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Immediate Effects of Whole Body Vibration on Proprioception and Upper Extremity Reaction Speed in Young Adult Students

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Abstract

Background: *There is limited information on the immediate effects of whole-body vibration (WBV) on the upper limb. This study aims to determine the immediate effects of WBV on reaction speed and proprioception in young adult students' upper extremities.* **Methods:** *In total, 62 students participated in the study. WBV was applied to the participants, and its immediate effects on proprioception and upper extremity reaction speed were examined. Participants' proprioception and perception of joint position at 30-60 degrees of shoulder flexion, shoulder abduction, and elbow flexion angles were measured with absolute error degrees. Reaction rates were evaluated with the Ruler-Drop Test and the mobile application SWAY.* **Results:** *A decrease was observed in the absolute error level of the participants' joint position perception at 30-60 elbow and shoulder position degrees, measured after immediate WBV application ($p < 0.05$). After the RDT application, a decrease in the length of catching the target was observed ($p < 0.05$). The SWAY test determined that they moved the smartphone in a shorter time ($p < 0.05$). Right and left RDT scores showed that the distance to catch the ruler was significantly lower in male individuals before the application. In comparison, the distance to catch the ruler was lower after the application (right/left $p<0.05$).* **Conclusions:** *The study found that applying WBV improved upper extremity proprioception perception and reaction speed in young adults. This information can guide clinicians in applying WBV to healthy individuals and those with symptoms.*

1. Introduction

Vibration is a mechanical stimulus that produces oscillatory motion and is used for therapeutic purposes to trigger various physiological responses [1]. Whole-body vibration (WBV) is a neuromuscular training method clinicians have recently used as a rehabilitation tool [2]. The application involves transmitting mechanical stimuli to the whole body through the individual's feet or upper extremities on a vibrating platform [3].

The WBV device produces vibrations that can affect the individual's musculoskeletal system. Neuromuscular muscle spindles and the skin, joints, and

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secondary nerve endings detect these vibrations. This stimulation is believed to lead to more effective muscle and nerve function. This effect of WBV on muscle and joint mechanoreceptors is a significant factor in its relationship with proprioception [4]. Proprioception is the sense that detects internal sensory information, including the position of different body parts in space, movement, and joint position [5]. These sensations arise from signals from sensory receptors in joints, muscles, and skin. Proprioception allows for perceiving limb movements, weight, forces, and positions. Furthermore, it controls static and dynamic joint stability and precise movements of the upper extremities [6]. Loss of proprioception may result in neuromuscular dysfunctions, an increased risk of injury, and poor segmental stability [6].

Functional gains following whole-body vibration (WBV) applications are associated with neuromuscular and joint deep sensory systems adaptations, improved neural activation, and muscle mobilization [7]. This explains how WBV affects the neuromuscular system and proprioception. It can be inferred that WBV potentially affects individuals' reaction speeds. Reaction time is defined as the time it takes to initiate a behavioral response after the presentation of a sensory stimulus [8]. Reaction time impairments are associated with poor reaction time and limb performance [9].

It is emphasized that WBV applications improve the functions of the trunk muscles [10] and enable the activation of the lumbar and abdominal muscles [11]. In addition to these potential benefits, it is argued that it can also improve proprioception [6, 7, 12]. The studies in the literature also contain gender comparisons of WBV effects, mainly on the lower limbs and trunk muscles [13, 14]. Very few studies compare the immediate effects of WBV application on proprioception and reaction speed of the upper extremity according to gender [15].

Based on the literature, the immediate effects of whole-body vibration on upper limb proprioception and reaction speed have yet to be discovered. This study aims to determine the immediate effects of whole-body vibration on reaction speed and upper extremity proprioception in young adult students. Our secondary findings were to compare the immediate effects of WBV on proprioception and reaction speed according to gender. The study's findings regarding the immediate effects of WBV on reaction speed and proprioception may guide clinicians working with patients and contribute to a better understanding of the complex effects of WBV on human health, injury risk, and performance.

