ORIGINAL ARTICLE

Acute effect of upper body vibration on shoulder joint internal and external active position sense in healthy female university students

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Abstract

Background and Study Aim Neuromuscular and joint deep sensation adaptations have been linked to functional alterations and skill acquisition after body vibration training via muscular recruitment, coordination of motor units, and enhanced neural activation. The aim of the current study is to explore the effect of upper body vibration on shoulder joint active position sense in healthy female university students.

Material and Methods Sixty healthy female university students were distributed into two equal groups; 30 subjects in the control group (mean age 21 ± 2.2) and 30 subjects in the experimental group (mean age 20.9 ± 2.3). The shoulder joint active position sense was evaluated using Biodex Isokinetic Dynamometer Multi-Joint System 4 pro. In addition, the Power Plate ® Whole Body Vibration device was used as an intervention method from the push-up position.

Results After three vibration exposures of 60 seconds for each, the MANOVA test showed statistically significant differences in the average error scores of active joint position senses of shoulder external rotation only in the pre-post-test of the experimental group (p= .000). Moreover, the statistically significant difference was detected in the average error scores of shoulders external rotation in post-treatment intervention between both groups (p= .000).

Conclusions These results suggested that short-term vibration training may reveal an improvement in shoulder joint active position sense, particularly the shoulder external rotation. The use of vibration training to improve shoulder awareness and reduce the risk of injury when the shoulder externally rotates during different functions may therefore be advocated to physiotherapists.

Keywords: isokinetic, vibration, joint, position, shoulder, rotation

Introduction

The scapula and humerus form the shallow ball-and-socket joint known as the glenohumeral joint. One of the most mobile joints in the body compromises joint stability by being so mobile [1]. Since there are no strong ligaments in the shoulder joint, it is a muscle-dependent joint [2] and it depends on proprioception and stabilization of the neuromuscular system more than any other joint inside the human body [1].

Due to the increased tension imposed on the joint during sports-related and work-related activities, the shoulder joint is one of the most prone to injury [3]. Shoulder external rotation and abduction are the most frequent high-risk positions for shoulder joint injuries in various sports, particularly in overhead throwing actions [4,5]. After shoulder joint injury, the internal proprioceptors signal of the joint will be affected; these receptors include the mechanoreceptors of the joint which are responsible for the sensorimotor input and active stability of the joint [6]. The overhead-throwing range at 90 degrees of shoulder abduction may research to 135 degrees from the scapular plane [7], and this range may increase in overhead-throwing athletes to reach 180 degrees due to shoulder joint adaptation [8,9]. Hyper-angulation happened during the overhead throwing shoulder motion. The overhead-throwing range is a critical range of shoulder injury that extended from the maximal shoulder external rotation to the beginning of internal rotation (from the arm cocking phase of the maximum external rotation to the follow-through phase). During the overhead throw's late cocking period, as the thrower's humerus extremely abducts horizontally, posterosuperior impingement of the shoulder joint may happen. To avoid this, the thrower must stay in the scapular plane motion [7].

Proprioception, or kinesthesia, is the sense that tends to detect internal sensory information including the joint position, movement, and location of different parts of the body in space [10, 11]. These senses arise from signals of sensory receptors in the joint, muscles, and skin. Proprioception detects the proper limb movements, heaviness, forces, and positions. Proprioception is closely related to the control of different body movements [10]. In

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addition, proprioception contributes to the motor planning for neuromuscular stability and control obligatory for static and dynamic joint stability and also donates to precision movements of the upper limbs [12].

Both fine movements and coordination of different joints inside the body as well as shoulder joint stability need fast and accurate sensory input from the proprioceptors of the shoulder joints and surrounding muscles [12]. Proprioception impairments would contribute to neuromuscular abnormalities and probable poor joint stability which may lead to a higher risk of injury [13]. Several previous studies confirmed that injuries to the neuromuscular system tend to alter proprioception and movement regulation, which causes movement variability and deficit in maintaining static posture [14, 15]. Therefore, the use of specific training planned to preserve and improve the functional stability and integrity of the shoulder joint is considered an important factor in most rehabilitation training processes.

