The acute effects of vibratory stimuli during exercise on the sensorimotor control of the shoulder complex: A pilot study

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ABSTRACT:

BACKGROUND: Functional stability of the shoulder requires a balance of active forces, passive forces, and control subsystems of the joint complex. Although whole-body vibration enhances shoulder muscle function and proprioception, the impact of vibration on the sensorimotor control of the shoulder joint remains unclear.

OBJECTIVE: To investigate the acute effect of vibratory stimuli on the sensorimotor control of the shoulder joint.

METHODS: Fifteen male participants (age, 22.7±2.3 years) were included and performed the exercise in a modified push-up position with partial weight-bearing on a vibration platform with and without vibratory stimuli. The vibration protocol included six sets lasting for 30 s each with a 30-s rest between sets. The main outcome measures included the upper limb static stability test, Upper Quarter Y Balance Test (UQYBT), and electromyography data of the upper limb.

RESULTS: Vibratory stimuli resulted in an increased UQYBT score (all directions; $P<0.01$) and infraspinatus, serratus anterior, and lower trapezius muscle activity ($P<0.05$) between pre- and post-exercise versus the control condition. Stabilometric parameters showed no significant interaction between condition and time.

CONCLUSIONS: Vibratory stimuli could maximize training benefits while limiting injury risk for athletes. Our findings could guide the development of rehabilitation programs for patients with shoulder instability.

Keywords: electromyography; joint instability; sensorimotor control; shoulder joint; shoulder stability; vibratory stimuli

1. INTRODUCTION

The glenohumeral joint has relatively poor osseous and capsuloligamentous stability and requires more reliance on stabilization and neuromuscular proprioception than any other joint in the human body [1]. Both the dynamic stability of the shoulder joint and the fine coordination of the multi-joint motion sequence require rapid and accurate afferent input from receptors around the shoulder joint and the muscles involved. The functional stability of the shoulders requires an exquisite balance of active and passive forces developed by the muscle and joint structures, respectively, and is regulated by the sensorimotor control system of the shoulder [2-4]. The sensorimotor control is expressed as static and dynamic stability and can be evaluated in detail by measuring the associated muscle activity [5]. Physical therapy for patients with shoulder instability aims to strengthen the rotator cuff to maximize the concavity-compression mechanism and stabilize the scapula, thus stabilizing the glenoid platform [6]. Thus, the use of exercises designed to maintain and enhance the integrity and functional stability of the shoulder joint is considered an important component of the training process for most training and rehabilitation programs.

Maximizing the benefits of training is an important concept. Recently, the interest concerning the use of vibrating platforms to increase muscle activation during training and rehabilitation for high-level throwing athletes has increased. The potential effect of vibration has been demonstrated primarily in the lower limbs [7,8], with few studies evaluating the upper limbs [9]. Whole-body vibration (WBV) improves neuromuscular performance by inducing involuntary reflex contractions via the tonic vibration reflex [10,11]. The oscillatory motion during WBV induces length changes in muscle groups, resulting in stimulation of the primary endings of the muscle spindle receptors; this leads to reflex contractions. Adding these reflex contractions to voluntary skeletal muscle activation improves neuromuscular performance [12,13]. Healthy proprioceptive, neuromuscular, and musculoskeletal systems are necessary to drive the relevant sensory information to the central nervous system and produce adequate motor responses, which could cause shoulder stability and coordinated movement patterns. Based on the theoretical mechanisms of vibration training proposed by the abovementioned studies, WBV induced in neural drive and muscle stiffness likely enhances shoulder muscle function and proprioception. However, previous studies on the upper limb and vibration stimuli have focused on scapular muscles and have not examined the effects on rotator cuff muscles and sensorimotor control.

Therefore, we aimed to investigate the acute effect of vibratory stimuli on muscle function and sensorimotor control of the shoulder joint in young healthy participants. We hypothesized that muscle activation and sensorimotor control of the shoulder joint would increase following acute exposure to vibration as an adjunct to exercise.