2. Methods

2.1. Participants

This study is an experimental study in which pretest and post-test were evaluated. The study was conducted at the measurement and evaluation laboratory of the Department of Physiotherapy and Rehabilitation at Gaziantep Islam Science and Technology University. All of the participants were university students aged between 18 and 35 years. Those who had no orthopedic or neurological upper extremity problems, no cardiac problems, and who agreed to participate in the study were included. Those with vertigo were excluded. Out of 63 volunteers, one individual was excluded due to vertigo. In this study, the Declaration of Helsinki was complied with, and written consent was obtained from the individuals in the survey stating that they participated voluntarily.

According to the power analysis conducted using the G-Power 3.1.7 program, based on a previous study, the number of samples required for the research was 62 (a = 0.05, 1-b = 0.95) [16].

2.2. Procedure and Measurements

The study began by measuring demographic characteristics, upper extremity proprioception, and hand reaction speed. Afterward, WBV was applied using the Compex Winplate (Novotec Medical GmBH, Germany) device. The application protocol of whole-body vibration is in the push-up position with a frequency of 30 Hz. The amplitude was 2 mm, 1 minute of application, and 1 minute of rest for five sets [17]. Immediately after the WBV application, a second evaluation was made, and hand reaction speed and upper extremity proprioception measurements were repeated. The procedure and measurements are presented in Figure 1.

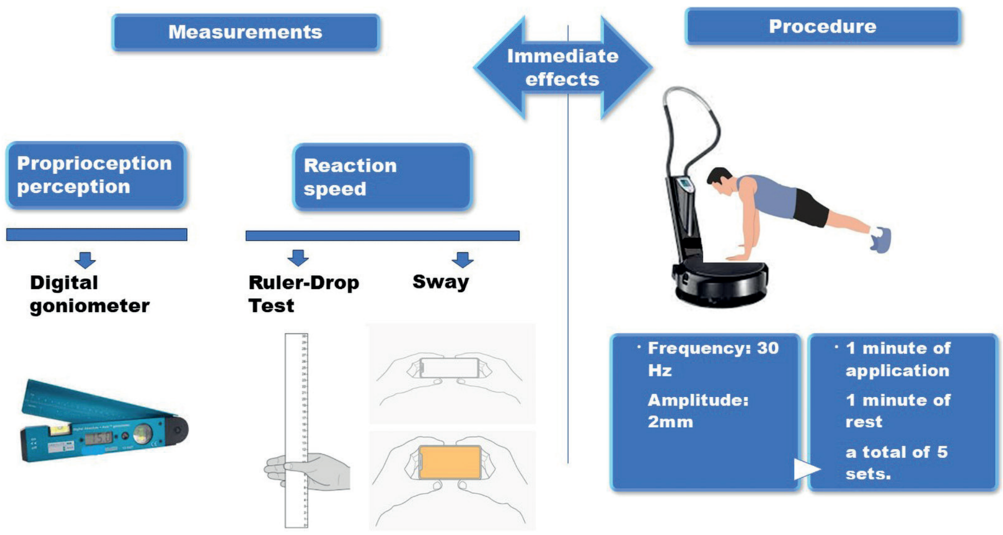

Figure 1. Procedure and measurements.

Proprioception perception was assessed in the upper extremities, specifically in the shoulder and elbow regions. The evaluation included measuring proprioception at 30 and 60-degree shoulder flexion, 30-60-degree shoulder abduction, and 30-60-degree elbow flexion angles. Before the review, the starting position was adjusted to the desired angle value, and participants were instructed to remember this position at the end of the movement. Next, the patient was asked to return the limb to the neutral position by closing their eyes and placing it in the remembered position. The passive and remembered positions were measured using a digital goniometer (Baseline®, USA), and the absolute degree of error in joint position perception was recorded [18].

