¥¥ | 144 ± 12¥ | -0.12 | Trivial |
| | ES | 0.61 | 0.43 | | |
| | Inference | Moderate | Small | | |

EG: Experimental group; CG: Control group; Mean ± Sd: Mean ± Standard deviation; ES [%95 CI]: Effect size [95% Confidence interval]; HFNDL: Non-dominant leg horizontal force; HFDL: Dominant leg horizontal force; **: p<0.05 within the groups; ¥: p<0.05 between the groups; ¥¥: p<0.01 between the groups.

motor neurons just enough to increase peak force. In contrast, [17] found no significant differences in isometric squat peak force immediately after WBV. Additionally, studies [42] indicated that isometric squats with WBV resulted in significant decreases in muscle force output, muscle activation, and vertical jump performance after WBV.

In the study by [43], involving 40 healthy adults, WBV combined with 12-week resistance exercises resulted in a statistically significant increase in knee extension isometric strength and CMJ. Resistance exercises combined with WBV for a total of 18 sessions, 3 days a week for 6 weeks, significantly increased electromyography activity ($p < 0.05$), indicating that resistance exercises combined with WBV can be used to enhance neuromuscular activity [44]. The supportive effect produced by WBV and resistance training is thought to be due to the resulting tonic vibration reflex [45]. This reflex allows for greater muscle contractions, which may provide a greater stimulus for the adaptation of muscle strength and power. The repetitive stretch-shortening cycle during dynamic lunges stiffened the muscle-tendon unit [44]. Changes in leg muscle activity that occur with WBV during dynamic lunges help to increase the voluntary muscle damage that occurs during the eccentric phase of these movements [46]. Since the main principle of WBV is to create enough vibration to overload the muscle-tendon complex, an increase in force in the overloaded muscle is the expected result. In the current study, although there were no statistically significant differences in SJ and CMJ in the EG between pre-tests and post-tests, there was a slight increase in SJ and CMJ in the post-tests. The results of this study on the acute effects of strength exercises with WBV are consistent with those of [44]. The results of this study might differ from previous findings due to differences in participant characteristics and exercise protocols.

Six weeks of WBV can significantly improve plantar flexion strength in young healthy individuals, but the mechanisms supporting this result are currently unclear, necessitating further studies [47]. In the study by [48], a static (30 s) and dynamic (15 repetitions in 30 s) heel lift exercise was applied to one leg at a frequency of 35 Hz and an amplitude of 2-4 mm, 72 hours apart, on individuals without a history of orthopedic medical injury who use their right leg dominantly. They found that static and dynamic heel lift exercises combined with acute WBV have a positive acute effect on mediolateral posture control during a single-leg stance. WBV leads to increased neuronal excitability in the corticospinal pathway, which may originate in the cortical, subcortical, or spinal neurons, coupled with inhibition of the reflex spinal pathway [49]. For this reason, Folland and Williams [50] stated that muscle strength and power may be affected by changes in the muscle activity of other agonist muscles or changes in other aspects of muscle activation, including changes in relative agonist-antagonist activities and/or changes in coordination and learning. In the present study, the dynamic lunge movement performed with DL and NDL with WBV increased PNDL and $HF_{NDL}$ statistically significantly, supporting the results of studies [47, 48, 50].

The study by [51] compared the effectiveness of two WBV protocols with equal training volume but different training frequencies on body composition and physical fitness. Participants were divided into three equal groups: a 3-days-a-week WBV group, a 5-days-a-week WBV group, and a control group. Both WBV groups followed a 10 x 1-minute protocol for each exercise session, which included 1 minute of WBV application (25-35 Hz, 4-6 mm) followed by 1 minute of rest. A statistically significant increase in maximum power ($p = 0.016$) was found in the 5-days-a-week WBV group. Similarly, SJ showed a statistically significant increase ($p < 0.01$) in both the 3-days-a-week and 5-days-a-week WBV groups. As a result, an intensified weekly WBV protocol was found to be more effective in improving lower extremity strength and power in young active individuals. It was observed that there was no significant effect on anaerobic power in the lower frequency training group compared to the higher frequency group. The results indicated that WBV performed 3 or 5 days a week increased SJ. Although there was no statistically significant increase in the current study, the increase in SJ from 35.4 ± 7.4 cm to 35.9 ± 8.2 cm demonstrates that this study supports the findings of [51].

The study by [41], which included WBV exercises at 26 Hz and 4 mm amplitude added to the warm-up routine, found a 6% increase in peak force applied by sprinters at the block start, while no difference was found in 30 m sprint times. Another study [52] concluded that WBV training performed 3 days a week, in addition to traditional training at 40 Hz and 2.5 mm amplitude, had no effect on improving sprint performance. In another study [53], a statistically significant increase in vertical jump performance was found in basketball players after 4 weeks of WBV training, but no change was observed in 10 m sprint performance. Additionally, the study by [54] investigated the acute effect of WBV exercises lasting 30 seconds at 50 Hz and 3 mm amplitude on 15 m, 30 m, and 45 m sprint performances and concluded that this WBV exercise protocol did not have an acute effect on sprint development.

In the study by [25], it was determined that both plyometric exercises and exercises with WBV had a statistically significant positive effect on CMJ and agility time ($p < 0.001$). While CMJ and agility performance were higher in the plyometric group, speed performance was higher in the WBV group; however, these differences were not statistically significant between the two groups. Additionally, the study by [55] stated that all fencing performances increased significantly within 1 minute and 2 minutes after WBV with a frequency of 30 Hz and an amplitude of 2 mm. As seen in the recent literature reviewed, while there are many studies on the acute and chronic relationship between WBV and motoric characteristics, there is no study examining the acute effect of WBV combined with dynamic exercise on DL and NDL on sprint and jumping. It is thought that the present study makes a significant contribution to the literature.

## Practical Applications

The acute effect on P and especially on $P_{NDL}$ and $HF_{NDL}$ during the 30 m sprint showed that WBV can be used as a short-term training method to improve $P_{NDL}$ and $HF_{NDL}$. In studies to determine the acute and chronic effects of exercises with WBV on various performance parameters, focusing on the frequency and amplitude differences in certain protocols will provide more specific information about the effects of this training method.

## Conclusions

In conclusion, dynamic movements such as repetitive lunges with WBV to DL and then to NDL highlighted the effect especially on sprinting, showing that WBV can also contribute to the training of different sports that require speed.

## Conflict of interest

The authors have no conflicts of interest to declare.

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