2. MATERIALS AND METHODS

2.1 Design

This was an observational laboratory-based cross-over trial. Each participant underwent each intervention in a random order.

The participants were randomly assigned to vibration (vibration condition) and no vibration (control condition) groups. For randomization, sealed envelopes were prepared in advance and marked inside with A or B representing vibration and no vibration, respectively. This randomization was performed by a third party unaware of the nature of the study.

2.2 Participants

Fifteen healthy male volunteers (mean±standard deviation: age, 22.7±2.3 years; height, 1.71±0.05 m; weight, 64.4±9.0 kg), recruited from the student population, participated in the study. The exclusion criteria for participation in the study were a history of cervical spine and shoulder injury or surgery, participation in overhead sports at a competitive level, and upper limb strength training for >5 h per week. The inclusion and exclusion criteria were assessed with a questionnaire by physical therapists who had 8 years of experience. The non-dominant arm was tested of all participants. All participants agreed to the purpose of the study and signed an informed consent form before participating in the experiment. The study protocol was approved by the Ethics

Committee of the Graduate School of Health Sciences, Hiroshima University (E-2038) in accordance with the tenets of the Helsinki Declaration.

2.3 Intervention

We used a Sonic Wave Vibration System (SW-VM10, Sonic World, Co., Ltd, Wonju-si, Korea) that was covered with a 25-mm thick, soft mat provided by the manufacturer for the exercises. This equipment uses electromagnetic technology and a speaker mechanism to generate precise vertical vibrations. The platform vibrated continuously at a frequency of 50 Hz [14] and an amplitude of 4 mm (peak acceleration of 15.7 m/s^2 and a g-force of 1.6 G) [15]. Each participant performed the exercise in a modified push-up position with partial weight-bearing with and without vibratory stimuli (i.e., the two conditions). They pressed their hands firmly against the middle of the vibration platform, shoulder-width apart, and elbows extended (Figure 1). The vibration protocol included six sets lasting for 30 s each, with a 30-s rest between sets. Between each set, the volunteers remained in the prone position without making contact with the platform.

2.4 Procedures

All participants underwent a sensorimotor control assessment of both the static and dynamic stability tests before and after each exercise task with and without vibratory stimuli. The participants were randomly assigned to vibration (vibration condition) and no vibration (control condition) groups. For randomization, sealed envelopes were prepared in advance and marked inside with A or B representing vibration and no vibration, respectively. This randomization was performed by a third party unaware of the nature of the study. The same examiner who was blinded to the data analysis performed all the procedures. To eliminate the carryover effects, all participants performed the exercise task after at least 1 week of rest between each exercise task condition, as in the previous study. No participants experienced pain or discomfort during the test sessions and stopped the assessment or complained of difficulty when performing the test.

2.5 Static stability of the upper limb

Assessment of the sensorimotor control of the shoulder with the force plate is a feasible and reliable tool [16]. It was previously used for people with recurrent anterior shoulder instability [17]. The stabilometric parameters of the upper limb were recorded using a force plate (AccuGait, AMTI, Hiratsuka, Japan). Signal processing was accomplished at a 200-Hz sampling frequency via an analog-to-digital converter. Following the procedure described previously, the participants were in a prone, upper extremity weight-bearing position with the lower extremities resting on an adjustable-height therapeutic bed from the anterior superior iliac spine downward (Figure 2) [16,17].

