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Original Article

The effects of two different whole-body vibration frequencies on isometric strength, anaerobic performance, and rating of perceived exertion

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Abstract:
We aimed to compare the effects of low- and high-frequency vertical whole-body vibration training in the static squat position for 3 days/week for 6 weeks on anaerobic power, anaerobic capacity, isometric back and leg strength, and rating of perceived exertion. Subjects were 16 recreationally active men (23.3 ± 3.3) randomly divided into 2 groups: low frequency (25 Hz) group (n = 9) and high frequency (40 Hz) group (n = 7). In the first 3 weeks of the study, we applied whole-body vibration for 5 × 1 minute with 1-minute resting intervals and, in the second 3-week period, for 7 × 1 minute with 40-second resting intervals with 2-mm peak-to-peak amplitude. Anaerobic performances, leg and back strength, and rating of perceived exertion during these performances was measured with the Wingate anaerobic power test, isometric leg strength test, and Borg scale, respectively. Isometric leg and back strength, fatigue index, and rating of perceived exertion were found to be unaffected by either frequency. However, anaerobic performance assessment variables showed that both frequencies improved anaerobic power (peak power and relative peak power) and anaerobic capacity (mean power and relative mean power) (low-frequency group, $0.84 \leq r \leq 0.89$; high-frequency group, $0.51 \leq r \leq 0.64$). In conclusion, both frequencies (25 Hz and 40 Hz) increased anaerobic performance variables. The small sample size was the most important limiting factor of this study. Another study with a larger sample size might be more beneficial for achieving more reliable results.
Key words: squat vibration exercise, anaerobic power, anaerobic capacity, isometric strength, Borg's scale

Introduction

Anaerobic performance consists of anaerobic power and anaerobic capacity, 2 of the most important performance criteria of sports requiring short-term explosive effort (Issurin and Tenenbaum, 1999; Özkan et al., 2009). Studies done in the last decade showed that there is positive correlation between anaerobic performance and leg strength (Kin-İşler et al., 2008). According to Arslan (2005), performance in basic motor skills such as running and jumping is highly related to leg strength; moreover, leg strength is one of the key components in modern sports.

It has been reported that both recreational and competitive athletes preferred modern strength training methods to traditional ones until the 1980s (Wirth et al., 2011; Cardinale and Erskine, 2008). Therefore, the number of athletes who use vibration-training methods is increasing (de Ruiter et al., 2003a).

Although the neuromyogenic mechanism of vibration applications is not fully understood, stimulation of muscle spindles, one of the sensory receptors of muscles, by the mechanical vibration may be one of the possibilities of this mechanism. This stimulation leads to the activation of the alpha-motor neurons and initiation of muscle contractions comparable to the previously described tonic vibration reflex (Delecluse et al., 2003). Although this information mostly explains the physiological mechanism of the vibration training, there is no consensus on which combinations of application variables (such as frequency, amplitude, application and resting periods, number of sets, contraction type [dynamic or static], use of additional load or body weight, and body position) are safest and most effective (Paradisis and Zacharogianis, 2007; Cardinale and Lim; 2003; Delecluse et al., 2003).

Cardinale and Wakeling (2005) stated that frequency, amplitude, and application duration in vibration training defines the intensity of the vibration application. Frequency and amplitude of vibration exercises are 2 of the most commonly discussed variables in whole-body vibration training (WBVT). Generally, low-amplitude and high frequency application is accepted as a safe and effective method for improving musculoskeletal fitness (Torvinen et al., 2002a; Paradisis and Zacharogiannis, 2007; Rehn et al., 2007). In contrast, Cardinale and Lim (2003) argue that low-frequency and low-amplitude vibration application is also an effective method and state that high-frequency applications can cause neuromuscular fatigue, activating inhibitor mechanisms that impair performance. Some researchers also stated that to improve different motor skills, different frequencies and

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amplitudes should be applied (Gerodimos et al., 2010). According to Ronnestad (2009), the optimal frequency for improving average peak power and vertical jump height is 40–50 Hertz (Hz). However, 4–8 Hz has been stated to be the optimal frequency for flexibility improvement according to Gerodimos et al. (2010).