The Ruler-Drop Test (RDT) is a method used to evaluate hand reaction speed. During the test, the participant is asked to sit comfortably in a chair with their forearm and hand resting on the table. The tips of their thumb and index finger should be positioned 8-10 cm away from the table, with the tops of the thumb and index finger parallel to each other. The tester then instructs the individual to hold the ruler between their thumb and index finger. Simultaneously, the participant was asked to fixate on the midpoint of the ruler while holding it between their fingers. They were instructed to grasp the ruler with their thumb and forefinger immediately upon release. The ruler was then released, and the numerical centimeter value on the upper edge of the participant's thumb, where they grasped the ruler, was recorded. This process was repeated ten times, and the results were averaged for data analysis [8].

The SWAY smartphone application is designed to evaluate upper extremity reaction speed. Users are instructed to sit comfortably on a chair, hold the smartphone with their thumbs on both sides and quickly turn the phone screen in the desired direction when the orange screen appears. A trial test is conducted to familiarize users with the application. The reaction rate was calculated by applying the procedure three times and taking the average time of these three applications [19].

2.3. Data Analysis

The data were analyzed using SPSS version 25 (IBM, Inc., Chicago, IL, USA). The Shapiro-Wilk test and histogram were used to assess the suitability of the normal distribution. Descriptive data are presented as mean and standard deviation (SD). Wilcoxon signed-rank test was used to compare the measurements before and after the WBV application. Figures were created using the GraphPad

Prism 8 program. Mann Whitney U test was used to compare between groups according to gender. A value of $P < 0.05$ was considered statistically significant.

3. Results

Table 1 presents the demographic characteristics of the 62 individuals (26 females, 36 males) who participated in the study.

Figure 2 presents a statistical comparison of the measurements before and after the application is presented the visual comparison.

A decrease in the absolute error level of joint position perception was observed after the application in the participants' 30 to 60-degree flexion and abduction positions of both shoulders (Figure 2). There was a decrease in the average value after the RDT application, which evaluates hand reaction speed. (Figure 2). This meant that the participants caught the target at a shorter distance. The SWAY test, which assesses the upper extremity reaction speed, determined that the participants moved the smartphone in a shorter time as an immediate effect after the application (Figure 2). The statistical comparison of the measurements before and after WBV application according to gender is presented visually in Figure 3. There was no statistically significant difference in comparing proprioception deviation values of male and female participants before and after the application ($p > 0.05$). Right and left RDT scores showed that the distance to catch the ruler was significantly lower in male individuals before the application (Figure 4). In comparison, the distance to catch the ruler was significantly lower after the application (right/left $p<0.001$/$p=0.043$, respectively, Figure 4). No significant difference was observed in SWAY measurement values before and after WBV application according to gender ($p>0.05$, Figure 4).

Table 1. Demographic characteristics.

	X±SD	Min-Max
Age (years)	20.6±2.6	18-34
Weight (kg)	68.8±16.2	40-130
Height (cm)	172.5±9.2	155-193
BMI (kg/m2)	22.96±4.2	15-36
	n	
Gender (female/male)	26/36	
Dominant side (right/left)	59/3	

BMI: Body mass index.

4. Discussion

During the application of WBV, skeletal muscles undergo minor changes in length. This vibration elicits a response known as the 'tonic vibration reflex,' which includes the activation of muscle spindles, modulation of neural signals by Ia afferents, and muscle fibers' activation via large α-motor neurons. The tonic vibration reflex can also increase the recruitment of motor units through the activation of muscle spindles and polysynaptic pathways [20]. The input of proprioceptive pathways (Ia, IIa, and IIb) plays an essential role in the occurrence of isometric contractions [21, 22]. Increasing isometric strength after WBV training with extensive sensory stimulation may result from more efficient use of the positive proprioceptive feedback loop [23]. Muscle functions can be improved with whole-body vibration. WBV also has the potential to provide proprioception training by modifying muscle stiffness, joint stability, and mechanoreceptor activity through gamma efferent stimulation [24].