In recent times, body vibration exercise has become progressively applied in sports rehabilitation and injury prevention as an effective neuromuscular exercise intervention. Body vibration is a procedure of management that has been shown to be an important element in improving neuromuscular integrity, gait mechanics, muscular power, balance, and quality of life [16]. A prior study proposes that body vibration training not only improves acute muscle strength and power abilities but also enhances proprioception [12, 17].

Numerous potential mechanisms for the acute effects of body vibration exercise have been proposed which involve neural adaptation. Acute vibration is associated with improved muscle stimulation of the muscle spindles caused by augmented sensory input [18]. According to the proposed theories of different mechanisms of acute body vibration exercise, it is expected that augmented neural activation and muscle stiffness produced by body vibration would improve not only the shoulder muscle function but also the shoulder joint proprioception [12, 19]. However, the shortage of standardization of acute vibration exercise protocols and the lack of studies focused on the acute vibration of upper extremities, make it hard to fully understand the fundamental mechanisms of the effect of acute vibration exercise on the upper extremity joints' proprioception [12, 20, 21].

Therefore, the purpose of this study was to examine the acute effects of upper body vibration on shoulder joint active position sense in young healthy female students. The null hypothesis stated that there is no significant effect of acute vibration training on active position sense (AJPS) of shoulder internal and external rotation.

Materials and Methods

Participants

The participants comprised sixty healthy female students distributed into two equal groups; 30 subjects in the control group (mean age= 21 ± 2.2, mean body mass= 55.8 ± 7.6, mean body height= 158 ± 5.1, mean BMI= 22.3 ± 2.2) and 30 subjects in the experimental group (mean age= 20.9 ± 2.3, mean body mass= 56.8 ± 8.3, mean body height= 157.2 ± 5.8, mean BMI= 22.9 ± 2.4). All subjects were selected from the College of Applied Medical Sciences, Jouf University. Each participant signed a consent form approved by the Local Committee of Bioethics of Jouf University (Approval No. 4-01-43) which was obligatory before the examination. The research process was clarified in detail for each subject included in the study prior to therapeutic intervention. The healthy female students must meet the following criteria for participation; all participants should be females, aged from 17-24 years, not engaged in specific physical activity, and their dominant upper limbs were included in the study. For the exclusion criteria, all participants shouldn't be pregnant at any stage; have no recent surgical history, or suffering from any musculoskeletal abnormalities such as shoulder laxity or abnormality, tennis elbow, golfer's elbow, carpal tunnel syndrome, rotator cuff tendinitis, or any other abnormalities that affect the upper extremity within 24 months of the conduction of the study. In addition, subjects who suffer from any degree of vestibular, equilibrium, and balance disturbances that affect the performance and joint proprioception of the dominant upper limb should be excluded. Moreover, all participants shouldn't take any kind of medications that affect the balance and concentration in the previous 24 hours before the examination.

Study design

In a cross-sectional study; a pre-test and post-test control group design was conducted to detect the acute effect of upper body vibration on the active joint position sense of shoulder external and internal rotation from the position of shoulder abduction 90 degrees. The three trials' average of absolute error values (difference between target angle and actual angle performed by a subject) for external and internal active joint position sense of shoulder joint was calculated by the Isokinetic Dynamometer device.