They placed their hands on the force plate, and to maintain upper limb of flexion at 90° to the ground and shoulder flexion of 90°, the height of the therapeutic bed was appropriately adjusted. Both hands were placed precisely on the force plate with reference to the transverse (X) and sagittal plane (Y) axes with 4 cm between each wrist and fingers of each hand pressed together. The wrists were dorsiflexed at 90° and placed on the force plate with the elbows in full extension. The participants were instructed to remain as still as possible during testing, keep their head in a neutral position relative to the axis of the trunk, and focus on a fixed visual reference on the force plate. A 30-s familiarization period with eyes open and supported by both hands was performed before each test. The test was performed under two conditions in a random order: 1) bilateral hand support with open eyes (OE) and 2) with closed eyes (CE). The recordings started 5 s after the participant attained the correct test posture and lasted for 25 s. The participants had a 60-s rest period between trials to avoid fatigue. Among the complete set of stabilometric parameters recorded by the force plate, we considered only the total displacement of the center of pressure (CoP-L, in mm) and the mean instantaneous CoP velocity (CoP-V, in $mm \cdot s^{-1}$). These parameters have been confirmed as the most reliable and related to the sensorimotor activity, which was needed to maintain static stability. Lower values of the parameters indicate greater stability and better sensorimotor control and vice versa [17]. For the stabilometric parameters, the "influence of vision index" was calculated using the following equation (Equation 1) to quantify the effect of eye closure:

Influence of vision index=100 × (CE-value – OE-value)/OE-value (Equation 1).

2.6 Dynamic stability of the upper limb

We assessed dynamic shoulder stability using the Upper Quarter Y Balance Test (UQYBT). This test examines the balance, proprioception, strength, and mobility of the shoulder [18,19]. A previous study on the UQYBT reported that there were no differences between the dominant and non-dominant shoulders in healthy baseball and softball players as well as in non-competitive healthy people [20]. The UQYBT was performed with the use of the "Test Kit" (Perform Better Japan, Tokyo, Japan), following the procedure described previously [21]. Prior to the test, we measured the upper limb length of each participant with the participant standing with his feet together and the shoulders abducted 90° in the frontal plane. The distance between the spinous process of the seventh cervical vertebrae and the tip of the right middle finger was measured with a cloth tape in this position. The starting position for the test was a plank position with three points of support comprising both lower limbs placed shoulder-width apart (one hand and two feet, with both feet ≤ 30 cm apart) and the thumb of the supporting upper limb placed in contact with the index finger. The blocks of the test kit were pushed out as far as possible from the supporting upper limb in three directions (medial, superior-lateral, and inferior-lateral) while maintaining the plank position; each block was left in position after being pushed away, and the arm was returned to the starting position to perform the next action (Figure 3). The participants performed three trials with the non-dominant limb as the supporting upper limb, and the average distance was recorded and normalized for the limb length. The test was repeated when balance could not be maintained at the three points (the supportive upper limb and both lower limbs), when the left hand was separated from the block such as by pushing the block hard during the reach motion, or when the reaching upper limb made contact with the floor when returning to the starting point after the reach motion.

2.7 Electromyography

The raw surface electromyography (EMG) data were collected at a sampling rate of 1000 Hz using Personal-EMG plus (Oisaka Electronic Equipment, Hiroshima, Japan) during the UQYBT. This unit provides differential signal amplification (1000×) and bandpass filtering of 10–200 Hz. After the skin was prepared by shaving and scrubbing the area with alcohol pads, bipolar Ag-AgCL surface electrodes with sensor areas of 13.2 mm^2 were placed over the upper and lower trapezius, serratus anterior, posterior deltoid, and infraspinatus muscles on the supportive upper limb of the non-dominant side according to the recommended procedure [22]. The electrodes were applied to the skin in a direction that was parallel to the muscle fibers, and the inter-electrode distance was 2.5 cm. A grounding electrode was placed over the ipsilateral clavicle. For all trials of the UQYBT, EMG data were recorded from the beginning of the movement to the furthest reach point [23]. The point of maximum reach indicated the end of the phase. For analysis, the rectified EMG was averaged over the phase that extended from the beginning of the movement to the end reach point. Upon completion of all trials, the maximal muscle activity was measured during a 5-s maximum voluntary isometric contraction (MVIC) against manual resistance [24]. The maximum EMG value recorded for each muscle during the MVIC tests was used as the reference value to normalize the data for that muscle during analysis.

