

## Plyometrics and vibration: no clear winner on efficacy

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**Objective:** Whole body vibration (WBV) and plyometrics are common training techniques which increase strength, blood flow, and lower body force and power. The effects these techniques have on sedentary population is unknown. It is our aim to assess the effectiveness of WBV and plyometrics on sedentary population.

**Design:** Experimental study.

**Methods:** Twenty-seven sedentary subjects were assigned to either the control group, jumping only group, or jumping with vibration group. Jump height (myotest or vertec), velocity, force, blood lactates, and rating of perceived exertion (RPE). Subjects were measured on the initial, seventh, and eighteenth visits. Control group attended measurements only. Jumping only and jumping with vibration groups performed jumping from a vibrating platform to a surface 7 1/2 inches higher for 3 bouts of 20 seconds. Each subject in jumping only and jumping with vibration groups attended three times per week for six weeks. Vibration was set at 40 Hz and 2-4 mm of displacement.

**Results:** There was no significant change among groups in force, velocity, vertec height, and myotest height. However there was a significant increase in vertec height from initial to final measure ( $p < 0.05$ ) for jumping with vibration group. RPE was significantly higher between control group and jumping with vibration group after intervention ( $p < 0.05$ ).

**Conclusions:** WBV with vibration increased jump height. Jumping with vibration group experienced increased exertion than for controls. WBV with plyometrics had no effect on force, velocity, blood lactates, or calculated jump height. Further studies controlling for initial measure of blood lactates and using an external focus may be necessary to elicit velocity, force and jump height changes.

**Key Words:** Exertion, Force, Jumping, Sedentary, Velocity, Whole body vibration

### Introduction

Whole body vibration (WBV) is a modality that continues to gain in popularity. WBV has been applied a number of ways however, one of the more common applications is with the participant standing on a machine which performs vertical vibration.

There had been no unanimous understanding of the optimal frequency for WBV until 2007. Cardinale *et al.* [1] identified optimal displacements of 30-50 Hz and small amplitudes of 2-5 mm of vertical displacement. Since that time many studies have accepted these measures. These studies have assessed several physiological changes during WBV

including increased  $VO_2$  [2], lower-body power [3], strength [4-6], and physical performance [6-8] and changes increasing jump height, velocity and force.

WBV started initially as a training tool to help increase strength and physical performance (i.e., jumping) [6,9-11]. Several studies have been performed showing physiological benefits with increased  $VO_2$  [2], skin blood flow [12], and bone mineral density [13]. Eckhardt *et al.* [14] recently investigated the effect WBV with exercise has upon serum lactates and concluded that there may be evidence of increased recruitment of muscle when WBV is performed with exercise versus the same exercise regimen without WBV. This study was performed over only two sessions and

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therefore the effect over time may not be significant. It should be noted that this study was performed on subjects that were described as “recreationally active men”.

Nearly every study was performed on either athletes or people who were either active or performing athletic activities. Gojanovic *et al.* [15,16] investigated the effects of WBV on sedentary subjects recently identified WBV as helpful for the sedentary population in cardiovascular improvements. Sedentary was described as “less than 20 to 60 minutes of vigorous physical activity. His second study identified WBV increasing levels of creatine kinase. However this was not long lasting and did no harm to the subjects. This is important as it identifies WBV as an effective and safe tool that sedentary people may use.

Plyometric training is another form of training that has been used for increasing strength [17,18] and reducing the risk of ACL injuries [19,20], increasing speed [21], and explosive movements [18,22], and jumping [23,24]. In addition to studies regarding physical performance, recent studies have begun to investigate physiologic changes including neural adaptations after plyometric exercise [25]. Brown *et al.* [26] describes an increase in blood lactates, increase in O<sub>2</sub> consumption and heart rate with a single bout of plyometric training. This was described as relating to aerobic power training.

Plyometric training is described as a quick, lengthening stretch of the agonist muscle followed by a rapid and forceful contraction of the agonist. Most notably, this is performed with jumping activities. An example would be standing still, then quickly squatting low prior to forcefully jumping upward (CMJ). Plyometric training is performed repetitiously. So one would not simply perform one jump, but multiple in succession.

There are a few studies where plyometrics and WBV are combined. Those studies typically involve athletes or physically active subjects. These two training concepts were combined to assess the effects they have on jumping, velocity of jumping, and force upon sedentary subjects. Additionally, we investigated the effects of those two concepts upon phys-

iological measures of blood lactates and affective measures using a the Borg rating of perceived exertion (RPE) scale.