Instrumentation

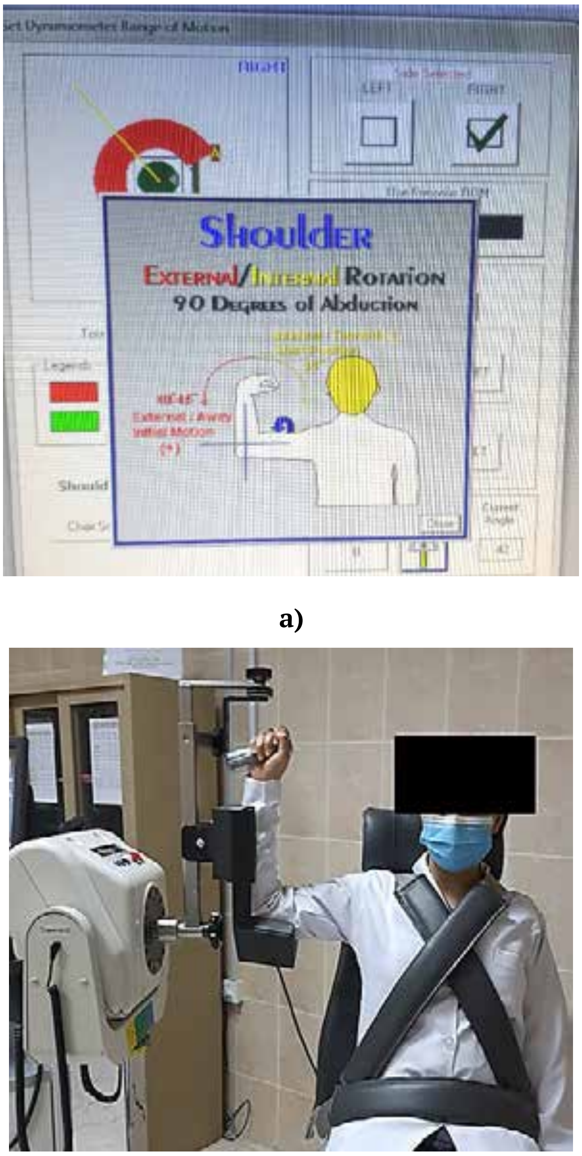
Active joint position sense (AJPS) of shoulder internal and external rotation from the position of shoulder abduction 90 degrees was evaluated using Biodex Isokinetic Dynamometer Multi-Joint System 4 pro (Biodex Medical System Inc, Shirley, NY, USA) with a low angular velocity of 60°/sec [22] as detected by the already present protocol in the device. The reliability of the Isokinetic Dynamometer was accepted as a standard referenced proprioception testing [23, 24]. On the other hand, good test-retest reliability for active joint position sense for the dominant limb with an inter-class correlation of 0.821 was confirmed by a study performed by Seven et al. [22]. Also, The Power Plate ® Pro7HCTM (Chicago, Germany) for upper body vibration was used for training between pretest and post-test measurements that were applied at 50 Hz frequency with 6 mm amplitude and applied three times (1 minute training period and 1 minute rest period between trials) [12].

Procedures

All the data were collected at the Physical Therapy Laboratory of All 256 healthy adult female students from the study settings were asked to participate and went through a screening procedure to determine their eligibility. A two-tailed test with a significance level of 0.05 and an assumption of 80% power was used to determine the necessary number of the sample (n=60). Blinding happened at the evaluation and data collection level. Using computer-generated random allocation cards (RANCODE®, IDV, Gauting, Germany) and a 1:1 allocation ratio, the participants were randomly assigned to the vibration and control groups. The two groups of 30 subjects each had subjects allocated to them, and the allocation concealment was done by using sealed opaque envelopes. As a result, the experimental group's thirty subjects got the vibration intervention and those subjects in the control group received the placebo intervention (The power plate was turned off while participants were instructed to adopt the experimental group's position).

The objective of the study was clearly explained to the participants, who were instructed first to perform warming up for at least 15 minutes in the form of static stretching and active exercises of the shoulder joint. Suitable clothes (not offering any restriction to shoulder joint motion) were ensured for the accuracy of measurements. A specific attachment was used which secured the subject's limb to the dynamometer. Before testing, each subject's maximal active external and internal rotation range of motion of the dominant shoulder was measured while seated in the chair of the dynamometer, with the shoulder in 90-degree abduction and elbow flexion 90-degree. The starting position or zero position (shoulder abduction 90 degrees, elbow flexed 90 degrees) and the target position (angle of 30 degrees external and -30 degrees internal rotation) of shoulder rotation were detected by Isokinetic software.