2.8 Statistical analysis

The Shapiro–Wilk test was conducted to examine the normality. We determined the effects of the intervention on all the outcome measures using two-way repeated-measures analysis of variance (ANOVA) with the conditions (vibration, control) and time (pre-exercise, post-exercise) as inter-participant and intra-participant factors, respectively. When interaction effects were detected, we performed post hoc comparisons using a paired t-test to test the differences in stabilometric parameters, shoulder dynamic stability, and muscle activity of the shoulder muscles between pre- and post-exercise in each condition. Moreover, we performed a paired t-test to compare the change of rate [%] in the stabilometric parameters, UQYBT score, and muscle activity of the shoulder muscles. A post hoc power analysis was performed to calculate the statistical power for the primary outcome using G*Power 3.1.9.2 (Universität Düsseldorf, Düsseldorf, Germany). P-values < 0.05 were considered to indicate statistical significance. Partial η^2 (ηp^2) was reported as a measure of effect size. Data analysis was performed using SPSS version 21.0 software for Windows (IBM Corp., Armonk, NY).

3. RESULTS

3.1 Upper limb static stability

No significant interaction in stabilometric parameters between condition and time were observed (F=0.006, P=0.94 for CoP-V with OE; F=1.092, P=0.315 for CoP-V velocity with CE) (Table 1). Moreover, the "influence of vision index" also showed no significant interaction between condition and time (F=0.881, P=0.365 for CoP-V; Table 1).

3.2 Upper limb dynamic stability

The reach motion in all directions of the UQYBT showed a significant interaction between condition and time (F=21.404, P=0.000, ηp^2=0.605 for the medial reach;

F=12.049, P=0.004, ηp^2=0.463 for the superior-lateral reach; F=13.583, P=0.002, ηp^2=0.492 for the inferior-lateral reach). The post-exercise UQYBT under the vibration conditions showed significantly greater medial (P=0.04), superior-lateral (P=0.003), and inferior-lateral (P=0.02) reach and composite score (P=0.0001) than the pre-exercise UQYBT (Table 2). Under the control condition, the post-exercise UQYBT showed significantly lower medial reach (P=0.017), laterosuperior reach (P=0.002) and composite score (P=0.002) than the pre-exercise UQYBT. The post hoc power analysis showed a power of 99.2% with an effect size (η^2) of 0.609 for the primary outcome (composite UQYBT score).

3.3 Shoulder muscle EMG

The outcome measures of shoulder muscle activity are presented in Table 3. The two-way repeated-measures ANOVA for the infraspinatus muscle during the reach motion of the UQYBT revealed a significant interaction between condition and time (F=6.294, P=0.025, ηp^2=0.310 for the medial reach; F=4.869, P=0.045, ηp^2=0.258 for the superior-lateral reach; F=7.655, P=0.015, ηp^2=0.353 for the inferior-lateral reach). Moreover, for the posterior deltoid muscles, serratus anterior and lower trapezius muscles during the reach motion of the UQYBT, we also found significant interactions between condition and time (F=7.134, P=0.018, ηp^2=0.338; F=6.944, P=0.02, ηp^2=0.332; F=6.109, P=0.027, ηp^2=0.304 for the medial reach, respectively).

3.4 The change of rate in the stabilometric test, UQYBR score, and muscle activity between the 0-Hz and 50-Hz conditions

Table 4 shows the change of rate in the stabilometric test, UQYBR score, and muscle activity between the 0-Hz and 50-Hz conditions. The UQYBT results were significantly improved in the 50-Hz than in the 0-Hz condition. Concerning muscle activities, the infraspinatus was significantly more activated in all directions during the UQYBT in the 50-Hz than in the 0-Hz condition; the posterior deltoid was activated more in the medial direction during the UQYBT in the 50-Hz than in the 0-Hz condition.