Furthermore, it has long been known that biological tissues also resonate with different frequencies. Internal organs, eyes, and muscles resonate at 8, 20, and 7–15 Hz, respectively (Mester et al., 2006). In some clinical studies, frequencies lower than 20 Hz were found to be harmful for human health (Schuhfried et al., 2005; Gusi, 2006; Paschold and Mayton, 2011). For this reason, the preferred frequency for vibration training should not be lower than 20 Hz. Torvinen et al. (2002) showed that 4 months of WBVT with nonathletic adults (21 men and 35 women aged 19–38 years) increased isometric lower limb extension strength. In contrast, Delecluse et al. (2005) found no increase of knee-flexor strength after 5 weeks of progressive WBVT with well-trained sprinters (6 women and 4 men, aged 17–30 years).

Many studies have shown that vibration training increases jump and anaerobic performance (Bosco et al., 1998; Torvinen et al., 2002; Wilcock et al., 2009; Paradisis and Zacharogianis, 2007). In some of these studies, countermovement jump and squat jump tests were used to assess anaerobic power and capacity and vertical jump. (Bosco et al., 1998; Torvinen et al., 2002; Wilcock et al., 2009; Paradisis and Zacharogianis, 2007). Duggan and Patton (1987) state that the Wingate anaerobic bicycle test is the most reliable method for testing anaerobic performance. Our review of the sport science literature found no study, with the exception of Oosthuyse et al. (2013), on short-term or long-term effects of chronic vibration application that assessed anaerobic performance with the Wingate anaerobic bicycle test. Therefore, the aim of this study was to compare the effects of low-frequency (25 Hz) and high-frequency (40 Hz) WBVT in a static squat position on anaerobic power, anaerobic capacity, isometric back and leg strength (IBS and ILS, respectively), and rating of perceived exertion (RPE).

Method

Participants

Twenty male students accepted to participate in this study were questioned regarding health issues (Roleants et al., 2004) to prevent health problems, especially during the Wingate anaerobic power test. All participants were evaluated by cardiologists and neurologists (neurological-cardiological testing, resting electrocardiogram, and echocardiography were performed, blood pressure was checked, and a treadmill stress test used to evaluate heart conditions) and approved as healthy according to results reported by the relevant doctors.

Procedures

After participants signed the consent forms, the study was presented to and approved by the local ethical committee (approval June 6, 2013, decision no. 16/10). Participants were randomly divided into 2 groups: the low-frequency (25 Hz) group (LFG) and the high-frequency (40 Hz) group (HFG). Three participants left the study for personal reasons. One participant from the HFG who had extreme values in statistical analysis was left out of the study, although he regularly attended the training sessions. The study was completed with 16 recreationally active male physical education and sports students. The LFG (age 22.8 ± 3.7 years, height 179.1 ± 6.3 cm, body mass 79.6 ± 11.9 kg, body mass index 24.7 ± 2.7 kg/m^2) and HFG (age 23.9 ± 2.9 years, height 175.4 ± 5.5 cm, body mass 72.0 ± 8.7 kg, body mass index 23.4 ± 2.7 kg/m^2) comprised 9 and 7 subjects, respectively.

All participants were informed about the testing procedures and watched an informative video about the Wingate anaerobic power, IBS, ILS, and 110° static squat tests before measurements were taken. Each participant then performed a 5-minute warm-up session on the Wingate bicycle ergometer at 60–70 rpm. They chose a saddle height on which they felt comfortable for pedaling. Two sets of IBS and ILS tests (with 1-minute resting intervals) were performed after warm-up. In every step of the study, dynamic/static stretching was avoided because of the possibility of a change in performance. In these trial sessions, the main aim was to introduce testing procedures to the participants.

All participants were also informed that engaging in regular physical activity (including strength, power, or jumping training) during the vibration sessions would result in exclusion from the study.

Pretest and posttest measurements were performed in the following sequence on the first day: 1) body mass and height measurement, 2) warm-up for ILS and IBS measurement (on the cycle ergometer, pedaling for 3 minutes at 60–70 rpm), 3) measurement of ILS, and 4) measurement of IBS. On the second day, 1) the standard warm-up for the Wingate anaerobic power test (Kin-İşler et al., 2008) was followed by 2) performing the Wingate test and determining the RPE score immediately afterward. Post-test measurements were completed within the first week after the vibration training program. For preventing anaerobic power, anaerobic capacity, and isometric power tests from being influenced by diurnal variations, each participant took the pretest and posttest at the same time of day. Pretest and posttest practices were conducted on 2 different days at 24-hour intervals.

Measures

Height and body mass measurement

Height and body mass measurements were performed with mechanical height and weight measurement equipment (ADE, M20/313/812, Germany). Measurements were performed without wearing shoes. Participants were allowed to wear only underwear. Mechanical height and weight measures were calibrated before each measurement by using free weights.

