*Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online)*
*An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2014/04/jls.htm*
*2014 Vol. 4 (S4), pp. 3241-3247/Hossein et al.*
***Research Article***

# THE EFFECTS OF PLYOMETRIC VERSUS WHOLE BODY VIBRATION TRAINING ON LOWER EXTREMITY BIOMECHANICS

**Hossein Rostamkhany, *Hojatolah Nikbakht and Heidar Sadeqi**
*Department of Physical Education and Sport Sciences, Tehran Science and Research Branch, Islamic Azad University, Tahran, Iran*
**Author for Correspondence*

**ABSTRACT**
Plyometric training has been shown to have numerous benefits for athletes, including reduced risk of injury and increased motivation. The purpose of the present research was to examine the effects of plyometric versus whole body vibration training on lower extremity biomechanics in male non-athlete students. 30 PE students voluntarily participated in the research and were assigned to three groups: (1) plyometric, (2) vibration and (3) control. Biodex System was used to assess biomechanical factors. After testing for normality and equality of variances using Kolmogorov-Smirnov test and Levine's test, descriptive statistics, one-way ANOVA and Scheffe's post hoc test were used for data analysis at the 0.05 significance level in SPSS. The results indicated that plyometric and the vibration exercises protocol improve biomechanical factors. However, plyometric exercises had a greater effect on almost all the variables. These exercises also reduce the risk of injury until peak performance without causing fatigue.

***Keywords:*** *Lower Extremity, Vertical Jump, Whole Body Vibration Training (WBVT), Plyometric Training*

## INTRODUCTION
The importance of the strength and power trainings, as common features of many sport activities, has been confirmed by many studies which demonstrated that working with weights and more recently plyometric exercises, enhance the performance in competitions (Earl, 2001). The coaches and athletes claim that the plyometric exercises, bridges the gap between the power and strength and directly enhances the performance. They often regard the power work-outs as sources that increase the general power and they also consider the plyometric training as a method for applying this power (the general power increased by power training) in order to enhance the performance of the athletes (Ferris, 2001). The plyometric exercises are designed in order to reach the maximum power and especially the maximum explosive power in the least possible time, which takes place by decreasing the amortization phase (Stane, 2005). Nevertheless, conducting plyometric exercises because of its consecutive jumps and hops can exhaust the athlete and increase the injury possibility; therefore many experts in the training field, suggest that for reaching the proper training results, besides the plyometric training, another training method be used for preparing the athletes.

### *Literature Review*
the many reasons preventing the athletes of certain sport fields, reaching the maximum capacity in the vertical jumps, one can mention the disregard to the effective issues on the vertical jump, or paying too attention to certain aspects of skills. Being unaware of the correct techniques of jumping, doing improper exercise movements for reinforcing the muscles involved in the jump, or using routine , repetitive and exhausting training methods in a certain sport field, are the causes which bring about severe consequences such as exercise-induced nausea, shortened championship period, frequent injuries , and athlete's failure in various competition levels. Considering the role of the joints and the various biomechanical parameters in optimum performance of various kinds of jumps, many studies have been conducted in order to detect the effective parameters like peak torque (PT) from different perspectives and aspects. For instance, Dowling and Vamoose (2008) in a research conducted using force plate, reported that the PT parameter can be used as an excellent predictor for the height of the vertical jump , in the lower limb joints (Dowling, 2008). In another research, Wiklander and Lysholim (2009), investigated the significant

relationship between the PT of the knee extensor muscle joint in the speed of 180 degree per second , and the height of the vertical jump (Wiklander, 2009). Also, in some other studies, the relationship among the joints and other biomechanical factors such as AT, ROPTD, AP, ATPT were discussed considering the jump action and the sport performance of the athletes that confirmed the significant relationship between the aforementioned factors and the sport performance. Studying the effect of various exercises on the factors underlying the vertical jump performance, besides offering us a more comprehensive knowledge about the mechanism of performing such a skill, can effectively contribute to the modification and reconstruction of the previous training methods or it can lead to novel exercise methods design , which in turn can help us in designing the training programs, especially the ones which are conducted in the phase of converting the general strength into strength in speed or power. A general review of the related literature indicates that there has been no study dealing with the effect of plyometric exercises and vibration on the mechanics of the lower limb. In addition, despite the fact that in the previous studies, the significant effect of the plyometric trainings on the explosive activities were confirmed, it should be noted that the effect of the plyometric exercises has not been studied in detail, on the biomechanical parameters affecting the power activities performance. Therefore, the purpose of the present study is to investigate the effects of plyometric versus whole body vibration training on lower extremity biomechanics male non-athlete students.