4. DISCUSSION

One of the main goals of this study was to clarify the acute effect of vibratory stimuli on the muscle function and sensorimotor control of the shoulder joint. Our results indicated that vibratory stimulus to the upper limb increased its dynamic stability, suggesting that it influenced shoulder sensorimotor control. A previous study reported significantly lower UQYBT scores in all directions in athletes with ongoing shoulder pathologies than in healthy control athletes [25]. Moreover, individuals with a history of acute or overuse shoulder injuries reportedly have a sensorimotor control deficit [17]. In this study, the use of vibratory stimuli resulted in increased dynamic stability of the shoulder joint, as evidenced by the UQYBT outcomes in all directions. To perform the reach motion of the UQYBT, it is necessary to control the transverse plane external flexion torque induced by gravity acting on the shoulder that supports the body's weight. Moreover, our findings suggested that vibratory stimuli could lead to significant changes in the muscle activity involved in stabilizing the glenohumeral joint and scapula.

To properly clarify the effect of vibratory stimulation on the sensorimotor control of the shoulder joint, we used a modified push-up position with partial weight-bearing that eliminates the effects of the pelvis and lower limbs on the intervention task. A vibrating platform transfers energy to the whole body or a specific body part [26]. A more recent study reported that muscle tuning and alterations in the central motor command had a role in governing the increased muscle activity, which was presented in response to vibratory stimuli [26]. Grant et al. reported that the use of vibration as an adjunct to exercise provokes a near-global increase in the shoulder muscle activation level [27]. Vibration selectively activates the primary terminations of the muscle spindle (i.e., the Ia afferent fibers) [28]. Continuous vibration decreases the movement-related afferent input through a "busy-line" phenomenon and decreases the excitability of the monosynaptic reflex, through presynaptic inhibition and homosynaptic depression of Ia afferents [29]. The EMG analysis results revealed that the vibration group experienced increased EMG activity during the UQYBT in the infraspinatus, serratus anterior, and lower trapezius muscles when compared with their pre-intervention state. In particular, this study showed increased muscle activity of the infraspinatus muscle in all directions after vibration. Along with the other rotator cuff muscles, the infraspinatus muscle contributes significantly to the compressive forces at the glenohumeral joint and performs the fundamental function of being a static and dynamic stabilizer of the glenohumeral joint [29]. Regarding dynamic stability in the shoulder joint, athletes with isolated infraspinatus muscle atrophy consistently demonstrated significantly lower UQYBT scores than those with contralateral shoulders and healthy athletes [5]. This result suggested that vibratory stimulation of the upper limb in the modified push-up position increases the muscle activity of the infraspinatus muscle and leads to improvement in the dynamic stability of the shoulder joint. A demanding task like the UQYBT requires improvement in the stability of the scapula–thoracic joint by increasing muscle cooperation [30]. Upon identification of scapular dyskinesis and its relationship with muscle imbalance, it is possible to suggest strategies for training the scapular stabilizing muscles, especially the serratus anterior and lower trapezius muscles [31]. Therefore, some works have suggested that rehabilitation of the scapula stabilizers is a process that needs a logical progression of exercises focused on strengthening the lower trapezius and serratus anterior muscles while minimizing upper trapezius activation [32,33]. A possible explanation for our findings is that the dynamic stability of the shoulder joint was improved by vibratory stimuli because of increased muscle activity in the rotator cuff muscles and in the serratus anterior and lower trapezius muscles, which are also required for scapular stabilization.

In contrast, static stability presented with no change before and after the intervention. The results may indicate that in this study, vibratory stimuli had no effect on static stability but was effective in improving the dynamic stability of the upper limb. In addition, the results of a previous study showed that sensorimotor control deficiency, as confirmed using the static stability test, was associated with recurrent anterior shoulder instability, especially in patients with a shoulder pathology on their dominant side [17]. It is conceivable that the static stability results might not have changed because our study participants were healthy men without shoulder pathology history.

