# The effect of Hand Positions on the Vibration Platform on Shoulder Muscle: Strength and Proprioception

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**Introduction:** To compare the short-term effect of one session of Whole Body Vibration (WBV) in two positions of hand on the vibration platform on isokinetic strength of Rotator cuff and shoulder proprioception. **Method and Materials**: A total of 60 young healthy students participated in the present study completing three positions of control (no vibration), push up with straight elbow, and push up with semi flexed elbow (two vibration positions) running for two minutes with 30-minute rest between the positions. After control position, vibration positions were tested randomly on the Power Plate device (F: 30Hz and low amp). The isokinetic strength of Rotator Cuff and the absolute angular error in joint repositioning test in 3 target angles of 0°, 45°, and 90° were measured using Kin-Com dynamometer before and after each position. Then, the results of the three positions were compared together. **Results:** Despite decrease in dynamic strength of medial rotators after three positions, this decrease was observed to be significantly less in push up with straight elbow compared with that in control position ($P$=0.03). Also, there was a significant difference in Concentric MPT of Lateral Rotators between the three positions with control position revealing the greatest decline in lateral rotators strength ($P$=0.01) and push up with straight elbow was found to be more effective than semi flexed elbow ($P$=0.03). Moreover, There was a significant improvement in angle repositioning for the three positions; however, it was considerably more only in zero degree in the push up with semi flexed elbow position as compared with that in the control position ($P$=0.03). No significant changes were found between push up with straight elbow and semi flexed elbow positions, either. **Conclusions:** The two different hand positions did not alter the effect of vibration on neuromuscular system in young and healthy individuals. Although a single session of WBV had a positive effect on the neuromuscular system of the young healthy participants, the two positioning did not make a significant difference.

**Key words:** Whole body vibration training, shoulder muscle strength, proprioception

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## Introduction

The shoulder joint complex demonstrates greater mobility than any other joint in the human body (1). The increase in the Range of Motion of shoulder joint, as a base of upper body, essential for its appropriate function, requires proper interaction between static and dynamic structures to provide stability of shoulder joint. In addition, The role of proprioception in allowing a feedback mechanism to work, which in turn allows a synergistic contraction of muscle groups, may be vital both for normal functioning of the muscle groups of the shoulder joint and in protecting the shoulder against potential instability (2). Consequently, rehabilitation is focused on re-establishing neuromuscular coordination and proprioception, along with Rotator Cuff muscle strength and endurance (1).

Whole Body Vibration (WBV) training is a novel neuromuscular training method introduced as a rehabilitative protocol. Several studies have shown the positive effect of WBV on muscle strength, power, balance, hormonal levels, physiologic factors, and bone mineral density. These studies are unanimous in the fact that WBV has stimulating effect on skin receptors, muscle spindles, joint mechanoreceptors, and changes in cerebral activity (3-11). Most studies on short term WBV have analyzed the effects of that muscle on the strength of lower limb (5, 9, 12), while ther studies reported no changes in muscle strength after WBV training (8, 13). Similarly, other studies have examined the effect of WBV on proprioception of lower joints (14-16).

To date, to the best of our knowledge, no published work has reported investigating the direct effect of the WBV on the shoulder joint, as one of the most important joints necessary for Activity Daily Living (ADL) in the upper limb. In addition, literature includes no mention of standard position of the shoulder joint during studying on the platform of the WBV system. It is OK. Therefore, the present study was carried out to investigate the effect of the WBV on the shoulder joint proprioception in two push up situations with "straight elbow" and "semi-flexed elbow" positions in order to find out if this technique can be useful to improve the Rotator Cuff muscle strength and shoulder joint proprioception.

## Methods and Materials

The present semi-experimental cross-over trial was carried out on 60 university students (age: 24.3±4 years old and BMI: 22.7±3.5) after signing a consent form, approved by The Ethics Committee of the School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran. All the tests were carried out at the time between 9 AM and 1 PM. Prior to administering the test, the participants were given a summary of the necessary information and the procedure of the study. Then, they were familiarized with the WBV as well as the isokinetic tools. Next, participants were allowed to have eight minutes of warm up including five minutes of work with biceps ergometer and three minutes for shoulder stretching and the Codman's exercise. Then, the test started by asking the participants to stay in the push up position, while their palms were on the power plate vertically as a control position (the WBV tool was off). The test included four 30-second sets with 30 seconds of rest between each set. Right before and after the positioning, the isokinetic muscle strengths of Rotator Cuff and the shoulder joint position sense were measured, as described below.

