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Short-Term Training Program Using Whole Body Vibration with Body Weight Exercises Improves Physical Functioning

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Abstract

Objective: The purpose of this study was to determine the efficacy of a short-term oscillatory high amplitude (15-24 mm) Whole Body Vibration (WBV) training program on muscular power, core strength, dynamic balance, and squat mechanics.

Methods: Twenty-seven recreational adults between 18 and 70 years old (n=9 females, n=18 males) volunteered to participate. We used a between group study to investigate the improvements associated with a 4 weeks (12 session) program of body weight exercises (Hip hinge, Squat, Quadruped, Single leg stance) performed on the Dr. Fuji® FJ-700 vibration platform (VIB) as compared to a control group (CON) and the same exercises performed without WBV (GRD). Pre and post intervention assessments included the timed plank, kneeling chest launch, Y-balance test, and composite score from Fusionetics squat analysis™ program.

Results: Pre to post percent changes for VIB group for the kneeling chest launch (10.3% ± 7.3%), timed plank (20.2% ± 5.9%), Y-balance (left) (10.7% ± 7.6%), Y-balance (right) (8.0% ± 1.2%), and for Fusionetics™ (4.6% ± 1.4%) were greater than improvements than GRD or CON. The Kneeling Chest Launch, Timed Plank and Y-Balance (left leg) demonstrated significant improvements for VIB group ($p<0.01$).

Conclusion: These data suggest physical improvements in minimal time with only 12 sessions when WBV is added to body weight exercises. Typically, it takes much longer time frame or a higher intensity of exercises to see gains in upper extremity and core muscular endurance and power and lower extremity dynamic balance.

Keywords: Balance; Oscillation; Power; Performance; Gravity

Introduction

Strength training programs are essential to prevent both traumatic and overuse injuries in recreational, professional, and collegiate athletes [1-3]. Walking/hiking, gardening, sports, and dancing are all common recreational activities; however golf was one of the most popular recreational sports listed across all age groups [4]. Golf is unique as it uses the whole body but presents a relatively low risk for injury and most injuries in golf are related to overuse mechanisms [5,6]. Golf is a popular recreational activity among older adults and requires various combinations of core muscular strength and endurance, dynamic balance, flexibility, and lower and upper body muscle endurance, strength, and power [1-3]. Therefore, improving these characteristics may have the twofold benefit of improving performance and reducing the risk of injury [7,1-3]. Progressive resistive strength training can correct muscle imbalances, improve physical characteristics, and prevent injuries in older adults [8,9]. Despite this evidence, exercise programs including traditional weight training programs are often avoided by older adults because of a lack of time or appropriate physical activity instruction [10]. The understanding of guidelines, equipment, and the supervision necessary to complete strength and conditioning exercises as part of a physical activity program may be daunting. Therefore, body weight exercise training programs that are easy and quick to complete at a local fitness facility or community recreation center may promote participation in physical activity programs.

The addition of Whole Body Vibration (WBV) to standard body weight exercises may provide a plyometric like stimulus and increase force development [11,12]. WBV is a stimulus delivered to the body through the use of platforms that deliver multiple consecutive rapid waves of vibration [11-16]. Bogaerts demonstrated near equal improvements in strength and power in older men using body weight vibration training as compared to a traditional strength training program of an equal length [13]. WBV provides a unique exercise stimulus due to its simplicity, little need for space and relative low impact delivery mechanism. Evidence regarding the effects of using WBV during body weight exercises on the physical characteristics associated with many recreational activities is under developed. Therefore, the purpose of this study was to determine the efficacy of a short-term low frequency (3-10 Hz), high amplitude (10-18 mm) oscillatory WBV training program on physical function characteristics including muscular power, trunk strength and endurance, dynamic balance, and squat mechanics. We hypothesize that body weight exercise movements performed on a WBV platform will improve physical function characteristics when compared to the same body weight exercises performed on stable ground.