We used a joint position sense testing protocol, which is presented in studies Hong et al. and Janwantanakul et al. [12, 25]. The main provisions of this protocol include the following. Three successful trials were performed on the dominant limb after notifying subjects of the examination protocol of active joint position sense. To start the shoulder examination, each participant should be blindfolded while seated on the dynamometer, with her shoulder in a functional anatomical position in the frontal plane of motion (shoulder joint at 90° abduction, and elbow joint at 90° flexion with the forearm in mid-prone position). The shoulder and trunk position for each participant was secured and fastened to the dynamometer to avoid any substitution as shown in Figure 1.



a)

b)

Figure1. The examination starting position of active joint position sense (IR from 0 to -30 and ER from 0 to +30). a) Software instructions for shoulder internal/external rotation ranges from 90-degree shoulder abduction; b) participant's starting position of shoulder internal/external rotation ranges from 90-degree shoulder abduction

With the shoulder being maintained at 90° abduction, the elbow was flexed to 90° around the longitudinal axis of the humerus (at the scapular plane), The subject was then asked to actively move towards the maximum shoulder external rotation similar to the starting position of throwing a baseball till stopped by a dynamometer at the target angle of 30 degrees shoulder external rotation. The target position was maintained for 10 seconds with subjects verbally instructed to "focus on the position of their shoulder". The arm was then actively returned to the starting position (shoulder abduction 90 degrees, and elbow flexed 90 degrees) as shown in the Figure 1. Subjects were instructed to rotate their arms to identify the target angle and press the dynamometer's hand-held cutoff switch to stop the dynamometer instantly when they perceived that the target position had been reached. Lastly, the shoulder was returned to the starting position (shoulder abduction 90 degrees, and elbow flexed 90 degrees), then the subject was asked to actively move toward internal rotation while the arm was maintained at 90° abduction with an elbow angle of 90° flexion till stopped by a dynamometer at the target angle of -30 degrees shoulder internal rotation. The target position was maintained for 10 seconds with subjects verbally instructed to "focus on the position of their shoulder." The arm was then actively returned to the starting position (shoulder abduction 90 degrees, elbow flexed 90 degrees). Subjects were instructed to rotate their arms to identify the target angle and press the dynamometer's hand-held cutoff switch to stop the dynamometer instantly when they perceived that the target position had been reached.

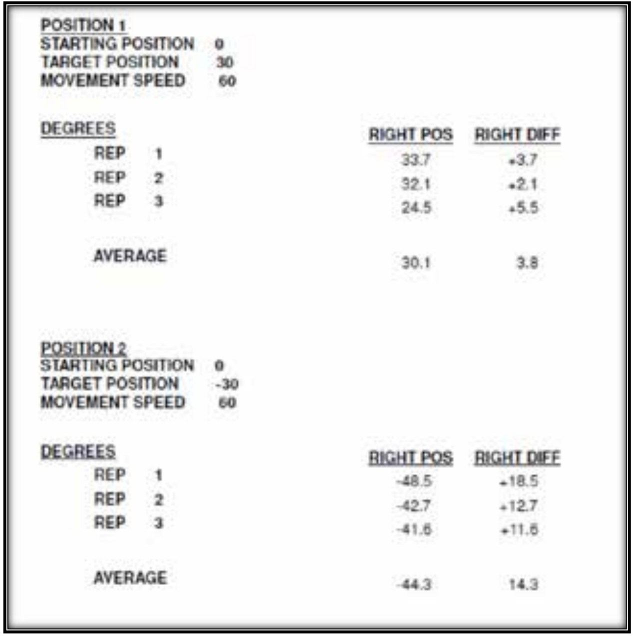
Three trials were performed for internal rotation and three trials were conducted for external rotation (A total of 6 successful trials were performed on the same shoulder joint). A rest period of 5 seconds was maintained between trials for each direction (internal rotation and external rotation) to control for bias caused by learning and/or testing effects and 10 seconds rest period was provided by the device before the transmission from the external rotation to internal rotation trials. The joint angle at which the participant stopped was documented and subtracted from the target angle.