## MATERIALS AND METHODS

*Subject Selection*

This research includes in the pretest and posttest studies, two experimental groups and one control group. Thirty male students of Physical Education, having similar applied syllabuses in the course of the semester, were voluntarily selected from Karaj Islamic Azad University. The subjects answered a structured questionnaire about their health. Subjects having injury records in the lower limb and also the ones, who had had nervous injuries and problems, were removed from the research.

***Experiment Conduct Method***

The subjects selected for participating the research, gathered in the physiology laboratory of Kharazami University of Karaj, one day before doing the exercises, so that their heights, weights and BMI values (weight in kilograms (kg) divided by height in meters, squared (m2)). Then, the stronger foot of each of the subjects was determined by using this particular data that by which lower limb, the subject is willing to kick the soccer ball. Afterwards, the style of administering the test was explained by the tester to the participants. Then, the subjects did a 5-minute warm-up phase (slow running), and after that, they stretched the hamstring muscles, the quadriceps, the sciatic muscles, the inferior gemellus muscle, the soleus muscle , the thigh flexors and the IT band for five minutes. After the warm-up, the maximum power of the subjects for the knee extensor muscle was recorded by a Biodex machine. Then the subjects were ranked according to the isometric power of the knee extensor muscles, and were put in three experimental groups and one control group. After putting the subjects in special groups, the pretest data as explained before was recorded with a 24-hour rest. The next day, the subjects of each group, started the trainings related to their groups, in the laboratory of Karaj Kharazmi University.

***Measuring the Isometric Power of the Knee Extensors***

The American 3-Model Isokinetic Biodex Machine was the instrument for measuring the maximum isometric power of the knee extensors. According to the manual of the device, the dynamometer of the machine was registered in 90-degree angle. The posterior slope angle of the chair was considered 85 to 90 degrees. Special tapes were used for fixating the thigh and the upper limb, so that only the thigh extensors muscles' power be recorded. On the basis of the previous studies findings, the maximum power of the knee extensors was registered in 30-degree angle. The reason lies in the fact that in this angle, the least changes of the maximum isometric power has been recorded for the knee extensor muscles. In order to record the data according to the maximum produced torque per Newton-meter, each subject made three 5-second attempts, had a 5-second rest in the intervals. The mode of the isometric and concentric machines was taken into consideration.

***Measuring the Biomechanical Parameters of the Knee Extensors Muscles***

The biomechanical parameters of the lower limb in the knee and stronger ankle joints were measured by the isokinetic machine in the angular speed of 180 degrees per second. In order to measure the biomechanical parameters of the knee extensors, each subject would get on the special seat of the Biodex machine, and his leg would be fixated by the special tapes from above the given joint, in such a way that during the movements and training, the activator muscles in the other joints would not be used. It should be remarked that the subject's position on the seat was in a manner that the angle of the body was 90 degrees in flexion status, and the ankle was free. The height of the seat was adjusted in such a way that the center of the knee joint (the external epicondyle of the femur) was situated opposite the dynamometer's rotation axis. For registering the isokinetic parameters of the knee, the knee special connection was used. The connection padding was installed 5 centimeters higher than the external ankle. Then, the subjects were asked to extend their knees with the maximum power on the Biodex machine, three times with an angular speed of 180 degrees per second. The measured biomechanical parameters (PT, the time of reaching the PT, the angle reaching the PT, the time of acceleration, and the average power) were recorded by the machine. The Biodex machine, among each subject's repetitive attempts, selected the one with the maximum amount of PT and presented all the other desired parameters in that repetition, as the output. In case of having the recorded coefficient of changes (uniformity coefficient of the repetitions) lower than 15, the measured parameters were regarded as valid enough. In the present study, the isokinetic parameters of the concentric contraction were recorded.