## Methods

### Subjects

Subjects were assigned to 3 groups, consisting of 9 subjects each (Table 1). To be included in this study, subjects were 18-40 years of age, not currently involved in an exercise program, and able to tolerate jumping activities. Subjects did not: 1) have any lower extremity or lumbar injury from the past 2 years; 2) have any injury from the past two months; 3) have balance or equilibrium deficits; 4) be engaged in any sort of exercise regimen; 5) have high blood pressure (defined as 140/90 or higher blood pressure).

As mentioned above, to be included in this study, subjects needed to be currently not involved in an “exercise program”. This was defined as any activity, in the previous 3 months, where the subject purposely participated or exercised as a part of a team in an organized or recreational setting; participated in any individualized exercise setting; performed any exercise in a recreational setting--including walking, jogging, hiking, etc. All protocols and procedures were approved by the institutional review board of Loma Linda University and all subjects signed a statement of informed consent.

### Mesurments

#### *Whole body vibration and plyometrics*

WBV was conducted using the stand-alone unit, Globus Physioplate (Hi Tech Therapy, Johannesburg, South Africa). Settings were adjusted for 40 Hz of vibration with 2-4 mm of amplitude displacement.

#### *Measurement of jump height*

Jump height was measured using a Vertec (Columbus, OH, USA) vertical jump equipment (VT height). This device is adjustable for jump height and has several short, plastic rungs that swing away when contacted, thus identifying

**Table 1.** Group demographics

	Gender	Age (y)	Height (cm)	Weight (kg)	BMI (kg/m <sup>2</sup> )
Control	8 females 1 male	26	165	66.8	24.46
Jumping	8 females 1 male	29	162	60.5	22.80
Jumping with vibration	7 females 2 males	26	165	66.4	24.39

BMI: body mass index.

the height achieved (in inches). It was used at the initiation of the study and then again at three and six weeks into the study. Subjects stood below the rungs and performed a counter-movement jump (CMJ) upward to touch the highest rung they could reach. Subjects would make three attempts to jump as high as possible and that average of the three measurements would be taken. This device does not need specific calibration. It has specific marks along the upright standard which identifies various heights (in inches). Measurements conducted with the use of measuring tape along the upright standard to verify the correct heights were as listed.

#### *Velocity to max jump height/force/jump height (calculated)*

The measurement for velocity to max jump height, force, and calculated jump height (MT height) was measured using the Myotest Performance Measuring System (Sion, Switzerland). This device is attached to the hip laterally. By inputting the subject's height and weight, a read out is given on the screen identifying the subjects velocity in jump height in cm/s. This device was also used to measure maximum height attained and force through lower extremities by similar method as velocity. Once the information was put into the device, subjects would wait for five separate beeps. After each beep, the subject would perform a CMJ as high as possible. After the five trials, the myotest unit would display the average of the five trials.

#### *Lactic acid measurement*

Measurement for blood lactic acid (LA) was conducted with the use of the Lactate Plus Analyzer from Nova Biomedical (Waltham, MA, USA). The finger tip blood was arterialized. Subjects pricked their finger with the lancets that accompanied the analyzer. The blood drawn would be placed on the analyzer test strips. This was conducted before and after exercise on the first, seventh and eighteenth visits (beginning of week 3 and end of week 6). Measurements of blood lactates were conducted prior to exercise and approximately 3-5 minutes after the exercise [27]. The change in blood lactate levels from pre- and post-exercise was then calculated.

#### *Rating of rating of perceived exertion measurement*

After completing each measurement session, the subject expressed their RPE. This was performed using the standardized Borg RPE scale which ranged from 6-20 where a rating of 6 corresponds to no exertion at all and 20 corresponds

to maximal exertion.

### Procedures

Upon arrival to the first session, subjects signed an informed consent form, were assigned to a group, and briefly instructed in procedures to be performed.

Initial measurement of blood lactates, vertical jump height, calculated jump height, force, jumping velocity, and RPE were conducted. Subjects, then, performed their intervention activity (no activity for the control group) as described below. The same procedure was performed for data collection on visits 7 and 18.

The control group did not receive any intervention throughout the study. They were measured as outlined; at initial measure, three, and six weeks.

The plyometric jumping only group performed plyometric training three times per week for the six week study. Subjects jumped laterally between the vibration platform (platform is not turned on) and a plyometric box 7 1/2 inches higher than the vibration platform situated to the right of the vibration plate. Subjects jumped between the two surfaces for three bouts of 20 seconds with one minute rest between bouts. The plyometric jumping with vibration group performed the same activity, but the machine was vibrating at 40 Hz with 2-4 mm of displacement. They also performed this activity three times per week for 6 weeks. No jumping was performed on consecutive days.