Knee angle measurement

A knee angle of 110° for the vibration application was measured with a plastic goniometer (Lafayette Instrument Europe, Richardson Products, Inc.; Sammons Preston J00240, 12-inch).

The Wingate anaerobic test

The Wingate anaerobic test (WAnT) was conducted by using a mechanically braked cycle ergometer (834 E; Monark, Vansbro, Sweden). The WAnT was administered for 30 seconds. The subjects warmed up for 5 minutes at a pedaling rate of 50 rpm against no load, after which they rested for 5 minutes. They were instructed to pedal as fast as they could. When the pedaling rate reached approximately 160–170 rpm, the resistance was applied and subjects continued pedaling as fast as possible for 30 seconds. Subjects were verbally encouraged during the test. Peak power (PP), relative PP (R-PP), mean power (MP), and relative MP (R-MP) were calculated automatically by the WAnT computer software. A fatigue index (FI) was calculated by the following equation (Alemdaroğlu, 2012):

$$FI (\%) = [(PP\ output - minimum\ power\ output)/PP\ output] \times 100$$

Borg's RPE scale

Exertion rates perceived by participants after the Wingate anaerobic power test were determined by using Borg's RPE scale. A value from the 15-point RPE scale, which consists of 15 reporting options between 6 and 20 (from "very very light" to "very very hard"), was given verbally (Garcia-Lopez et al., 2012).

Whole-body vibration platform and WBVT

Power Plate (Power Plate® Next Generation PRO 5, 2x1A) vertical whole-body vibration platform with a standard dampening mat of 2 cm thickness was used during the vibration treatments. Vibration treatments were performed barefoot in 110º static squat position, 3 times per week for 6 weeks, with 1-day interval between successive treatment days. Before vibration treatments, warm-up was carried out by pedaling on a bicycle ergometer at 50–60 rpm for 3 minutes. Peak-to-peak amplitude was fixed at 2 mm for both groups. Vibration at 25 Hz was applied to the LFG, and vibration at 40 Hz was applied to the HFG. Frequency identification as high or low was performed in accordance with Cardinale and Lim (2003). In the first 3 weeks of the study, vibration treatments were for 5 × 1 minute with 1-minute breaks and for the following weeks were for 7 × 1 minute with 40-second breaks.

Why static squat position was preferred during WBVT

The primary aim of this study was to determine the impact of whole-body vibration treatment applied at 2 different frequencies (25 and 40 Hz) on anaerobic performance and isometric leg/back strength. According to Arslan (2005), there is a positive correlation between dynamic and static muscle contraction and anaerobic power performance. However, it is known that vibration stimuli are transferred to the whole body through the lower extremities, particularly on vertical vibration platforms (Rehn et al., 2007). When viewed from this aspect, the greater part of the vibration stimulus applied in the squat position is absorbed by the active muscles of the lower extremities. These muscles are also the ones that determine the Wingate test performance (Sands et al., 2004). For this reason, squat and variations of squat exercises are the most preferred positions during vibration treatments (Rehn et al., 2007; Ritzmann et al., 2013).

Measurement of ILS and IBS

ILS and IBS were evaluated with a digital dynamometer (Takei Physical Fitness Test, TKK 5106, China). For the ILS evaluation, participants maintained a straight body position with knees in 130–140° flexion on the dynamometer platform. The chain of the dynamometer was adjusted to maintain the knee angle at 130–140° flexion. While the participant was trying to bring his knees to extension slowly but powerfully, maximum measure detected on the dynamometer was recorded as the ILS of the participant. The test was performed twice with a 1-minute interval, and the average of the 2 measurements was recorded as ILS. For IBS evaluation, participants took a position with strained legs and body slightly in flexion on the dynamometer platform. The chain of the dynamometer was adjusted to be in line with the kneecaps. The participant was asked to bring his body to extension slowly but powerfully without bending his legs. The test was performed twice with a 1-minute interval, and the average of the 2 measurements was recorded as IBS. All measurement results were recorded as newtons per kilogram and normalized to the body mass of the participant.

Statistical Analysis

The data of this study were analyzed by using the IBM® SPSS® Statistics for Windows version 20 software (IBM Corp., Armonk, NY). Because the small and unequal sample sizes limit the statistical power of the parametric tests and it is hard to assess the actual non-normality of the data with commonly used standard normality tests and graphing methods (Shapiro-Wilk test, Q-Q plots, normality graph with histograms, etc.), nonparametric tests were used in the statistical analyses of this study. Descriptive statistics are expressed as group median (25th–75th percentiles). Possible significant differences in the mean ranks of investigated variables and relative performance changes between high- and low-frequency vibration groups were assessed with the Mann-Whitney *U* test. The Wilcoxon signed-rank test was used in the assessment of possible differences between pre- and posttreatment measures within groups. The statistical significance level was set at $p \leq .05$ for all analyses. Effect sizes (*r*) are also indicated.