According to the literature, WBV training on a vibrating balance board has been shown to improve proprioception in patients with knee osteoarthritis [23]. In a study by Fontana et al., adding whole-body vibration to a simple weight-bearing exercise increased lumbosacral position sensation after a single 5-minute session [25]. Although the study used hand vibration as the stimulus, which differs from recent vibration studies, Tripp et al. demonstrated that it reduces the variability of elbow joint position sense [26]. The authors suggested that vibration provides additional afferent input to the sensorimotor system, which may facilitate joint position sense. It has been suggested that vibration increases joint stiffness by activating joint mechanoreceptors and stimulating gamma efferents, which is closely related to improved joint position sense [25]. In this study, 32 students received WBV training

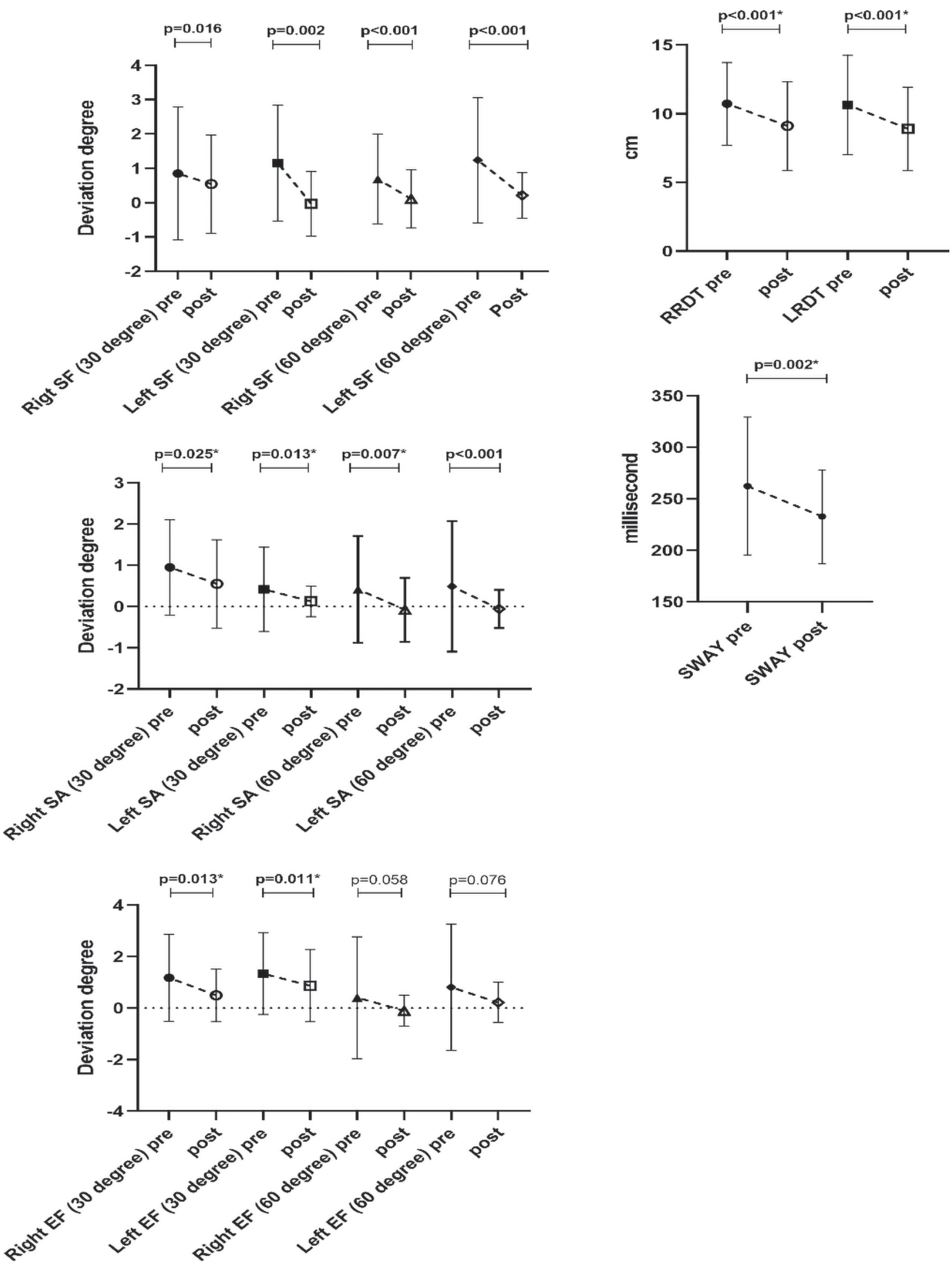

Figure 2. Comparison of proprioception and reaction speed of all participants before and after WBV application. (SF:shoulder flexion, SA:shoulder abduction, EF: elbow flexion, RRDT and LRDT: rigt and left side Ruler-Drop Test, SWAY: mobil application).