Once baseline testing had been completed, participants were instructed to place their arms shoulder-width apart on the vibration platform in a plank position, with their feet shoulder-width apart on the ground [12]. The investigator demonstrated the correct position to prevent participants from arching their backs or raising their gluteal region as much as possible (Figure 2). Participants were instructed to hold this position for 1 minute for three sets, with one-minute rest in between to prevent fatigue. Those in the experimental group received vertical vibration at 6 mm amplitude and 50 Hz frequency.

Figure 2. Vibration training position (push-up position).

This approach is based on the recommendations of Aman et al. [26]. The authors showed that applying vibration at frequencies higher than 30 Hz for longer periods of time improved joint position sense, with an average improvement of 48%.

After the vibration intervention, the same testing protocol from baseline testing was applied and the average of the absolute value of the 3 errors in each joint movement was calculated by the software of the device for statistical analysis as shown in Figure 3, then the differences between the results were analyzed. The participant in the control group underwent the identical vibration routine, but the vibration platform was turned off (placebo intervention).



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POSITION 1
STARTING POSITION   0
TARGET POSITION     30
MOVEMENT SPEED      60

DEGREES                              RIGHT POS   RIGHT DIFF
        REP    1                       33.7        +3.7
        REP    2                       32.1        +2.1
        REP    3                       24.5        +5.5

        AVERAGE                        30.1         3.8


POSITION 2
STARTING POSITION   0
TARGET POSITION     -30
MOVEMENT SPEED      60

DEGREES                              RIGHT POS   RIGHT DIFF
        REP    1                      -48.5        +18.5
        REP    2                      -42.7        +12.7
        REP    3                      -41.6        +11.6

        AVERAGE                       -44.3         14.3
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Figure 3. The average of the absolute value of the 3 error scores in each joint movement direction.

Data Reduction and Analysis

The angle at which the subject stopped was recorded and subtracted from the initial preset angle. An average of the absolute value of the 3 errors for each movement direction (internal and external rotations) was used for statistical analysis. Statistical Package for Social Sciences (SPSS) version 20.0 was used. The exploration of data was performed as a preliminary check to certify data normality in each group using the Shapiro-Wilk test. Descriptive statistics were conducted to detect the mean and stander deviations (SD) of each variable of interest. The paired sample *t*-test was used to identify the mean differences in demographic data, while the Multiple Analysis of Variance (MANOVA) was conducted to compare the experimental and control groups in pre-post vibration effect on the average of the absolute value of the 3 error scores of shoulders' internal and external active joint position sense. Also, the effect size (r) (Cohen's d) was calculated to find out the magnitude of change in the mean score of an outcome measure from one-time point to another. Besides, the standard deviation (SD) approach is a distribution-based method used to calculate the minimum clinically significant difference (MCID) in shoulders' internal and external active joint position sense measurements. All statistical analyses were performed at a 5% significance level.

Results

The means and standard deviations of demographic data are shown in Table 1. Preliminary checks were conducted and the Shapiro-Wilk test confirms the normality of distribution ($p > 0.05$). In addition, Levene's test for equality of variances showed no violation of the assumptions of normality and homogeneity of variances ($p > 0.05$). The Independent *t*-test showed no statistically significant differences between experimental and control groups in age, body mass, height, and BMI ($p > 0.05$) as shown in Table 1.