Results

When the demographic characteristics and investigated performance measures of the participants were considered, no significant difference was found between the low- and high-frequency vibration groups (Table 1).

Table 1: Differences in demographic characteristics and pre-intervention and post-intervention measures between low- and high-frequency vibration groups

	Low- and high-frequency vibration groups				
	Low (n = 9)	High (n = 7)	*Z*	*p*	*r*
Age (y)	22.0 (20.0-24.5)	23.0 (21.0-27.0)	0.96	.35	0.24
Height (cm)	177 (174-185)	176 (173-180)	-0.75	.47	0.19
Mass (pre) (kg)	77.0 (74.5-82.5)	73.0 (65.0-79.0)	-1.43	.17	0.36
Mass (post) (kg)	76.0 (72.5-82.0)	73.0 (67.0-77.0)	-0.59	.61	0.15
PP (pre) (W)	523 (458-812)	622 (539-807)	0.69	.54	0.17
PP (post) (W)	758 (601-897)	824 (579-975)	0.58	.61	0.15
R-PP (pre) (W/kg)	7.70 (4.93-10.5)	9.10 (8.23-9.75)	0.79	.47	0.20
R-PP (post) (W/kg)	10.8 (6.70-12.3)	10.7 (10.2-12.5)	0.37	.76	0.09
MP (pre) (W)	406 (372-535)	430 (411-597)	1.01	.35	0.25
MP (post) (W)	505 (455-585)	589 (367-618)	0.37	.76	0.09
R-MP (pre) (W/kg)	5.37 (4.15-6.91)	6.32 (5.73-7.54)	1.11	.30	0.28
R-MP (post) (W/kg)	7.07 (5.34-8.25)	7.66 (6.44-8.30)	0.48	.68	0.12
ILS (pre) (N)	1248 (1160-1589)	1214 (1118-1366)	-0.79	.47	-0.20
ILS (post) (N)	1250 (1122-1429)	1204 (1074-1442)	-0.27	.84	-0.07
R-ILS (pre) (N/kg)	16.8 (13.5-21.2)	16.6 (14.9-18.3)	-0.05	1.00	-0.01
R-ILS (post) (N/kg)	16.8 (13.8-19.3)	17.2 (14.9-19.3)	-0.27	.84	-0.07
IBS (pre) (N)	1270 (1084-1402)	1312 (1141-1346)	-0.11	.92	-0.03
IBS (post) (N)	1182 (1141-1265)	1292 (1241-1410)	-1.48	.14	-0.37
R-IBS (pre) (N/kg)	15.1 (13.5-18.9)	17.2 (15.8-17.5)	-1.22	.25	-0.31
R-IBS (post) (N/kg)	15.2 (13.7-17.6)	17.5 (16.1-17.7)	-1.06	.30	-0.27
FI (pre) (%)	66.5 (48.7-75.3)	56.7 (54.0-62.7)	-1.22	.25	0.31
FI (post) (%)	56.2 (49.1-71.8)	59.6 (52.8-61.1)	0.11	.92	0.03
RPE (pre)	16.0 (13.5-17.5)	15.0 (15.0-18.0)	-0.05	1.00	0.01
RPE (post)	16.0 (10.0-19.0)	18.0 (15.0-19.0)	0.81	.47	0.20

PP = peak power; R-PP = relative peak power; MP = mean power; R-MP = relative mean power; FI = fatigue index; RPE = rate of perceived exertion according to the Borg scale (6–20)
ILS=Isometric Leg Strength; R-ILS=Relative Isometric Leg Strength; IBS=Isometric Back Strength; R-IBS=Relative Isometric Back Strength; pre=pre-intervention measure; post=post-intervention measure; y=year; r=Effect Size for Mann-Whitney U test (0.1=Small, 0.3=Medium, 0.5=Big Effect Size).