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Materials and Methods

Participants and design

Twenty-seven healthy adults (n=9 females, n=18 males) who self-reported as recreationally active adults from a local country club volunteered and qualified for inclusion (Table 1). Inclusion criteria required the participant to be between 18 and 70 years old, healthy with no surgeries within the last year, and identify as recreationally active including participation in golf. Subjects were excluded if they reported an acute musculoskeletal injury, severe pain, or pregnancy. Subjects who possessed a contraindication mentioned in the WBV platform's operations manual (e.g., epilepsy or active migraines) or indicated another medical condition (e.g., high blood pressure, cancer) on their health history form could participate only with physician's clearance. There were no subjects who presented a contraindication for the equipment and one subject had to obtain medical clearance; however, clearance was granted. All subjects were randomly assigned to an intervention group: Vibration Training (VIB) (n=11), Stable Ground Training (GRD) (n=8), or Control (CON) (n=8). The VIB group performed exercise movements on the vibration platform, the GRD group performed the exact same exercise movements but on the stable floor, and the CON group was asked to cease all outside exercise activity other than golf for the month. The research study was conducted ethically according to international standards (Table 1) [17].

To investigate the effects of WBV on physical function measures in recreationally active adults, we used a 3 × 2 (group × time) mixed model repeated measures design. Independent variables included intervention group (VIB, GRD, CON) and time (pre and post) (Figure 1). Dependent variables collected were Y-balance™ composite score for right and left leg (%), timed plank (sec), kneeling chest launch (cm), and a composite score from fusionetics® squat analysis program (Figure 1).

Pre Tests	Week 1	Week 2	Week 3	Week 4	Post Tests
• Y-balance Test (cm) • Timed Plank (sec) • Kneeling medicine ball throw (in) • Fusionetics™ squat analysis	Training groups (VIB and GRD) performed exercises 3 X week. • Hip hinge • Squat • Quadruped • Single leg stance Three sets of 1-minute duration were performed in each position. • Maximum repetitions were completed using a 3 second eccentric phase, 3 second concentric phase pace One-minute rest between all movements and all positions.				• Y-balance Test (cm) • Timed Plank (sec) • Kneeling medicine ball throw (in) • Fusionetics™ squat analysis

Figure 1: Outline of study procedures including pre and post assessments and training regimen.

Table 1: Demographic characteristics of the participants mean ± SD (range).

Group	Participants	Gender	Age (yrs.)	Height (cm)	Mass (kg)
VIB	n=11	n=7 males, n=4 females	51.9 ± 13.9	173.6 ± 13.6	80.8 ± 12.2
GRD	n=8	n=6 males, n=2 females	52.1 ± 14.1	178.8 ± 12.4	83.9 ± 16.5
CON	n=8	n=6 males, n=2 females	55.9 ± 4.7	177.8 ± 12.1	84.5 ± 14
	n=27	n=19 males, n=8 females	53.1 ± 11.7 (27-69)	176.4 ± 12.5 (152-193)	82.8 ± 13.7 (52-102)

Assessments

Pre and post intervention assessments are described below, these tests aligned with the recommendations of PGA strength and conditioning specialist. The Y-balance Test™ is a highly reliable dynamic balance test [18]. The participant stood with the arch of their foot on a spot at the center of a "Y". The participant then balanced on one leg and reached with the other leg in three directions (anterior, posterior medial, and posterior lateral). Three trials in each direction were performed and the maximum reach was recorded. The composite score for "Leg function" of each leg was calculated by adding up the distances for all 3 directions of reach and dividing it by 3 times the participant's leg length [18,19]. The Kneeling Chest Launch involves throwing a weighted medicine ball for maximum distance while kneeling to exclude the distal lower extremities [20]. The participant started in a kneeling position with the back erect and faced the direction they were to throw. Their thighs were parallel and their knees were at a start line. Their toes were pointed backwards and not curled up so there was no traction advantage. The ball was grasped in both hands at the chest and the hips were brought back to the heels. Then in one motion the ball was pushed forward and up trying for maximum launch distance to assess hip strength and power. The participant could fall forwards over the line after the ball was released but their knees were not to leave the ground and they could not favor one arm or rotate the spine. The maximum throw of two attempts was recorded [20].