***Measuring the Biomechanical Parameters of the Ankle Plantar Flexors***

For measuring the biomechanical parameters of the ankle joint plantar flexors, the subject in a manner similar to the previous status (the position for measuring the knee extensors parameters) took the seat and his knees were in 20 to 30 degree flexion state. Then, he would do the plantar flexion for three times with an angular speed of 180 degrees per second, with the utmost power. The measured biomechanical parameters (PT, the time of reaching the PT, the angle reaching the PT, the time of acceleration, and the average power) were recorded by the machine, during the ankle plantar flexion. The height and the angle of the seat, and also the direction and the angle of the dynamometer, were adjusted in a way that the external ankle would be placed facing the dynamometer rotation axis. The dynamometer angle was adjusted 90 degrees and its tilt amount was set in 50 degrees. The resulting information (the Biodex output), was used in both cases measuring the knee extensors and ankle plantar flexors, in calculating the parameter of the peak torque development rate. The peak torque development rate is calculated by dividing the PT by the parameter of time of reaching the PT.

***Vibration Training Course***

The vibration training plan design of this study, was based on in the previous studies conducted in the same field. The posture was adapted from the Bosco training protocol including the standing on the vibration device in 5 different bodily positions which are as follows: 1. direct standing posture, 2. 90-degree squat on knees, 3. 90-degree squat on knees with external rotation of the legs, 4. 90-degree squat on the right leg, and 5. 90-degree squat on the left leg. The frequency of the training was 30 Hz and the domain was 4 mm. The training duration in every bodily position, was 60 seconds. In the intervals, a 60-minute rest time, was observed. The number of repetitions for each bodily position as intervals, was 2 times in every session, in such a way that the subject would do all the five bodily positions in the first round, and then the next round of training would commence.

**Table 1: Vibration Training Protocol**

| **Performance** | **W** | **S** | **V** | **R** | **V** | **R** | **V** | **R** | **V** | **R** | **V** | **R** | **V** | **R** | **V** | **R** | **V** | **R** | **V** | **R** | **V** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time (s) | 300 | 120 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |

1. *W: warm-up, S: stretching V: vibration training, R: rest*

 

The duration of the training course was 6 weeks, in each week, the subjects would undergo the workout and exercises every other day , in this manner that in one week , four sessions were held , and in the next week , three 30-minute sessions would follow (Yen, 2010). The protocol of the vibration training was as above (Table 1):

***Plyometric Training Course***

The subjects of the plyometric training group did a variety of plyometric exercises, designed for the lower limb, in a 6-week training program. This training protocol consisted of three and four sessions of exercises in a week, in every other manner, with a training capacity of 90 to 110 foot-contacts in every session. The training plan included five plyometric movements, that the subjects would do each movement for 60 seconds. These movements were: 1.double-leg forward jump over the hurdles, 2. Double-leg lateral jump over the hurdles using the stronger foot, 3. Single-leg forward jump over the hurdles using the stronger foot, 4. Single-leg lateral jump over the hurdles using the stronger foot, and 5. Double-leg forward and backward zigzag jump. As usual, between each action, a 60-second rest interval was observed. The subjects in each training session, after doing all the five movements, accomplished the next round, in the same manner with the first one, and by completing the second round , the trainings ended (Yen, 2010). The timing of the plyometric training plan was exactly in line with the vibration training group plan.

***Statistical Analysis***

In order to verify the normality of the data distribution, Kolmogorov-Smirnov test; for unifying the variances of the observed groups, Levene's test; and for describing the individual characteristics of the subjects in each four group, the descriptive statistics were used. The analysis of the collected data in the pretest and posttest stages in different groups was done by the use of one-way variance analysis and the Scheffé's post-hoc test in the significance level of 0.05, and it was executed in the interface of SPSS Software version 16.

## RESULTS AND DISCUSSION

***Results***

Three descriptive statistical data is shown in Table 3, belonging to the individual characteristics of the research participants, separately three each group.