PP, R-PP, MP, and R-MP measures of subjects in the low-frequency vibration group increased significantly over the course of the study ($Z = 2.67$, $p = .008$, $r = 0.89$; $Z = 2.67$, $p = .008$, $r = 0.85$; $Z = 2.55$, $p = .011$, $r = 0.89$; and $Z = 2.67$, $p = .008$, $r = 0.84$, respectively). However, no significant change was detected in these variables in the high-frequency vibration group. None of the groups showed significant changes in the other investigated variables (Table 2). In addition, no significant difference was detected in the relative performance changes between the different frequency groups (Table 3). Individual performance changes over the course of the 6-week WBVT in power and strength measures are shown in Table 4 and Figure 1.

Table 2: Pairwise differences in investigated variables in low- and high-frequency vibration groups

Low-frequency vibration group (n = 9)				
Variables	Δ	*Z*	*p*	*r*
Mass (kg)	2(+), 6(-), 1(=)	-1.65	.10	0.55
Peak power (W)	9(+)	2.67	.008 **	0.89
Relative peak power (W/kg)	9(+)	2.67	.008 **	0.85
Mean power(W/kg)	8(+), 1(-)	2.55	.011 *	0.89
Relative mean power (W/kg)	9(+)	2.67	.008 **	0.84
Isometric leg strength (N)	4(+), 5(-)	-1.01	.31	-0.34
Relative-isometric leg strength (N/kg)	3(+), 6(-)	-0.89	.37	-0.30
Isometric back strength (N)	4(+), 5(-)	-0.83	.41	-0.28
Relative isometric back strength (N/kg)	4(+), 5(-)	-0.42	.68	-0.14
Fatigue index (%)	5(+), 4(-)	-0.42	.68	0.14
Rate of perceived exertion	3(+), 3(-), 3(=)	-0.32	.75	0.11

High-frequency vibration group (n = 7)				
Variables	Δ	*Z*	*p*	*r*
Mass (kg)	4(+), 1(-), 2(=)	0.97	.33	0.37
Peak power (W)	6(+), 1(-)	1.69	.09	0.64
Relative peak power (W/kg)	6(+), 1(-)	1.35	.18	0.51
Mean power(W/kg)	6(+), 1(-)	1.69	.09	0.64
Relative mean power (W/kg)	6(+), 1(-)	1.52	.13	0.57
Isometric leg strength (N)	4(+), 3(-)	-0.51	.61	-0.19
Relative isometric leg strength (N/kg)	4(+), 3(-)	-0.17	.87	-0.06
Isometric back strength (N)	5(+), 2(-)	-1.35	.18	-0.51
Relative isometric back strength (N/kg)	6(+), 1(-)	-1.52	.13	-0.57
Fatigue index (%)	2(+), 5(-)	-0.17	.87	0.06
Rate of perceived exertion	4(+), 1(-), 2(=)	1.63	.10	0.62

***p≤.01; *p≤.05; Δ = number of changes in the related variables (post-pre), "+", "-", "=" stands for inc decrease, and no change, respectively; r = effect size for Wilcoxon signed-rank test (0.1=Small, 0.3=Medium, 0.5=Big Effect Size).*

Table 3: Differences in relative performance changes between low- and high-frequency vibration groups over the course of the study

Low- and high-frequency vibration groups					
	Low (n = 9)	High (n = 7)	*Z*	*p*	*r*
Δ Mass (%)	-2.35 (-2.68-0.63)	1.20 (0.00-2.67)	-1.97	.06	-0.49
Δ PP (%)	20.8 (13.8-39.4)	23.5 (15.8-32.4)	-0.27	.84	-0.01
Δ R-PP (%)	22.4 (17.6-40.2)	23.5 (18.8-29.0)	-0.05	1.00	-0.15
Δ MP (%)	21.5 (3.94-31.7)	14.7 (3.54-24.9)	-0.05	1.00	-0.38
Δ R-MP (%)	24.5 (4.93-34.5)	14.7 (6.23-24.7)	-0.58	.61	-0.49
Δ ILS (%)	-4.22 (-13.3-5.98)	2.54 (-5.21-9.38)	-1.01	0.35	-0.25
Δ R-ILS (%)	-1.60 (-13.0-8.74)	4.31 (-6.44-6.12)	-0.79	0.47	-0.20
Δ IBS (%)	-3.40 (-15.3-12.3)	3.99 (-0.72-8.79)	-0.58	0.61	-0.15
Δ R-IBS (%)	-4.59 (-16.1-14.3)	1.86 (0.89-8.79)	-0.48	0.68	-0.12
Δ FI (%)	4.79 (-22.2-18.9)	-2.22 (-5.01-18.9)	-0.37	.76	-0.01
Δ RPE (%)	0.00 (-15.6-9.44)	5.56 (0.00-26.7)	-1.51	.14	-0.09