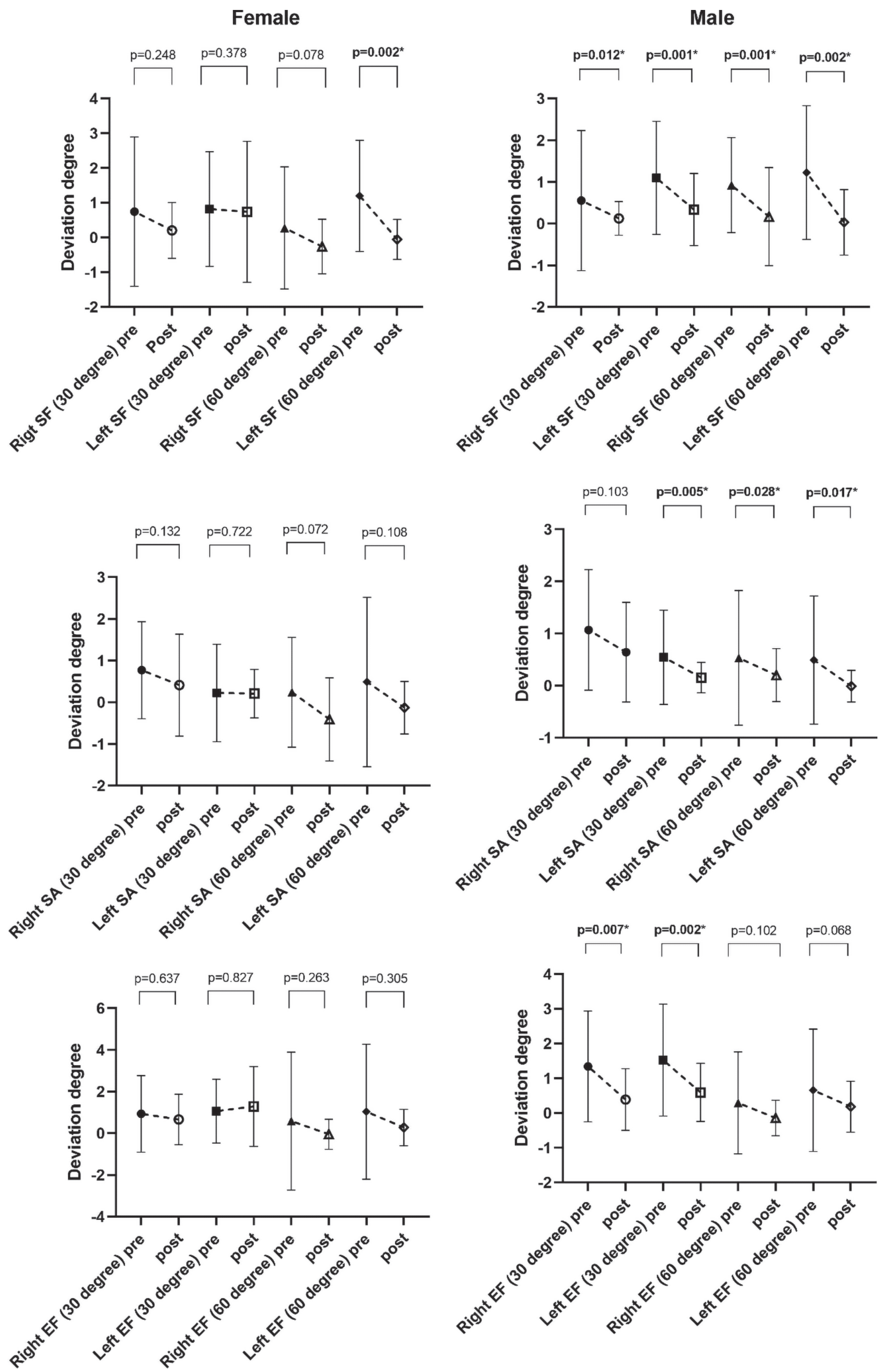

Figure 3. Comparison of proprioception before and after WBV application according to gender (SF:shoulder flexion, SA:shoulder abduction, EF: elbow flexion).

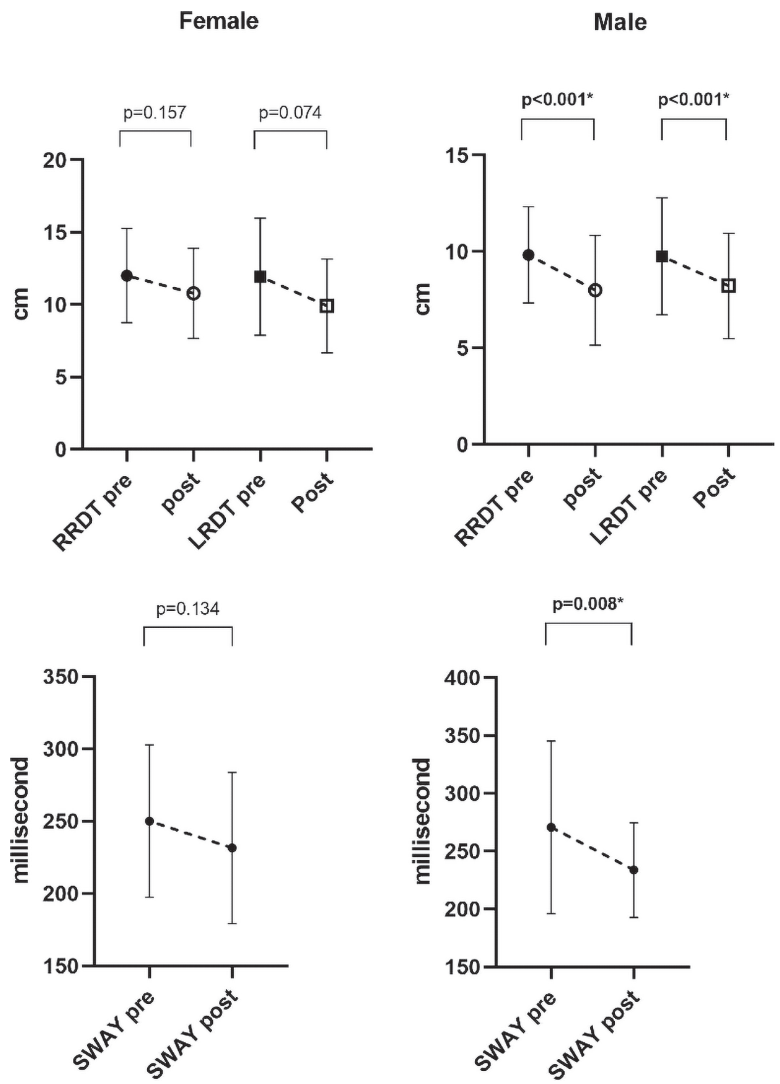

Figure 4. Comparison of reaction speed before and after WBV application according to gender (RRDT and LRDT: rigt and left side Ruler-Drop Test, SWAY: mobil application).

in three positions: control (no vibration), push-up with a straight elbow, and push-up for 2 minutes with 30-minute intervals. The results significantly improved angle repositioning in all three positions [27]. The present study observed that WBV resulted in an immediate decrease in the absolute degree of error in bilateral upper extremity proprioception. This development, in line with the literature, is believed to occur due to vibration providing additional afferent input to facilitate joint position sense.