**Table 3: The mean and standard deviation of the individual characteristics of the subjects distinguished by groups**

| **Variable**<br>**Group** | **Age (year)** | **Weight (kg)** | **Height(cm)** | **BMI** |
|---|---|---|---|---|
| Plyometric | 23.46 ± 2.61 | 71.39 ± 4.68 | 176.42 ± 7.41 | 32.10 ± 3.69 |
| Vibration | 22.65 ± 2.76 | 75.29 ± 6.38 | 178.03 ± 7.93 | 23.73 ± 3.91 |
| Control | 22.12 ± 1.86 | 70.87± 5.12 | 175.53 ± 6.25 | 22.87 ± 3.59 |

The results showed that after finishing the plyometric and vibration the time of reaching to PT, PT, the average power, the acceleration time, and PT development amount related to knee extensors, and the same parameters related to ankle plantar flexors, enhanced.

However, the angle of getting the peak torques of knee extensors and ankle plantar flexors, and also the acceleration time and the ankle plantar flexor development amount, after completing the trainings, did not show any significant changes.

Plyometric trainings caused a reduction in the time of reaching the PT and also the acceleration time of the knee extensors. Moreover, executing the plyometric training protocol for 6 weeks significantly increased the knee extensors PT, average power, PT development amount, and the ankle plantar flexors PT and average power.

Executing vibration trainings for 6 weeks significantly increased the knee extensors PT, average power, PT development amount, and the ankle plantar flexors PT and average power. Also, doing this training method, reduced the time of reaching to PT of the knee extensor muscles (Table 4).

**Table 4: Isokinetic Parameters of the Lower Limb, Before and After the Plyometric, Vibration Training and Control group in Knee and Ankle Joints**

| Joint | Knee Joint | | | | Ankle Joint | | | |
|---|---|---|---|---|---|---|---|---|
| Parameter | Plyometric | Vibration | Control | p | Plyometric | Vibration | Control | p |
| TTPT | 41.2 ± 4.3 | 22.6± 3.32 | 2.4± 1.14 | 0.000 | 7.23±2.3 | 6.6±4.6 | 4.2± 0.45 | 0.006 |
| PT | 45.4 ± 8.5 | 24.3 ± 7.26 | 3.14± 0.9 | 0.004 | 16.34±4.7 | 14.3±3.26 | 4.7± 1.66 | 0.004 |
| ATPT | 1.18±0.7 | 0.86 ±0.32 | 1.2± 0.3 | 0.016 | 0.98±0.6 | 1.13±0.74 | 1.03± 0.23 | 0.43 |
| AP | 53.2±12.6 | 26.7±11.3 | 6.2± 0.3 | 0.014 | 21.36±6.5 | 22.6±6.3 | 3.53± 0.27 | 0.003 |
| AT | 14.44±8.3 | 6.7±11.3 | 3.2± 0.3 | 0.000 | 6.18±2.3 | 5.2±2.83 | 4.7± 1.93 | 0.874 |
| ROPTD | 2.23±0.07 | 1.14±0.13 | 0.12± 0.3 | 0.001 | 0.18±0.01 | 0.19±0.021 | 0.14 | 0.36 |

***Analysis of the Results***

The purpose of this study is to define the effect of plyometric versus whole body vibration trainings on a set of selected biomechanical variables of the lower limb in the male non-athlete students. In general, the results showed that after executing the plyometric and vibration training methods, the time of reaching to PT, PT, the average power, the acceleration time, and PT development amount related to knee extensors, and the same parameters related to ankle plantar flexors, enhanced. However, the angle of getting the peak torques of knee extensors and ankle plantar flexors, and also the acceleration time and the ankle plantar flexor development amount, after completing the trainings, did not show any significant changes. Also, the results showed that after doing the trainings, of all the measured biomechanical parameters, the effect of the plyometric trainings was significantly higher.