Δ = relative changes in the related variables (post-pre), PP = peak power; R-PP = relative peak power; MP = mean power; R-MP = relative mean power; ILS = isometric leg strength; R-ILS = relative isometric leg strength; IBS = isometric back strength; R-IBS = relative isometric back strength; FI = fatigue index; RPE = rate of perceived exertion according to the Borg scale (6–20); pre = pre-intervention measure; post = post-intervention measure; r = effect size for Mann-Whitney U test

Discussion

To the best of our knowledge, this is the first study that investigated the effects of chronic vibration exercises on anaerobic performance assessed by the WAnT. The findings of our study revealed that whole-body vibration during static squat exercise applied for 6 weeks at 2 different frequencies (40 and 25 Hz) did not affect the ILS, IBS, RPE, or FI values of recreationally active individuals. However, the Wilcoxon signed-rank test indicated that low-frequency vibration treatment could be more suitable than high-frequency treatment for improving anaerobic power (PP and R-PP) and anaerobic capacity (MP and R-MP). Nevertheless, we cannot conclude whether high-frequency WBVT is ineffective for improving PP, R-PP, MP, and R-MP. It is conceivable that the poor performance of only 1 participant in the HFG in the last Wingate test may have caused this result. Evaluation of differences concerning anaerobic performance variables in terms of effect sizes shows that each WBVT frequency enhanced the anaerobic power (PP and R-PP) and anaerobic capacity (MP and R-MP) ($0.84 \le r \le 0.89$ for LFG and $0.51 \le r \le 0.64$ for HFG). However, replication studies with greater sample sizes are needed to identify the effects of different WBVT on related performance measures more reliably.

In general, it is accepted that low-amplitude, high-frequency vibration treatments are reliable and effective in improving strength, power, and vertical jump performance (Torvinen et al., 2002; Paradisis and Zacharogiannis, 2007; Rehn et al., 2007). Although it is thought that high-frequency vibration treatments cause neuromuscular fatigue and trigger inhibitory mechanisms that lead to reduction in power generation capacity

(Cardinale and Lim, 2003; Cochrane et al., 2004), as stated above (Paradisis and Zacharogiannis, 2007; Rehn et al., 2007; Cochrane et al., 2004; Cardinale and Lim, 2003; Torvinen et al., 2002), there has been no conventional guideline in the literature showing which combination of WBVT variables provide the most effective performance enhancement. In this study, improvement in the anaerobic performance of both groups may have resulted because of the participants' relatively low training levels and sports experience. Wilcock et al. (2009) states that strength and power improvement potentials from vibration exercises of untrained individuals having low muscular strength and power levels are higher in comparison with highly trained athletes.

However, as the only study to date evaluating the impact of chronic vibration treatment on anaerobic performance by the WAnT, our data provide an important contribution to the literature. Although the Wingate test may be peculiar to cyclists and thus uncertain whether it is effective for other groups, this test still maintains its popularity and is commonly accepted for the evaluation of anaerobic performance (Karakoç et al., 2012; Sands et al., 2004). In this regard, Oosthuyse et al. (2013) stated that the WBVT applied with a 30-Hz frequency and 4-mm amplitude in a static standing position was effective on PP and MP in a road cyclist.

In the literature, contradictory results on the impact of whole-body vibration exercises on isometric and isokinetic strength improvement are remarkable. Although some researchers maintain that whole-body vibration exercises have a positive impact on strength attainment (Roleants et al., 2004; Torvinen et al., 2002; Paradisis and Zacharogiannis, 2007; Karatrantou et al., 2012), others assert that WBVT is ineffective on strength improvement (de Ruiter et al., 2003a; de Ruiter et al., 2003b; Humphries et al., 2004; Osawa et al., 2011; Wilcock et al., 2009). The different results from these studies may have arisen from methodological differences or variations in loading parameters of the vibration exercises (such as frequency, amplitude, treatment and resting duration, repetition number, muscular contraction type [dynamic or static], additional load or body weight, and body position).

The RPE scale is used to determine the perceived exertion of individuals arising from physiological responses caused by physical exercises. RPE scale is also used in the assessment of rate of perceived exertion during WBVT as well as other types of exercises/treatments (Garcia-Lopez et al., 2012). However, we have not found any studies evaluating the effects of chronic vibration treatments on anaerobic power and anaerobic capacity performance in terms of RPE score. In this study, the reason that we did not detect any alteration in RPE score in either of the 2 groups may be participant adaptation to the Wingate test or an increase in their power production levels.