After 30 minutes of rest, the participants experienced two randomly vibration positions (push up with straight elbow and semi-flexed elbow) with 30-minute rest in between and again the isokinetic muscle strength of Rotator Cuff and the shoulder joint position sense were measured right prior to and after both positions. Overall, each participant performed three positions of control, push up with straight elbow, and semi-flexed elbow.

***WBV positions***

Both vibration positions (push up with straight elbow and semi-flexed elbow) were performed on the power plate machine (Fre: 30Hz, Amp: low).

1- Participants were asked to stay in the push up position while the palms were placed vertically on the vibration platform with the equal distance to the center of vibration platform. Then, they were exposed to vibration four times for 30s with 30s of rest between each set.

2- Similar to the position above, the participants stayed in the push up position while their palms were placed on the platform with more distance from the center with the elbow angle of 30° flexion and the forearm perpendicular to the platform. Participants were exposed to vibration four times for 30s with 30s of rest between each set (Figure 1). In both positions, the head and neck were aligned with the trunk.

***Assessment of dynamic strength of Rotator cuff muscles using an Isokinetic system***

In the current study, the assessment of isokinetic strength of Rotator cuff muscles was performed using Kin-Com dynamometry machine at the speed of 90°. The validity and repeatability of this isokinetic system were already shown by many researchers to range from 0.86 to 0.85. (17, 18). The participants sat and their trunks were fastened using seatbelts. The drum of the dynamometer was tilted 25° from the vertical axis and rotated 70° as required by the scapular plane, which is the dominant shoulder position in 45° abduction and 30° forward flexion, and 90° elbow flexion and forearm pronation. The horizontal position of dynamometer lever arm was set as the standard baseline on 0° and then measurements were made through a total range of 90° from the 0° (90° of internal rotation and 90° of external rotation). The type of test was continuous. At first, all muscle groups (internal rotators and external rotators) were tested concentrically and then eccentrically after 30s of rest interval. After a brief explanation of the testing procedures, participants were asked to execute three sub maximal trials to get familiar with the device and the test protocol. Then, three maximal practice repetitions were done prior to data collection. During all the tests, participants received standardized verbal commands. The mean peak torque generated from the three maximal contractions was calculated and recorded as the criterion for each strength measurement.

***Assessment of proprioception through Active Angle Reconstruction (AAR) method using an isokinetic system***

Shoulder proprioception was evaluated using Kin-Com machine. In the present study, the participants listened to blank noises using headphones while sitting on the isokinetic chair blindfolded and their trunks fixed using chest straps to avoid excessive movements. The isokinetic dynamometer speed was set at 5° per second, while the participant's shoulder was firmly fixed on the scapular plane. The horizontal position of dynamometer lever arm was set as the standard baseline on 0° and then measurements were made through a total range of 90°

***Table 1.*** Participants' characteristics

| | Mean (SD) | Max | Min | n |
|---|---|---|---|---|
| **Age(years)** | 24.97 (3.71) | 30 | 19 | **60** |
| **Height(cm)** | 172.72 (7.41) | 187 | 156 | **60** |
| **Weight(kg)** | 69.59 (13.84) | 100 | 47 | **60** |
| **BMI** | 22.7 (3.5) | 29.86 | 17.21 | **60** |

from the 0°. The participant was asked to reconstruct 0°, 45° and 90° in the internal and external rotations as the target angles in randomized order (Figure 2).

The starting angle to reproduce 0° and 90° was 45° and to reproduce 45°, it was 90°. The participants were asked to rotate their shoulders to the required angle actively, holding it for 10 seconds and concentrate on this position. Next, they were asked to actively return it to the starting position and repeat the whole test after a 5-second rest. Then, they were asked to actively reconstruct the target angle previously presented. Three trials for each target angles were performed. The difference between the target and the reconstructed angle was measured and called as "Absolute Angular Error" and used for the statistical analysis.

***Data analysis***

SPSS (version 16) and Microsoft Excel (2007) were used for statistical analyses. Kolmogrov-Smirnov test revealed that our data enjoys normal distribution and the parametric tests were used for data analyses. A mixed linear model with diagonal co-variance structure was used to compare the means of all variables of the three positions of control, push up with straight elbow, and semi-flexed elbow. A suitable post-hoc test was also used on the parameters concluded from the mix model to compare and to find out the significance effect of each three position. A paired *t*-test was also run to compare the before-after test data. Moreover, a Pearson test was run to find out any correlation between the pre/post data in each position.

## Results

Table 1 shows the demographic data of the participants of the study. A repeatability test was carried out on eight participants after a week to find if the results are repeatable. Table 2 shows the results of this pilot study. An ICC between 0.68 and 0.91 revealed that the data was repeatable with the significance level of α= 0.05.