In the previous studies in the field, it is proved and confirmed that executing plyometric trainings, increases the power. Hewett *et al.*, (1999) reported an increase in the isokinetic power of the quadriceps and hamstring muscles and also an enhancement in the power ratio of the hamstring to the quadriceps in female trained athletes affected by plyometric exercises (Hewett *et al.*, 1999). Influenced by the power increase caused by the plyometric trainings, the voluntary individual effort for producing force increases that considering the recruitment of bigger motional units with bigger cell germ and thicker axon , one can expect that the produced torque of the muscular group undergoing plyometric training increase. In sum, it can be said that executing plyometric training, besides increasing the muscular power, especially in quadriceps, increases the neurotic conduct speed and consequently the contraction speed, and apart from increasing the average power and the peak torque, it would bring about the increase in the knee extensors peak torque development amount, and the ankle plantar flexors' average power and peak torque.

Of the other possible reasons by which, the effect of the plyometric training on the factors of vertical jump can be justified, one can refer to the neuromuscular harmony improvement and the effective changes taken place in the activities of muscular spindles and Golgi tendon organ. The previous studies, have confirmed the increases of the activities of the muscular spindles, and the decrease of the activities of the Golgi tendon receptors after doing the plyometric trainings (Hewett, 1999; Jeffrey, 2001). The results of the research showed that in spite of the significant reduction in the time of reaching the peak torque and the knee extensors muscles' acceleration time, it was also observed that the aforementioned factors in ankle plantar flexors had not experienced any significant change. The previous studies did not report any significant relationship between the acceleration times of the ankle plantar flexors with the vertical jump; however the knee extensors' acceleration time has rather important relationship with the vertical jump execution (0.46). Also, the relationship between the peak torque reaching time in knee extensors muscles and vertical jump is more significant compared to the relationship of ankle plantar flexors and vertical jump (0.37 against 0.09). Each plyometric training session consists of several kinds of single-leg or double-leg jumps, so it is probable that the parameter whose relationship with the vertical jump is almost zero (at the time of acceleration time) or very low (the time of reaching the peak torque), after completing these trainings, would not experience any significant changes.

Executing vibration trainings for 6 weeks significantly increased the knee extensors PT, average power, PT development amount, and the ankle plantar flexors PT and average power. Also, doing this training method, reduced the time of reaching to PT of the knee extensor muscles. In any case, applying the vibration exercises as a training method for improving the sport performances has become very popular in the recent years, and from 1998 to 2008 , more than 15 studies , have confirmed the positive impact of such training method in improving athletic performances (Punakallio, 2005). Presenting definite theories on using the method with a training protocol or certain intensity , is very difficult and needs further studies whose results requires careful analysis and discussion.

The results of the present study is compatible with the study results of
Reyes *et al.,* (2008) and Bogaerts *et al.,* (2007), that had reported the sport performance enhancement, and also the concentric and eccentric power of the knee extensor muscles after the execution of vibration trainings. In addition, the results of this study about improving the vertical jump execution are in line with the results of Marco Cardinal's (2002) study, in which, after 10 days, the vertical jump of the experimental group had improved 11.9 percent, and also with the results of Bosco *et al.,* (2000), that showed a 5-percent improvement of the power after the vertical jump test (Reyes, 2008; Bogarts, 2007; Marco Cardinale, 2002; Bosco, 2000). However, the results of this study are not compatible with study results of Yosuku *et al.,* (2011), Artero *et al.,* (2011), Javier *et al.,* (2010) and Stifansen (2005), that reported no significant changes in isometric and isokinetic power of the knee extensor muscles, no improvement in the performance and no increase in explosive power and the vertical jump height after the vibration training (Osawa, 2011; Artero, 2011; Javier, 2010; Stefanson, 2005).

***Conclusion***

The possibility that the results of the present study are compatible or incompatible with the results of the other studies is due to the similarity of the training variables to the compatible studies results and the difference of the training variables with the incompatible studies. In an investigation done, most of the studies reporting the effects of vibration training on sport performances, used frequencies between 25 to 30 Hz, and domains 10 mm or less.

The training variables of the frequency and the domain of the present study, are equal or very close to the compatible studies, especially the frequency was almost the same in all the studies. Since Bosco calls frequency as the most important training variable leading to vibration effects, so possibly one of the main reasons why our results are compatible with the other studies results, is the similarity of the aforementioned variable, which is the frequency (Torovinen, 2002).