The Timed Plank Test tests core muscle strength and endurance [21,22]. Subjects held an elevated trunk position (front plank) for as long as possible. The upper body was supported on the ground by their elbows and forearms and their legs were kept straight with the weight taken by the toes. The hips were lifted off the floor creating a straight line from head to toe. The test was over when the hips were lowered and the subject was unable to hold the elevated trunk position in a straight line [22]. The Fusionetics® Squat Analysis software was used to track movement efficiency during an overhead squat [23]. Deviations in optimal overhead squat form are usually an indication of poor flexibility, muscle imbalances or nervous system dysfunction. The software allows for the tester to organize and track squat deficiencies into four main areas including the shoulder, lumbopelvic hip complex, knee, and foot/ankle. The software identifies common movement inefficiencies include varus and valgus knee deviations, excessive forward lean of trunk, arching or rounding of the low back, or the weight shifting from one leg to the other. Each subject performed 10 parallel body weight squats with arms overhead and then the software presented the tester with a composite score on a scale of 0-100 [23,24]. Typical classification related to composite score is poor (0-49.99) moderate (50-74.99), or good (75-100) movement efficiency.

Instrumentation

The Dr. Fuji® FJ-700 vibration platform (Fremont, CA) (Figure 2A) was used in all VIB sessions. Dr. Fuji® FJ-700 has an oscillation amplitude range between 10 and 18 mm and a frequency range from 3 Hz-10 Hz (Levels 1-Level 10). The platform oscillates rather than using a vertical displacement pattern (Figures 2B and 2C). The oscillating (pivoting) amplitude pattern allows for greater magnitude of displacement when compared to linear or vertical vibration plates. An oscillating machine can support more body weight and have a smaller impact on the body because it is not creating an up and down piston-like vibration but rather a swing-like vibration that encourages the body to actively contract muscles on alternating sides in an effort to maintain equilibrium. The Dr. Fuji® FJ-700 amplitude range is based on the width of foot placement on the vibration plate (Figure 2A). The amplitude experienced will be greater with a wider foot stance. The oscillation pattern and greater amplitude range provides gravity force amplification or muscular overload during body weight exercises (Figure 2).

Figure 2: (A) Dr Fuji-700 vibration plate and oscillation patterns of vibration plates (B) Vertical displacement and (C) Oscillation.

Training intervention protocol

Subjects from the VIB group and the GRD group reported to the fitness center 3 times a week for one month (4 weeks) to perform the exercise protocol while guided by a fitness instructor (Figure 1). The control group did not perform any specific exercises. All training sessions lasted 21 minutes and all movements were timed. The exercises performed included: A double legged hip hinge (Romanian Deadlift motion), double legged quarter squat, a kneeling quadruped with the hands on the platform, and a single legged stance (Figure 1 and 3 A-D). Every subject wore shoes. The participants stood with knees slightly flexed and/or maintained a neutral back position to prevent any possible injuries during the start and finish positions and exercises were performed with standard form and technique. All subjects began at frequency level 5 (~6.5 Hz) on the platform on their first visit and spent the first 5 sessions gradually increasing the frequency following a progressive overload. The first 5 sessions were as follows: session 1–Level 5, session 2–Level 6, session 3–Level 7, session 4–Level 8, session 5–Level 9, sessions 6–12 were all at level 10 (Figure 3).

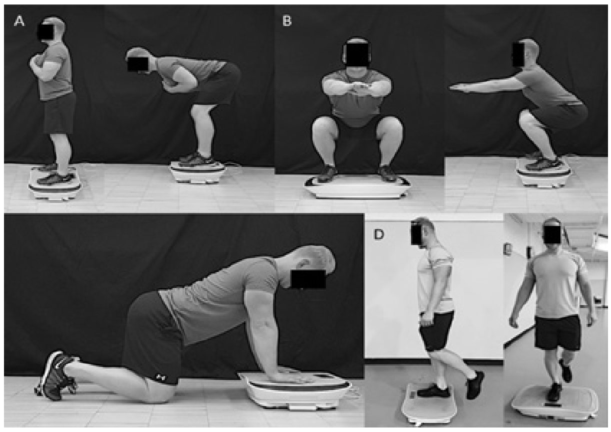

Figure 3: Body weight exercises performed in VIB and GRD groups. (A) Hip hinge, (B) Squat, (C) Quadruped, and (D) Single leg stance..