The major limitations of this study were its small sample size and the focus on the acute effect of vibration only. However, this preliminary study aimed to determine the effectiveness of our training and vibratory stimuli on the upper limb. Future larger studies are needed to investigate the long-term effects of training with vibratory stimuli on sensorimotor control and physical performance. Another limitation of this study was that only the UQYBT was used to assess the dynamic stability of the shoulder joint. Several other measures could have been used, such as the one-arm hop test and the closed kinetic chain upper extremity stability test that were used to evaluate dynamic stability in previous studies [34,35]. However, the UQYBT is considered a reliable test for measuring upper extremity reach distance while in a closed-chain position at the limits of overall upper-body stability [36]. Finally, in this study, the frequency of the vibratory stimulus was 50 Hz. The optimal frequency of vibrations was unclear. Further studies are required to investigate the effects of different frequencies on the sensorimotor control of the shoulder.

Considering the aforementioned findings, vibration used as an adjunct to upper limb exercises increased infraspinatus, serratus anterior, and lower trapezius muscle activities, which helped stabilize the shoulder joint and improve motor control. This result occurred because of α-motor neuron mobilization increase during vibration stimulus, neuromuscular control, global muscle strengthening, and proprioception feedback [37].

Rehabilitation programs, such as the use of vibration as an adjunct to upper limb exercises, showed more improvement and should be considered when clinically choosing a shoulder disease rehabilitation program in the future.

5. CONCLUSIONS

To our knowledge, this is the first study to examine the effects of vibratory stimuli on the sensorimotor control of the shoulder joint in young healthy men. Our results indicated that exercise with vibratory stimuli effectively increased muscle activity in the rotator cuff and the stabilizing muscles of the scapula and improved the dynamic stability of the upper limb to a greater extent than exercises performed without vibratory stimuli. Vibratory stimuli could maximize training gains while limiting injury risk in athletes. Our findings could guide the development of rehabilitation programs for patients with shoulder instability and pain.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethical approval: The study protocol was approved by the Ethics Committee of the Graduate School of Health Sciences, Hiroshima University (E-2038).

Conflicts of interest: The authors have no conflicts of interest relevant to this article.

Acknowledgments: The authors would like to thank everyone who participated in this study.

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Table 1. Outcome measures in the stabilometric test at pre-exercise and at the end of exercise

	Control condition			Vibration condition			Interaction effect (condition × time)		
Variables	Pre	Post	P	Pre	Post	P	F	P	ηp^2
Stabilometric test									
CoP velocity with eye open [mm/s]	9.7±1.15	9.78±1.29		9.66±1.33	9.73±1.17		0.006	0.94	0
CoP velocity with eye closed [mm/s]	9.71±1.36	9.7±1.3		10±1.58	9.77±1.25		1.092	0.315	0.078

CoP, center of pressure; ηp^2, partial η^2; Pre-, pre-exercise; Post, post-exercise

Table 2. Outcome measures in the UQYBT score at pre-exercise and at the end of exercise

	Control condition			Vibration condition			Interaction effect (condition × time)		
Variables	Pre	Post	P	Pre	Post	P	F	P	ηp^2
UQYBT score (%)									
Medial	101.7±6.6	99.9±7	<0.05	101.5±6.2	104.7±6.5	<0.05	21.404	<0.01	0.605
Laterosuperior	77.4±7.4	75.5±8.6	<0.01	76.3±8.5	80.1±8	<0.01	12.049	<0.01	0.463
Lateroinferior	87.2±9.1	85.1±10.3	0.081	85.5±8.1	89.1±7.4	<0.05	13.583	<0.01	0.492
Composite	88.8±6.5	86.9±7.4	<0.01	87.8±5.9	91.1±5.3	<0.01	21.362	<0.01	0.604

ηp^2, partial η^2; Pre, pre-exercise; Post, post-exercise; UQYBT, Upper Quarter Y Balance Test