Consequently, it has been determined that either low-frequency or high-frequency whole-body vibration treatment has no influence on ILS, IBS, RPE, or FI in recreationally active individuals. Differences arising after the exercise period and effect sizes of these differences have shown that low-frequency (25 Hz) and high-frequency (40 Hz) vibration treatments in terms of anaerobic performance improvement have a similar effect on recreationally active individuals. However, it is obvious that the small sample size in our study creates some restrictions in interpreting the findings. The fact that whole-body vibration exercises are not well-known among the students of our school and the students do not want to participate in a regular treatment prevented us from obtaining a larger sample group. For this reason, replication of this study on larger samples will be helpful to obtain more reliable results and present explicit cause-and-effect relationships. In addition, conducting similar studies on trained individuals and competitive athletes with the aim of using vibration treatments for performance improvement could provide valuable information to the field of exercise science.

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References

Alemdaroglu, U. (2012). The relationship between muscle strength, anaerobic performance, agility, sprint ability and vertical jump performance in professional basketball players. *Journal of Human Kinetics*, 31: 99-106.

Arslan, C. (2005). Relationship between the 30-second wingate test and characteristics of isometric and explosive leg strength in young subjects. *Journal of Strength and Conditioning Research*, 19: 658-666.

Bosco, C., Cardinale, M., COLLI, R., TIHANYI, J., VON DUVILLARD, S.P. & VIRU, A. (1998). The influence of whole body vibration on jumping ability. *Biology of Sport*, 15: 157-164.

Cardinale, M., & Erksine, J.A. (2008). Vibration training in elite sport: effective training solution or just another fad? *International Journal of Sports Physiology and Performance*, 3: 232-239.

Cardinale, M., & Lim, J. (2003). The acute effects of two different whole body vibration frequencies on vertical jump performance. *Medicina Dello Seport*, 56: 287-292.

Cardinale, M., & Wakeling, J. (2005). Whole body vibration exercise: are vibrations good for you?. *British Journal of Sports Medicine*, 39: 585-589

Cochrane, D.J., Leggs, S.J., & Hooker, M.J. (2004). The short-term effect of whole-body vibration training on vertical jump, sprint, and agility performance. *Journal of Strength and Conditioning Research*, 18: 828-832.

Delecluse, C., Roelants, M., Diels, R., Konincksx, E., & Verschueren S. (2005). Effects of whole body vibration training on muscle strength and sprint performance in sprint-trained athletes. *International Journal of Sports Medicine*, 26: 662-668.

Delecluse, C., Roelants, M., & Verschueren, S. (2003). Strength increase after whole-body vibration compared with resistance training. *Medicine and Science in Sports and Exercise*,35: 1033-1041.

De Ruiter, C.J., Van Raak, S.M., Schilperoort, J.V., Hollander, A.P., & De Haan, A. (2003a). The effects of 11 weeks whole body vibration training on jump height, contractile properties and activation of human knee extensors. *European Journal of Applied Physiology*, 90: 595-600

De Ruiter, C.J, Van Der Linden, R.M., Van Der Zijden, M.J., Hollander, A.P, & De Haan, A. (2003b). Short-term effects of whole-body vibration on maximal voluntary isometric knee extensor force and rate of force rise. *European Journal of Applied Physiology*, 88: 472-475.

Garcia-Lopez, D., Garatachea, N., Marin, J.P., Martin, T., & Herrero, A.J. (2012) .Acute effects of whole-body vibrations on balance, maximal force and perceived exertion: vertical platform versus oscillating platform. *European Journal of Applied Physiology*, 12: 425-430.

Gerodimos, V., Zafeiridis, A., Karatrantou, K., Vasilopoulou, T., Chanou, K., & Pispirikou, E. (2010) .The acute effects of different whole-body vibration amplitudes and frequencies on flexibility and vertical jumping performance. *Journal of Sports Science and Medicine*, 13: 438-443.

Gusi, N. (2006) .Low-frequency vibratory exercise reduces the risk of bone fracture more than walking: a randomized controlled trial. *BioMed Central Musculoskeletal Disorders*, 7: 92.

Humphries, B., Warman, G., Purton, J., Doyle, Tim La., & Dugan, E. (2004). The influence of vibration on muscle activation and rate of force development during maximal isometric contractions. *Journal of Sports Science and Medicine*, 3: 16-22.