Data analysis

Data were analyzed using SPSS version 25.0 for Windows 10 (Armonk, New York). The distributions were analyzed for normality and the existence of outliers using histogram plots, boxplots and Quantile-Quantile plots. A single factor ANCOVA was used to determine the effects of training type (VIB, GRD, CON) on the change (post–pre) of the following dependent variables: plank time (secs), kneeling chest launch distance (cm), Y balance composite left (%) and right (%) (5), and Fusionetics® composite score (%). Pre-measurements were used as the covariates. Follow-up tests for group differences were done using the Sidak post hoc test. The level of significance was set at alpha = 0.05. Values are expressed as means ± SE (95% CI).

Results

Trunk muscle strength and endurance

Group differences were detected ($F(2,23)=6.31$, $p=0.007$, $\eta2=0.365$, $ß=0.852$) for the timed plank test. There was a significant difference between the VIB and the GRD group ($p=0.002$), where the VIB group demonstrated significantly better holding times for the timed plank test (Table 2).

Upper extremity and lumbopelvic hip strength and power

Group differences were detected ($F(2,23)=6.74$, $p=0.005$, $\eta2=0.37$, $ß=0.877$) for the kneeling chest launch. Both the VIB and GRD training groups had significantly greater changes ($p<0.04$) than the CON training group (Table 2).

Dynamic balance

There were no group significant differences for the Y-Balance Test™ for the right leg ($F(2,23)=2.7$, $p=0.089$, $\eta2=0.19$, $ß=0.48$) but there was a larger improvement in composite score change for the VIB group (Table 2). Group differences were detected in the Y-Balance™ left leg composite score ($F(2,23)=7.9$, $p=0.002$, $\eta2=0.41$, $ß=0.93$). The VIB group was significantly greater than the GRD training group ($p=0.001$) and the CON group ($p=0.013$) (Table 2).

Movement efficiency

There were no group significant differences ($F(2,23)=1.81$, $p=0.187$, $\eta2=0.14$, $ß=0.34$) for the composite score from the Fusionetics® Squat Analysis but there was a larger improvement in composite score change for the VIB group (Table 2).

Table 2: Functional performance data pre and post intervention (pre and post: mean ± SD (95% CI); Change: mean±SE (95% CI). Covariate Pre-test value appears in model for change score.

	VIB group			GRD group			CON group		
Dependent variable	Pre	Post	Percent Change	Pre	Post	Percent Change	Pre	Post	Percent Change
Timed plank (s)	99.5 ± 51.1 (69.4-29.7)	119.9 ± 11 (113.4-26.4)	20.2 ± 5.9* (7.9-32.5)	100.6 ± 31.6 (81.9-119.3)	95.1 ± 6.7 (91.1-99.0)	-12.1 ± 6.9 (-26.4-2.3)	124.5 ± 40.5 (101-49)	113.7 ± 6.4 (110-118)	3.7 ± 7.4 (-12-19)
Kneeling chest launch (cm)	189.2 ± 62.7 (152-226)	208.7 ± 44.9 (182-235)	19.4 ± 7.0† (4.9-33.5)	212.8 ± 38.9 (190-235.9)	221.5 ± 42.4 (197-247)	8.7 ± 24.7† (-11-24)	188.4 ± 40.7 (163-212)	174.5 ± 68 (134-215)	-3.9 ± 40.9 (-37- -2.8)
Y balance right leg (%)	76.3 ± 10 (70.4-82.2)	85.4 ± 8.8 (80.1-90.6)	9.2 ± 1.5 (6.0-12.4)	77.4 ± 6.4 (73.6-81.1)	82.3 ± 11 (75.8-88.8)	4.4 ± 1.8 (0.6-8.2)	74.4 ± 6.2 (70.7-78.1)	79.7 ± 8.9 (70.7-78.1)	4.7 ± 1.8 (0.9-8.5)
Y balance left leg (%)	77 ± 8.0 (72.3-81.7)	84.9 ± 5 (81.9-87.9)	8.0 ± 1.2‡ (5.6-10.5)	77.6 ± 10.6 (71.1-83.9)	79.8 ± 4.1 (73.4-82.2)	1.1 ± 1.4 (-1.8-4.0)	72.6 ± 7.9 (68-77.3)	76.2 ± 3.7 (74-78.4)	2.9 ± 1.4 (-0.2-5.9)
Fusionetics™ score (%)	92 ± 4.4 (89.4-94.6)	97.4 ± 4.0 (95.0-99.7)	4.6 ± 1.4 (1.7-7.6)	91.9 ± 5.0 (88.9-94.9)	95.3 ± 5.6 (91.9-98.6)	1.5 ± 1.6 (1.9-4.9)	96.8 ± 4.3 (94.2-99.3)	96.6 ± 5.8 (93.1-100)	0.6 ± 1.9 (-3.3-4.6)