The means and SD of all variables of interest are demonstrated in Table 2. The MANOVA test, within groups, showed no statistically significant differences between the pre-test and post-test of active joint position sense for shoulder internal rotation in both experimental and control groups (p=0.113 and p= 0.856 respectively), with no clinically significant difference observed in the internal rotation active joint position sense between pre- post-intervention stage in the control group with a none or negligible effect size (r= 0.046), while moderate clinically significant difference was observed in the internal rotation active joint position sense between pre- post-intervention stage in the experimental group (r= 0.414). On the other hand, a statistically significant difference was detected between the pre-test and post-test of active joint position sense for shoulder external rotation in the experimental group (p= 0.000) rather than the control group (p= 0.849) with a strong clinically significant difference in the experimental group (r= 0.903) and negligible clinical effect in the control group (r=0.056). In between group comparison, pre-assessment of active joint position sense showed no statistically significant difference in shoulder joint internal and external active position sense between experimental and control groups (p=0.864 and p= 0.622 respectively) with a none or negligible effect size (r= 0.043 and 0.132 respectively). On the other hand, post-assessment of active joint position sense showed no significant difference in shoulder joint internal rotation (p=0.116) with moderate effect size (r= 0.434) and significant difference in shoulder external rotation (p=0.000) with strong clinically significant difference (r= 1.098) between control and experimental groups as shown in Table 2.

Discussion

The main aim of the current study is to detect the acute effect of upper body vibration on the active joint position sense of shoulder internal and external rotation in healthy female students. The crucial range of shoulder injury that was chosen for examination ranged from the maximum range of shoulder external rotation to the start of internal rotation, much as the arm cocking phase of the maximum external rotation to the follow-through phase in throwing sports. The results of the current study showed improvement in the average error scores of active joint position senses of the shoulder

Table 1. Independent t-test for participants anthropometric data.

Variables	**The experimental group (n=30) X̄ ± SD**	**The control group (n=30) X̄ ± SD**	***t*-value**	***p*-value**
Age, years (years)	20.9 ± 2.3	21 ± 2.2	0.262	0.794
Body mass (kg)	56.8 ± 8.3	55.8 ± 7.6	-0.494	0.623
Height (cm)	157.2 ± 5.8	158 ± 5.1	0.603	0.549
BMI (kg/cm^2)	22.9 ± 2.4	22.3 ± 2.2	-1.065	0.291

Note: BMI= Body Mass Index. *Significant level at p-value<0.05.

Table 2. MANOVA test for shoulder internal and external active joint position sense within and between two tested groups.

Descriptive statistics

Measured variables	The experimental group (n=30)				The control group (n=30)			
	Pre $\bar{X}$ ± SD	Post $\bar{X}$ ± SD	95% CI of Difference		Pre $\bar{X}$ ± SD	Post $\bar{X}$ ± SD	95% CI of Difference	
			Lower	Upper			Lower	Upper
IR active joint position sense (°)	6.01 ± 2.64	4.96 ± 2.43	-0.25	2.35	6.12 ± 2.50	6 ± 2.63	-1.18	1.42
ER active joint position sense (°)	6.73 ± 2.16	4.62 ± 2.50	1	3.22	7 ± 1.94	7.11 ± 2	-1.21	1

Inferential statistics within groups

Measured variables	Pre-testing vs. Post-testing	
	The experimental group (n=30) F-value (p-value)	The control group (n=30) F-value (p-value)
IR active joint position sense (°)	2.54 (p= 0.113)	0.033 (p= 0.856)
ER active joint position sense (°)	14.24 (p= 0.000*)	0.036 (p= 0.849)

Experimental Group vs. Control Group *(p-value)*

Groups	IR active joint position sense						ER active joint position sense					
	Pre	95% CI of Difference		Post	95% CI of Difference		Pre	95% CI of Difference		Post	95% CI of Difference	
		lower	Upper		lower	Upper		lower	Upper		lower	Upper
Experimental Group vs. Control Group	p= 0.864	-1.19	1.42	p=0.116	-0.261	2.35	p=0.622	-0.831	1.38	p=0.000*	1.39	3.60

Note: IR= Internal Rotation; ER= External Rotation *Significant level at p-value<0.05

external (30 degrees) and internal rotation (-30 degrees) of the experimental group in comparison with the control group after vibration exposure. Although the significant difference was only detected in the active joint position sense of shoulder external rotation rather than shoulder internal rotation in the experimental group. This finding indicates improvement of external rotation active joint position sense after vibration training (three sets of one-minute vibration of 50 Hz frequency and 6 mm amplitude). These results may be attributed to the effect of vibration in improving neuromuscular excitability and increasing the compression stress on the joint surfaces. This compression stress from muscle contraction may stimulate the joint receptors and improve the joint position sense [2]. Theoretically, the effect of vibration produces more excitability to the afferent nerve fiber from the muscle spindles that became more delicate to stretch and increases the initiation of alpha motor neurons in response. This reaction may lead to augmented motor unit stimulation, increased firing frequency, and/or improved muscular contraction [27].