Issurin, V.B., & Tenenbaum, G. (1999). Acute and residual effects of vibratory stimulation on explosive strength in elite and amateur athletes. *Journal of Sports Sciences,* 17: 177-182.

Karatrantou, K., Gerodimos, V., Dipla K., & Zafeiridis, A. (2013). Whole-body vibration training improves flexibility, strength profile of knee flexors, and hamstrings-to-quadriceps strength ratio in females. *Journal of Sports Science and Medicine*, 16: 477-81.

Karakoç, B., Akalan, C., Alemdaroğlu, U., & Arslan, E. (2012). The relationship between the yo-yo tests, anaerobic performance and aerobic performance in young soccer players. *Journal of Human Kinetics*, 35: 81-88.

Kin-Işler, A., Ariburun, B., Özkan, A., Aydan A, & Tandoğan R. (2008). The relationship between anaerobic performances, muscle strength and sprint ability in American football players. *Isokinetics and Exercise Science*, 16: 87-92.

Mester, J., Kleinoder, H., & Yue, Z.(2006). Vibration training: benefits and risks*. Journal of Biomechanics*, 39: 1056-1065.

Oosthuyse, T., Viedge, A., Mcveigh, J., & Avidon, I. (2013). Anaerobic power in road cyclist is improved after 10 weeks of whole-body vibration training. *Journal of Strength and Conditioning Research,* 27: 485-494.

Osawa, Y., Oguma, Y., & Onishi, S. (2011).Effects of whole-body vibration training on bone-free lean body mass and muscle strength in young adults. *Journal of Sports Science and Medicine*, 10: 97-104.

Ozkan, A., Ariburun, B., & Kin-Işler, A. (2009). Relationships of body composition, isokinetic knee strength and anaerobic performancein American football players. *Türkiye Klinikleri Journal of Sports Science*, 1: 47-52.

Paradisis, G., & Zacharogiannis, E. (2007). Effects of whole-body vibration training on sprint running kinematics and explosive strength performance. *Journal of Sports Science and Medicine*, 6: 44-49.

Paschold, H.W., & Mayton, A.G. (2011). Whole-Body Vibration - Building Awareness in SH&E.Available at: http://www.asse.org/professionalsafety/docs/030_035_F1Paschold_0411Z.pdf; accessed on 31.05.2012

Patton, J.F., & Duggan, A. (1987). An evaluation of tests of anaerobic power. *Aviation, Space, and Environmental Medicine*, 58: 237-242.

Rehn, B., Lidstrom, J., Skoglund, J., & LINDSTROM, B. (2007). Effect on leg muscular performance from whole-body vibration exercise: a systematic review. *Scandinavian Journal of Medicine and Science in Sports*, 17: 2-11.

Ritzmann, R., Gollhofer, A., & Kramer, A. (2013). The influence of vibration type, frequency, body position and additional load on the neuromuscular activity during whole body vibration. *European Journal of Applied Physiology and Occupational Physiology*, 113: 1-11.

Roelants, M., Delecluse, C., Goris, M., & Verschueren, S. (2004). Effects of 24 weeks of whole body vibration training on body composition and muscle strength in untrained females. *International Journal of Sports Medicine*, 25: 1-5.

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: 1309-1315.

Sands, W.A., Mcneal, J.R., Ochi, M.T., Urbanek, T.L., Jemni, M., & Stone, M.H. (2004). Comparison of the wingate and bosco anaerobic tests. *Journal of Strength and Conditioning Research,* 18: 810-815.

Schuhfried, O., Mittermaier, C., Jovanovic, T., Pieber, K., & Paternostro-Sluga, T. (2005). Effects of whole-body vibration in patients with multiple sclerosis: a pilot study. *Clinical Rehabilitation*, 19: 834-842.

Torvinen, S., Pekka, K., Sievanen, H., Jarvinen, Tah, Pasanen, M., Kontulainen, S., Jarvinen, T.L.N., Jarvinen, M., Oja, P., & Vuori, I. (2002). Effect of four-month vertical whole body vibration on performance and balance. *Medicine and Science in Sports and Exercise*, 34: 1523-1528.

Wilcock, I.M., Whatman, C., Haris, N., & Keogh, J.W.L. (2009). Vibration training: could it enhance the strength, power, or speed of athletes? *Journal of Strength and Conditioning Research,* 23: 593-603.

Wirth, B., Zurfluh, S., & Muler, R. (2011). Acute effects of whole-body vibration on trunk muscle in young healthy adults. *Journal of Electromyography and Kinesiology*, 21: 450-457.