*VIB group significantly better change in core muscle endurance compared to GRD group (p=0.002)
†VIB and GRC group demonstrated significantly better change in power than CON (p<0.04)
‡VIB group significantly better change in dynamic balance on left leg compared to GRD (p=0.001) and CON (p=0.013)

Discussion

The purpose of this study was to determine the efficacy of a short-term low frequency (3-10 Hz), high amplitude (10-18 mm) oscillatory WBV training program on physical performance characteristics of recreationally active adults including muscular power, trunk strength and endurance, dynamic balance, and squat mechanics. Our data suggests the possibility for physical performance improvements with the addition of WBV to simple body weight exercises within a short 4-week training period. The VIB group improved in several variables compared to GRD and CON [Table 2]; therefore, we believe the VIB training overloaded the muscles and activated neuromuscular pathways via a plyometric like stimuli without heavy weights or impact loading [11,12,25]. Only the kneeling chest launch was significantly different between the GRD and CON group [Table 2]. Therefore, exercises without vibration may need to be more aggressive and include plyometric and heavier weights; however, both of these can increase the possibility for injury, overtraining and excessive fatigue. The effects of WBV as a training stimulus has been noted across many peer reviewed research studies and commentaries [11-16,25,26], so our adaptations in the VIB group were not surprising. We demonstrated that body weight only exercises with the addition of WBV can accomplish changes in muscle strength, endurance, power, dynamic balance, and movement efficiency in less time. Whereas, previous studies that focused on improving physical function and performance needed more time and used more aggressive exercises [27].

We theorize the low frequency but higher amplitude oscillatory swing like vibration waves delivered to the contact limb(s) caused a multiplication of the participant's body weight which caused an overload stress but with minimal impact loading [25]. The repetitive and comfortable overload of mechanoreceptors within the muscle during the concentric and eccentric phases of body weight exercises may allow for better timing of agonists and antagonist muscles thereby providing for better movement efficiency and strength improvements [28]. The vibratory perturbations may also improve the amount and rate of force development and muscle performance. However, there may be a vibration threshold with increasing frequency because the inertia of the body may be too great to dampen with muscular contractions [29].

The time course (4 weeks) of our improved physical performance outcomes with body weight exercises performed on the FJ-700 was faster than other interventions [13-16,26]. For example, Fort et al. demonstrated a 10% increase in power and a 14% increase in postural control during a single leg hop test after 15-weeks of WBV combined with a normal basketball training regimen [30]. In comparison, our study used a higher amplitude vibration platform and demonstrated slightly greater improvements while only using a 4-week training program. Limitations to this study include small sample sizes which likely reduced power and prevented significance from occurring in each assessment and our subjects were a convenience sample of interested participants. It is also possible that a learning effect occurred in the squat assessment and Y-Balance Test™ from the pre to post test and this may have washed out any group differences. We also did not measure isolated strength gains of any specific muscle groups targeted by body weight exercises and did not measure golf performance variables associated with swing mechanics or swing outcomes.

Conclusion

Body weight exercises combined with a low frequency (3-10 Hz) and high amplitude (10-18 mm) oscillatory vibration stimulus may be able to overload targeted musculature safely without unnecessary impact or discomfort. Therefore, these data provide promising results for fitness professionals looking to provide increases in key components of physical performance when their clients do not have advanced weight training equipment or access to guided personal training sessions. The four body weight exercises can be easily instructed and WBV plates are easy to store in fitness centers. An oscillatory vibration stimulus with body weight exercises can also be simply integrated into an any existing strength training program.

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