***Dynamic strength of Rotator Cuff***

Pre- and post-mean concentric and eccentric peak torques of IR and ER and the P-values are presented in Table 3. Paired t-test revealed a decrease in dynamic strength of IR after all the three positions.

AE0: absolute angular error in the reconstruction of 0°; AE45: absolute angular error in the reconstruction of 45°; AE90: absolute angular error in the reconstruction of 90°; TCIR: Mean Concentric Peak Torque of Internal Rotators; TCER: Mean Concentric Peak Torque of External Rotators; TEIR: Mean Eccentric Peak Torque of Internal Rotators; TEER: Mean Eccentric Peak Torque of External Rotators

Comparison of the findings between positions revealed no significant difference in the mean concentric peak torque of IR according to the mixed linear model. Regarding the mean eccentric peak torque of IR, a significant difference was observed between control position and push up with straight elbow (*P*=0.03) in which the decline in the strength of IR was significantly less in the push up with straight elbow position than that in the control position (3.30% and 4.8%, respectively). Moreover, no considerable difference was found between the two vibration positions (*P*=0.1).

Considering the dynamic strength of ER, based on the paired t-test, there was an insignificant increase in the mean concentric and eccentric peak torque of ER in the push up with semi-flexed elbow (Table 3). In both control and push up with straight elbow positions, the dynamic strength of ER decreased, which was significant only in the eccentric mode.

Comparison of the findings between positions showed no difference between positions in mean eccentric peak torque of ER. But there was a significant difference among all positions in the mean concentric peak torque of ER among which the control position resulted in the highest decrease in concentric strength of ER (p=0/01) and push up with straight elbow position was more effective than push up with semi-flexed elbow position (p=0/03).

***Absolute angular error***

The paired t-test revealed a significant decline of absolute angular error of all target angles in all positions, as shown in Table 3.

The results showed that a significant difference exists only in 0° angle reconstruction between the control and push up with semi-flexed elbow positions (p=0.03). No significant difference was observed between the two push ups with straight elbow and semi-flexed elbow positions.

Table 4 shows the mean of the percentages of improvement for all variables in the three tested positions which was obtained by calculating the difference between the values after the test and before the test multiplied by 100. According to the percentage of improvement, both vibration positions caused less decline in isokinetic strength and more enhancement of proprioception sense in comparison with that in the control position.

***Table 2.*** Interclass correlation coefficients (ICC 95%) of values

| | Variables | ICC 95% |
|---|---|---|
| | TCIR | 0.819 |
| | TCER | 0.832 |
| | TEIR | 0.913 |
| **Control position** | TEER | 0.808 |
| | AE0 | 0.860 |
| | AE45 | 0.780 |
| | AE90 | 0.836 |
| | TCIR | 0.893 |
| | TCER | 0.777 |
| | TEIR | 0.837 |
| **Push up with straight elbow** | TEER | 0.762 |
| | AE0 | 0.912 |
| | AE45 | 0.858 |
| | AE90 | 0.887 |
| | TCIR | 0.913 |
| | TCER | 0.967 |
| | TEIR | 0.893 |
| **Push up with semi-flexed elbow** | TEER | 0.896 |
| | AE0 | 0.802 |
| | AE45 | 0.684 |
| | AE90 | 0.843 |

*AE0: Absolute angular error in the reconstruction of 0°; AE45: absolute angular error in the reconstruction of 45°; AE90: absolute angular error in the reconstruction of 90°; TCIR: Mean Concentric Peak Torque of Internal Rotators; TCER: Mean Concentric Peak Torque of External Rotators; TEIR: Mean Eccentric Peak Torque of Internal Rotators; TEER: Mean Eccentric Peak Torque of External Rotators*