### Data analysis

A two-way repeated measures analysis of variance (ANOVA) was used to analyze changes between groups and over time. Paired t-tests were used to assess for changes groups over the length of the study. The assumption of equal variances was met for each of these outcome measures. A one-way ANOVA was used to determine if the blood lactate response to exercise changed over time and differed by group. Kruskal-Wallis test was used to assess the differences in the ordinal RPE measure. The statistical analysis was performed with the use of SPSS software (SPSS Statistics Faculty Pack, IBM Co., Armonk, New York, USA). Level of significance was set at  $p=0.05$ .

### Results

For each of the measures presented, there were no significant differences among the groups in vertec jump, myotest height, force, or velocity. From this data we further in-

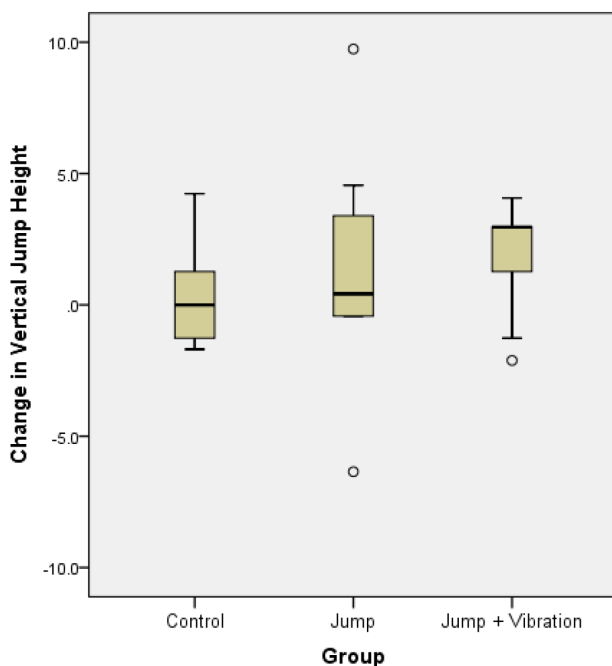
**Table 2.** Percent change in blood lactate levels (pre-post single bout of exercise) over the 6 weeks

	Control group (n=9)	Jumping only group (n=9)	Jumping+ vibration group (n=9)
	Median (min, max)	Median (min, max)	Median (min, max)
Baseline	0 (-85, 58)	168 (-23, 400)	282 (-22, 382)
3 weeks	4 (-43, 66)	130 (10, 570)	123 (63, 433)
6 weeks	4 (-74, 120)	149 (-44, 644)	118 (67, 262)
<i>p</i>	0.25	0.90	0.12

**Table 3.** Comparison of vertec jump height (cm) over the 6 weeks of the study between the treatment groups

	Control group (n=9)	Jumping only group (n=9)	Jumping+ vibration group (n=9)	<i>p</i> <sup>a</sup>
	Mean (SD)	Mean (SD)	Mean (SD)	
Baseline	242 (12.5)	239 (14.8)	240 (13.2)	
6 weeks	243 (13.1)	241 (13.1)	242 (13.8)	0.91
<i>p</i> <sup>b</sup>		0.05		
<i>p</i> <sup>c</sup>	0.67	0.31	0.04	

<sup>a</sup>Two way ANOVA effect of groups. <sup>b</sup>Two way ANOVA effect of time. <sup>c</sup>Paired t-tests.

**Figure 1.** Changes in jumping height in pre-data collection vs. post-data collection among the three groups.

investigated into percent of change. When we repeated the analyses using percent of change from initiation of the study to completion in each measure, there remained no significant differences between groups in vertec height, myotest height, Force, or velocity. The change of blood lactates from initial measure to the three week measure and six weeks were not significant (Table 2).

There was, however an overall a change in the vertec jumping measure from initiation of the study to completion ( $p=0.05$ ). Further assessment revealed a significant increase only within the JV group ( $p<0.05$ ). There was also no significant difference among the groups at initial data collection or six weeks (Figure 1, Table 3).

Statistical analysis of RPE measures demonstrated a significant overall difference between groups at initial measurement ( $p<0.05$ ), three weeks ( $p<0.05$ ), and six weeks ( $p<0.05$ ). Further post hoc testing using independent samples Mann-Whitney test revealed that there were significant differences between the control group and jumping with vibration group at initial measurement ( $p<0.05$ ), three weeks ( $p<0.05$ ), and six weeks ( $p<0.05$ ). There was also a significant difference between the control group and jumping only group at initial measure but not at three and six weeks. There were no significant difference between the jumping only and jumping with vibration groups.