Table 3. Outcome measures of shoulder muscle activity at pre-exercise and at the end of exercise

	Control condition			Vibration condition			Interaction effect (condition × time)		
Variables	Pre	Post	P	Pre	Post	P	F	P	ηp^2
Muscle Activity (%)									
Infraspinatus									
Medial	45.1±28.6	49.4±31.0	<0.01	44.1±21.8	55.2±25.9	<0.01	6.294	<0.05	0.31
Laterosuperior	74.9±31.8	75±32.2	0.983	94.4±38.6	110.4±48.6	<0.05	4.869	<0.05	0.258
Lateroinferior	57.7±32.6	62.2±33.3	<0.05	57.3±27.2	72.4±34.2	<0.01	7.655	<0.05	0.353
Posterior deltoid									
Medial	13.9±6.2	17±7.4	<0.05	16.3±10.6	17.1±11.5	0.407	7.134	<0.05	0.338
Laterosuperior	12.2±6.5	12.4±5.9		11.1±6	12.9±9		2.188	0.161	0.135
Lateroinferior	11.9±5	13.3±5.7		10.4±4.1	13.4±6.1		1.346	0.265	0.088

Serratus anterior									
Medial	54.9±19.7	53.9±16.2	0.678	57.3±23.7	64.1±27.4	<0.01	6.944	<0.05	0.332
Laterosuperior	50.8±16.6	49.9±10.8		48.3±18.8	51.3±22.5		1.217	0.289	0.08
Lateroinferior	78.1±28	76.7±22.8		76.7±30.2	84.4±32.5		2.47	0.138	0.15
Upper trapezius									
Medial	6.4±3.5	6.8±2.9		8.2±6	8.3±4.6		0.188	0.671	0.013
Laterosuperior	13.9±9	15.2±9		19.7±16.7	18±12.8		2.471	0.138	0.15
Lateroinferior	14.7±9	14.5±6.8		17.2±11.9	18.3±11.9		1.24	0.284	0.081
Lower trapezius									
Medial	11.1±4.1	11.2±5	0.921	11.4±4.9	15.4±6.7	<0.01	6.109	<0.05	0.304
Laterosuperior	11.4±4.9	8.7±6		10.6±6.8	10.3±7.2		0.184	0.675	0.013
Lateroinferior	8.4±4.6	6±3		6.4±3.6	6.8±4.7		0.031	0.863	0.002

ηp^2, partial η^2; Pre, pre-exercise; Post, post-exercise; UQYBT, Upper Quarter Y Balance Test

Table 4. Change of rate in the stabilometric test, UQYBT score, and muscle activity between the 0-Hz and 50-Hz conditions.

Change of rate [%]	Vibration frequency		
	0Hz	50Hz	*p*
Stabilometric Test			
COP velocity with eye open	0.8 ± 4.8	9.8 ± 1.3	0.894
COP velocity with eye closed	0.2 ± 6.1	9.7 ± 1.3	0.395
Influence of vision index	-17.3 ± 316.0	-0.7 ± 5.1	0.458
UQYBT score			
Medial	-1.7 ± 2.4	3.2 ± 3.3	**<0.001**
Laterosuperior	-2.5 ± 5.1	5.2 ± 5.7	**<0.001**
Lateroinferior	-2.4 ± 4.0	4.4 ± 4.9	**<0.001**
Compiste	-2.2 ± 3.2	3.9 ± 3.0	**<0.001**
Musle Activity			
Infraspinatus			
Medial	11.0 ± 13.4	27.6 ± 17.1	**0.006**
Laterosuperior	1.3 ± 13.8	18.0 ± 19.5	**0.011**
Lateroinferior	8.2 ± 15.4	27.8 ± 21.6	**0.008**
Posterior deltoid			
Medial	25.2 ± 28.3	4.5 ± 14.7	**0.018**
Laterosuperior	4.0 ± 18.1	11.8 ± 17.6	0.237
Lateroinferior	15.7 ± 26.8	27.7 ± 27.3	0.237
Serratus anteroir			
Medial	0.8 ± 17.3	11.5 ± 12.8	0.065
Laterosuperior	2.1 ± 18.5	5.4 ± 14.8	0.591
Lateroinferior	2.1 ± 19.4	12.4 ± 24.3	0.212
Upper trapezius			
Medial	19.4 ± 32.3	68.0 ± 169.7	0.286
Laterosuperior	13.5 ± 24.5	5.6 ± 34.5	0.480
Lateroinferior	9.7 ± 27.8	16.2 ± 37.5	0.593
Lower trapezius			
Medial	0.7 ± 31.4	36.7 ± 48.7	**0.023**
Laterosuperior	-0.4 ± 20.3	-1.1 ± 31.7	0.948
Lateroinferior	14.1 ± 44.0	6.4 ± 26.9	0.566