***Table 3.*** Intervention effect in the three positions [Mean (SD)]

| | Variable | Pre-test | Post-test | *P*-value |
|---|---|---|---|---|
| | TCIR | 6.08 (17.91) | 4.75 (16.10) | 0.0005 |
| | TCER | 5.73 (14.47) | 4.57 (14.33) | 0.43 |
| | TEIR | 5.14 (16.70) | 4.33 (15.66) | 0.01 |
| **Control** | TEER | 6.12 (19.74) | 5.40 (17.62) | 0.0005 |
| | AE0 | 4/01 (2/28) | 3/00 (1/58) | 0.01 |
| | AE45 | 1.73 (4.28) | 1.75 (3.34) | 0.01 |
| | AE90 | 2.25 (4.34) | 1.99 (3.62) | 0.05 |
| | TCIR | 6.13 (17.12) | 5.30 (16.15) | 0.02 |
| **Push up with** | TCER | 5.43 (15.15) | 5.97 (15.06) | 0.43 |
| **straight** | TEIR | 4.63 (16.53) | 5.32 (16.05) | 0.13 |
| **elbow** | TEER | 6.79 (18.25) | 6.69 (17.13) | 0.02 |
| | AE0 | 2.15 (4.08) | 1.39 (2.45) | 0.000 |
| | AE45 | 2.18 (3.98) | 1.66 (3.01) | 0.002 |
| | AE90 | 2.21 (4.65) | 1.93 (3.03) | 0.000 |
| | TCIR | 5.43 (16.79) | 4.95 (16.58) | 0.36 |
| **Push up with** | TCER | 5.16 (14.27) | 4.87 (15.00) | 0.18 |
| **Semi-flexed** | TEIR | 5.09 (16.10) | 4.85 (15.10) | 0.02 |
| **elbow** | TEER | 4.43 (17.27) | 5.61 (17.33) | 0.46 |
| | AE0 | 2.40 (3.62) | 1.96 (2.79) | 0.000 |
| | AE45 | 2.07 (5.09) | 1.70 (3.20) | 0.002 |
| | AE90 | 2.27 (4.13 | 1.92 (2.87 | 0.000 |

*AE0: Absolute angular error in the reconstruction of 0°; AE45: absolute angular error in the reconstruction of 45°; AE90: absolute angular error in the reconstruction of 90°; TCIR: Mean Concentric Peak Torque of Internal Rotators; TCER: Mean Concentric Peak Torque of External Rotators; TEIR: Mean Eccentric Peak Torque of Internal Rotators; TEER: Mean Eccentric Peak Torque of External Rotators*

***Table 4.*** The percentage of the improvement of all variables in the three positions of control, Push up with straight elbow, and Push up with semi-flexed elbow [mean(SD)]

| Variable | Control | Push up with straight elbow | Push up with semi-flexed elbow |
|---|---|---|---|
| | Improvement percentage | Improvement percentage | Improvement percentage |
| TCIR | % 2.77 (7.83 ) | %2.18 (3.93) | %4.19 (1.60) |
| TCER | %32.58 (31.56) | %2.78 (0.14) | %23.27 (26.31) |
| TEIR | %2.42 (4.86) | %2.42 (3.30) | %2.71 (4.30) |
| TEER | %2.55 (7.79) | %3.71 (5.78) | %5.65 (1.75) |
| AE0 | %18.83 (12.19) | %14.11 (18.49) | %14 (14.90) |
| AE45 | %9.65 (9.27) | %13.01 (13.70) | 21.02 (16.28) |
| AE90 | %26.61 (11.78) | %8.79 (26.78) | %10.79 (17.12) |

*AE0: absolute angular error in the reconstruction of 0°; AE45: absolute angular error in the reconstruction of 45°; AE90: absolute angular error in the reconstruction of 90°; TCIR: Mean Concentric Peak Torque of Internal Rotators; TCER: Mean Concentric Peak Torque of External Rotators; TEIR: Mean Eccentric Peak Torque of Internal Rotators; TEER: Mean Eccentric Peak Torque of External Rotators*

## Discussion

**Isokinetic torques of Rotator Cuff**

The present study showed the decline of dynamic strength of internal rotators in both positions of push up with straight elbow and semi-flexed elbow. Considering the mean eccentric peak torque of IR, there was a significant difference between control position and push up with straight elbow (*P*=0.03) in which the decline in the strength of IR was significantly less in the push up with straight elbow position compared with that in the control position (3.30% and4.8%, respectively). There was no remarkable difference between the two vibration positions, either (*P*=0.1).

Considering the dynamic strength of ER, there was an insignificant increase in the mean peak torque of ER in the push up with semi-flexed elbow. In both control and push up with straight elbow positions, the dynamic strength of ER decreased. Comparing the findings between the three positions, a significant difference was observed among all positions in the mean concentric peak torque of ER among which the control position demonstrated the highest decrease in concentric strength of ER (31.56%) and push up with straight elbow position was more effective than push up with semi-flexed elbow position (0.14% and 26.31%, respectively).

Although the results of the present study revealed a reduction in isokinetic torques of IRs and ERs after WBV, which could be the consequence of the neuromuscular fatigue due to our long and tiring protocol, the decrease of strength for control group was more than that for the two vibration positions. This finding shows that vibration has had a positive affect on the participants of the current study by causing delay in muscle fatigue. In spite of our finding, some studies reported the negative influence of WBV in neuromuscular function of muscle. For example; de Roiter *et al.* suggested that WBV (five 60 s bouts of WBV) had no effect on the Maximal rate of isometric force rise of knee extensor muscles (13). But this study had no control group to compare the results with those of the vibration group. Likewise, Cochrane *et al.* reported no improvement in the maximal grip strength after 5-min of WBV(8). Overall, it seems that different training protocols, different vibration characteristics (vibration amplitude, vibration frequency, and the duration of vibration), various exercises on vibration platform, having or not having warm up and control group and different participants (healthy or patients, athlete or non-athlete, young or elderly) can probably explain the contradiction in the findings.