## Discussion

Very few studies regarding WBV currently exist in regards to controlling for the subject's activity level. Most studies involve subjects that are either athletes [4,6] or active, but not trained [5,9]. Plyometric training has had a significant influence in the trained athlete, so most of its understanding has been focused with that population [23,28,29]. Therefore there is a lack of information regarding the effects of WBV and plyometrics to the sedentary person. This is important as WBV is being included in more clinical use and plyometrics are starting to be used more for rehabilitation.

Studies have concluded both WBV and plyometrics not only have performance benefits, but physiologic benefits including  $VO_2$  increases in young and older populations [2,26] and blood lactates [14,30]. Once again, the combination of these two training techniques have not been used to assess these same physiologic effects upon a sedentary population.

No standardized protocols exists for use of plyometrics. Several recent studies [31-33] have varied in their protocols of plyometrics in type of exercise, height/depth of exercise,

and amount of repetitions/time. In this study, plyometric jumping required subjects to jump onto and off of a 7 1/2 inch high box laterally for 3 bouts of 20 seconds. This time and height was selected due to likely subject fatigue and a standardized amount of time for performing the jumping task. Subjects performed the intervention three times per week for 6 weeks. This has been demonstrated in several studies to be sufficient for identifying strength changes [34-36].

In this study, we investigated the effects that combined training of WBV and plyometrics had upon two measures of jump height, velocity, force, blood lactates, and Borg's RPE in the sedentary population. Several measures were deemed as having no significant changes when compared to a control group. However jump height was deemed to be significant when using vertec.

In merging both plyometric training and WBV, we noted that there were several studies that concluded positive benefits of both. Pérez-Turpin *et al.* [6] noted an increase in jump height in trained volleyball players with the increased benefit of WBV in conjunction with jumping activities. In this study, we combined jumping (plyometrics) with WBV and similarly obtained positive results in jump height when assessing with the use a vertec measure. Yet, we did not find similar results with the use of the myotest to calculate the changes. What the myotest does not assess is the subject's ability to stretch and reach with a lean of the trunk and full forward flexion of the shoulder. There is also an external drive by the subjects when trying to knock away rungs. Wulf and Dufek [37] alludes directly to this phenomena using the vertec as the external focus for attaining this increase in jump height. In her study on behavior with relation to kinetics of movement, she concludes that an external focus produces an increase in effective and efficient movement patterns.

As the use of WBV and plyometrics are becoming more prevalent within the physical therapy settings, more research is needed to validate the use of these training techniques on all populations. As with any modality or training tool, selecting the appropriate population for use of each of these training techniques requires careful attention to each person's need and current physical level. Thus the age range selected (18-40 years old) was restricted for this study.

We attempted to control for a sedentary population and found that recruiting proved to be difficult, as subjects who are currently not active, tend to want to remain inactive. Shorter study times or a less restrictive exclusion criteria

may be helpful for future studies.

Monitoring blood collection times for blood lactates became difficult. Goodwin *et al.* [27] cited specific peak collection times (3-8 minutes) for blood lactates and we stayed within those parameters for post-exercise measures. However many subjects had to walk a notable distance from their vehicle or residence to the study. This may have altered the pre-intervention blood lactates collection and presented a level of lactates than someone who did not have to walk that distance.

Measurement of RPE was significant for jumping with vibration group compared to controls at all three measures. This result is not entirely unexpected as the two experimental groups involved physical activity, whereas the control group had no exercise. At the completion of the intervention and measures on the initial, third and sixth week, subjects were asked, according the RPE scale, how they felt that particular day was (both numbers and the standardized, corresponding words describing each level were visible for the subjects to understand each level). The controls were rating their perceived exertion according to measures only. Whereas the other two groups (jumping and jumping with vibration) were rating their perceived exertion according to measures and the intervention they performed.

Among a sedentary population, WBV with plyometrics is an effective tool for increasing jump height. It is helpful however, to have a source of external motivation for this to be realized. Simply having subjects jump as high as they can, may not be enough to achieve an increase in jump height. Jumping with vibration creates a higher level of perceived exertion than not jumping and when comparing not jumping to jumping and not jumping to jumping with vibration, jumping with vibration resulted in greater perceived exertion than jumping alone. WBV nor plyometrics have an effect on force, velocity, or jumping without external motivation. Due to measurement procedures, it is unclear as to whether blood lactates are effected by WBV or plyometrics. Further study on blood lactates with strict control over pre-intervention levels are needed for clearer results.

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## Conflict of Interest

The authors declared no potential conflicts of interest with respect to the authorship and/or publication of this article.

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