In case of the difference of the effect of the plyometric training with vibration training, the results show that the created adaptabilities is dependent to the type of the training. Hence, since the measured variables in the present study were mainly power variables, and had more significant relationship with the muscular contraction speeds compared to the maximum power of the muscles, one can regard the adaptability to the training type as the main reason for the more percentage of changes of the variables after the plyometric training compared to the vibration training.

**REFERENCES**

**Artero EG and Espada-Fuentes JC (2011).** Effects of whole-body vibration and resistance training on knee extensors muscular performance. *European Journal of Applied Physiology* **10** 2078- 2091.

**Bogaerts A, Verschueren S, Claessens AL and Boonen S (2006).** Effects of whole body vibration training on postural control in older individuals: A 1 year randomized controlled trial. Gait & Posture.

**Bosco C, Iacovelli M and Tsarpela O (2000).** Hormonal responses to whole-body vibration in men. *European Journal of Applied Physiology* **81** 449-54.

**Cardinale M and Wakeling J (2005).** Whole body vibration exercise: are vibrations good for you? *British Journal of Sports Medicine* **39** 585-89.

**Cardinal M (2002).** PhD Thesis: The effect of vibration on human performance and hormonal profile, Budapest. Semmelweis University Doctoral School, Faculty of Physical Education and Sport Sciences.

**Darryl J, Cochrane J, Lgg J and Michael J (2004).** The short effect of whole body vibration training on vertical jump, sprint, agility performance, *Journal of Strength & Conditioning Research* **18**(4) 828-32.

**Delecluse C, Roelants M and Verschueren S (2009).** Strength increase after wole body vibration compared with resistance training. *Medicine & Science in Sports & Exercise* **12** 1033-41.

**Dowling JJ and Vamos L (2008).** Identification of kinetic and temporal factors related to vertical jump performance. *Journal of Applied Biomechanics* **9** 95-110.

**Earl JE and Hertel J (2001).** Lower-extremity muscle activation during the star excur sion balance tests. *Journal of Sport Rehabilitation* **10** 93-104.

**Ferris CM and Freedman AD (2001).** Nearomuscular and biomechanieal lower extremity training for female athletes. *Athletic Therapy Today* **6**(4) 54-62.

**Hewett TE, Lindenfeld TN, Riccobene JV and Noyo FR (1999).** The effect of neuromuscular training on the incidence of knee injury. *American Journal of Sports Medicine* **27**(6) 699-705.

**Jeffery S and David N (2001).** Effect of intense strength training on standing balance, walking speed and sit to stand performance in older adults. *Journals of Gerontology: Series A* **56** 281-86.

**Javier F and Nicolas T (2010).** Effects of vibration training on force production in female basketball players. *Journal of Strength and Conditioning Research National Strength and Conditioning Association* **24**(5) 1373–1380.

**Lord SR and Ward JA (2006).** Exercise effect on dynamic stability in women: a randomized controlled trial. *Archives of Physical Medicine and Rehabilitation* **77**(3) 232-6.

**Punakallio A (2005).** Balance abilities of workers in physically demanding jobs: With special reference to firefighters of different ages. *Journal of Sports Science and Medicine* **4**(8) 7-14.

**Reyes FB and Nashner LM (2008).** Effect of vibration training on the muscle power. *Journal of Neurophysiology* **55** 1369-1381.

**Stane ML and Powers ME (2005).** The effects of plyometric training on selected measures of leg strength and power when compared to weight training and combination weight and plyometric training. *Journal of Athletic Training* **42**(3) 186-92.

**Wiklander J and Lysholm J (2009).** Simple test for surveying muscle strength and muscle stiffness in sportsmen. *International Journal of Sports Medicine* **8** 50-55.

**Yen KT, Tsai CB and Chang KY (2010).** Effects of vibration training combined with plyometric training on muscular performance and electromyography. *Life Science Journal* **7**(1) 78-82.

**Yusuke O, Yuko O and Shohei O (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.