The study conducted by Hong et al. [12] showed statistically significant improvements in the shoulder internal and external rotation peak torque and internal rotation time to peak torque after three bouts of upper body vibration. Also, there were improvements in active joint position senses but without any significant differences. This finding may be attributed to the use of low-frequency vibration (30Hz) with low amplitude (5mm).

The study performed by Fontana et al. [17] detected that the body vibration was able to improve the repositioning accuracy of the lumbosacral joint when associated with weight-bearing exercises due to improvement in the joint proprioception and muscle function. Another experimental study conducted by Tripp et al. [28] stated that only 15 Hz vibration improved accuracy and decreased errors of elbow joint sense of position. Regarding the results of this study, the authors indicated that vibration tends to enhance sensorimotor system stimulation with more afferent feedback that may improve joint position sense. In addition, vibration tends to enhance joint stiffness by the stimulation of gamma efferent and mechanoreceptors that are closely associated with enhanced active and passive joint position senses [17]. The justification for no significant difference in active joint position sense of shoulder internal rotation rather than external rotation was confirmed by a study conducted by Hong et al. [12] and Hadzic et al. [29]. This study indicated the importance of shoulder external rotation eccentric strength, which is difficult to control, in providing more balance to the dominant shoulder for throwing range and detecting the functional capabilities of the shoulder joint. This may return to internal rotation may be more commonly used for activities of daily living and also that much of the training practice targets internal rotation for athletes (e.g., push-ups, bench press, etc.), which in turn may lead to better motor control of that movement needs internal rotation [12]. The authors also highlight a significant improvement in shoulder external rotation compared to internal rotation [12, 29]. This difference can be attributed to the limited range of motion in external rotation, particularly when the shoulder is abducted at 90 degrees, as it approaches its endpoint. In contrast, internal rotation involves a broader range of motion, leading to increased awareness of joint positioning among the subjects. This indicated the significant improvement of active position sense of shoulder external rotation after vibration exposure rather than the internal rotation range which may easily be controlled by the examiner before the vibration exposure.

Like any other research work, our research has some limitations. A small sample size may hinder the generalization of the results. The current study focused only on the active joint position sense in certain ranges without any attention to any other shoulder ranges. The sample is only from female students and didn't include any male subjects which did not consider the gender differences. Also, the current study investigates the effect of acute vibration rather than the long-term effect of vibration which needs further exploration. Future research should include the study of muscular activity and muscle peak torque in combination with vibration training in multiple angles to better investigate the effect of vibration on all structures that surround the joint. It is also recommended to perform this kind of study on patients with shoulder pathology to detect any implication of vibration exercise training as a treatment tool.

Conclusions

In conclusion, the results of the current study indicate the positive effect of upper body vibration (UBV) in improving the active position sense of shoulder external rotation. This implies the significance of incorporating upper body vibration training into shoulder training and rehabilitation in order to enhance the active joint position sense and raise awareness of shoulder joint motion in order to avoid any kind of injuries. Further effort in research work is needed to explore other joint mechanisms such as muscle torque and active joint position sense from different shoulder joint angles that may lie beneath the physiological reactions and adaptation to UBV, and how these reactions may occur among persons with shoulder joint injuries and abnormal neuromuscular function.

Highlight

- The upper body vibration may help improve shoulder joint active reposition sense, particularly in external rotation.
- Shoulder injuries may be avoided by having a strong active joint reposition sense.
- Kinesthetic sense is the major factor that influences the improvement of shoulder stability and function.

Acknowledgment

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Conflict of Interest

No potential conflict of interest with any financial party regarding the material used or discussed in the manuscript was stated by the authors.

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