UQYBT; upper quarter Y balance test.

Figure legends

Figure 1. Experimental set up for vibration exercise in the modified push-up position

Figure 2. Experimental set up for the upper limb static stability test in the modified push-up position

Figure 3. Upper Quarter Y Balance Test reach directions

Figures

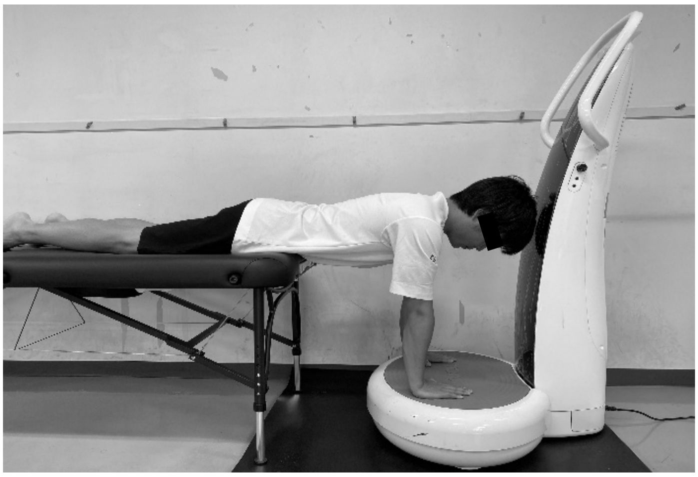

Fig. 1

Fig. 2

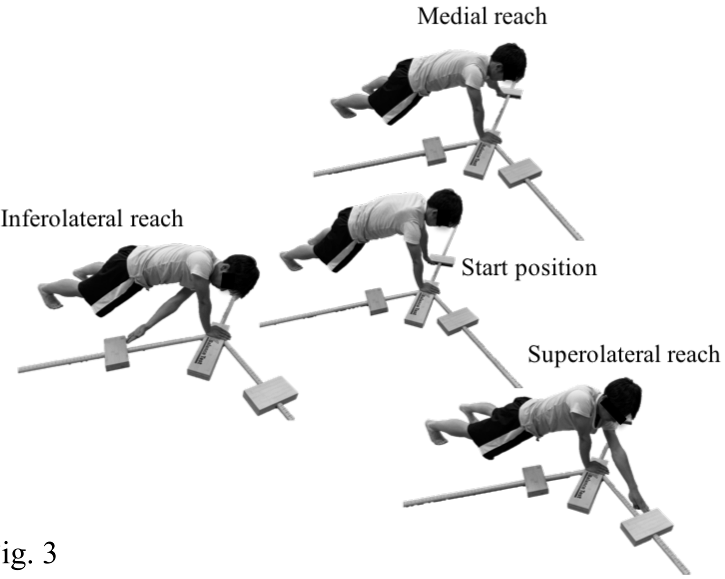
Medial reach
Inferolateral reach
Start position
Superolateral reach

Fig. 3