On the other hand, the insignificant increase in concentric and eccentric strength of ERs following WBV is the positive result of vibration on neuromuscular and biomechanical behavior of these muscles. Several studies have demonstrated the improvement of strength after one-session of WBV (3, 5, 19).

The exact mechanism through which acute vibration causes strength and power increase is yet to be fully elucidated. The current theory is that vibration has been shown to elicit a response known as 'Tonic Vibration Reflex' (TVR). The TVR involves activation of muscle spindles, mediation of the neural signal by Ia afferents, and activation of the muscle fibers via large α-motor neurons. It is also capable of causing an increasing recruitment of motor units by activation of muscle spindles and polysynaptic pathways which is seen as a temporary increase in the muscle activity (5, 6, 10, 12).

In the current study, there was no shoulder rotation in neither of the two push up positions. However, the results showed insignificant increase of external rotators muscle strength in push up with semi-flexed elbow position. It has been shown that among weight-bearing positions, the infraspinatus has relatively the most activity among other rotator cuff muscles due to its role as a compressor of the humeral head to stabilize the glenohumeral joint (20).

Although EMG activity of rotator cuff muscles were not measured in the present study, this greater activity of the infraspinatus as an external rotator of shoulder joint can partially explain the increase in the strength of this muscle group in push up with semi-flexed elbow position.

***Proprioception (Absolute angular error in repositioning test)***

The present study showed a significant improvement on shoulder proprioception in all control, push up with straight elbow, and semi-flexed elbow positions in all the three tested angles (0, 45, and 90 degrees), although with more significance in the experimental group. In terms of the difference among the three groups, the difference was only significant in 0° angle reconstruction between the control and push up with semi-flexed elbow positions. Both push up with straight elbow and semi-flexed elbow positions showed equally significant reduction in Absolute angular error.

The current study confirms the results of some preliminary studies in this area (14-16). The most important effect of vibration is stimulation of mechanoreceptors of skin and joint (15). During WBV, proprioceptive pathways are strongly stimulated (6). These extensive sensory stimulations cause more efficient use of the positive proprioceptive feedback loop and the increase in joint stability.

When comparing three positions, a significant difference was observed only when an internal rotation occurred during a movement from 45 degrees to 0 degree between control and push up with semi-flexed elbow positions. Although no rotation existed in the shoulder during semi-flexed elbow joint, it seems that the shoulder internal rotators were more stimulated in this position. Moreover, the horizontal position of dynamometer lever arm was set as the standard baseline on 0° which was near the end range of internal rotation. In this angle, passive agents have more significant role to stabilize the shoulder joint (21). Therefore, in reconstructing the 0 degree, relative to 45 and 90 degree angles, all the static and dynamic structures are responsible to cause proprioception improvement. Another possible mechanism is more involvement of this position (0 degree) relative to the internal/external positions during many ADL. This helps more immaculate and perfect angle reconstruction for the individuals.

The improvement of the prorioception in the shoulder joint in control group, where there was no intervention, could be attributed to the application of push up as a closed packed position. Myers *et al.* reported an improvement of the shoulder proprioception when a co-activation occurs in muscles surrounding the shoulder joint during a task, such as push up in the extended elbow (22).

Limitations in the present study, i.e. the small number of the participants of each group and the occurrence of muscle fatigue following a long test protocol, must be taken into account when generalizing the findings.

## Conclusion

Application of two-minute WBV had relatively stimulating effect on the neuromuscular system of young and healthy participants. The present study showed the decline of dynamic strength of rotator cuff muscles following WBV which was less in vibration positions compared with that in control position. Also, it seems that vibration has a greater impact on external rotators. Moreover, WBV showed to be effective enough to improve shoulder prorioception. However, no difference was found between two positions of the elbow joint during vibration exposure in the strength of rotator cuff and shoulder proprioception. Although being in the semi-flexed position of the elbow was somewhat annoying for some participants, no real pain or complication was observed in the current; even some participants described WBV as a pleasant and novel experience. Overall, in comparison with prorioception and closed-packed position shoulder exercises, the short-term training of WBV might increase the effects of traditional training on muscle strength and shoulder proprioception.

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