It has been found that WBV improves muscle performance parameters such as strength and endurance [28]. Therefore, WBV may impact reaction time by influencing muscle nerve activity. However, there is limited literature on the effects of WBV on reaction time, particularly in the upper extremity muscles [29]. In a study of forty healthy young women, timing parameters were measured in the intervention (WBV) group using reaction time, premotor time, motor time, and pre- and post-vibration

EMG. The same protocol was used for the control group (without WBV) but without flicker. The results showed that whole-body vibration did not significantly affect lower extremity reaction rate [29]. WBV immediately positively affected reaction time in both groups: the intervention group with lumbar lordosis and the control group without lumbar lordosis. Another study on Parkinson's patients showed improvements in reaction time with WBV, but no apparent effect was observed compared to the control group. The study suggested that this lack of effect may be due to the age of the participants [30]. Our study found a decrease in hand-holding reaction distance in the RDT, which evaluates WBV reaction speed. Additionally, we observed a parallel reduction in phone movement time in the SWAY evaluation. This suggests that the nerve activity of WBV may be affected, potentially impacting reaction speed.

Structural and functional differences exist between the upper and lower extremities. According to these anatomical differences, the central nervous system plays a more active role in hand and arm functions than in foot and leg functions [31]. It has also been suggested that there is a more significant decrease in reaction time and movement time in the lower extremities than in the upper extremities with age, as they are the most frequently used areas [32]. The variations in the outcomes of the studies mentioned above may be attributed to the varying effects of WBV in different body regions and the influence of factors such as age and gender on reaction time. More extensive research in the literature is crucial for generalizing the results.

Hormonal differences in males and females play a critical role in understanding the effects of WBV on proprioceptive and motor responses [33]. In a study investigating the difference in shoulder position sense according to gender, it was reported that the calculation of shoulder absolute repositioning error did not show a significant difference between males and females. The same study also reported that men had significantly more variable error than women, i.e., there was more variability in position sensation [34]. The present study showed no significant difference in shoulder and elbow joint position sense before WBV application. The decrease in the proprioception error margin of men after the application explains more changes in their position sense. Research on upper limb reaction speed by gender shows that males generally have shorter reaction times than females. This is due to biological differences such as males' muscle mass, strength levels, and nerve conduction velocities [35]. In our current study, the difference between RDT scores in favor of males before the WBV application supports previous studies. We think that the lack of difference in SWAY scores before and after the application according to gender may be because young adults have shown similar familiarity with the use of smartphones, which may affect the reaction speed. However, further studies are needed to confirm this.

A study comparing the effect of WBV application on upper extremity reaction speed according to gender is quite limited. In a study on lower extremity muscle activity, women showed higher hamstring activity than men in the pre-application test, especially before 50 milliseconds. However, this difference was reported to disappear after WBV [13]. The significant difference in RDT scores after WBV application in our study may have been due to biological differences according to gender. Additional studies are needed to determine the generalizability of this information.

The main limitation of our study is the need for a control group and randomization. The lack of a control group limited the results. In addition, examining immediate effects at different frequencies would have been more helpful in understanding the effects of frequencies on proprioception and reaction rates. In addition, testing proprioception and reaction with more sensitive measurement methods could have given more objective results. Analyzing WBV effects according to age groups may help to understand age-related biological differences. This study was limited to flexion and abduction movements of the shoulder. Studies evaluating the multidirectional joint movements of the shoulder are needed.

5. Conclusion

Our study showed an improvement in upper extremity proprioception and reaction speed of young university students with the acute effect of WBV.

As a result of this study, the immediate effects of WBV on upper extremity proprioception and reaction speed may guide clinicians who will work on patients and contribute to a better understanding of the complex effects of WBV application on human health and performance. Studies evaluating the effects of WBV on proprioception and reaction speeds on a gender basis are lacking. While the current findings reveal general effects, further controlled research is needed to examine gender differences.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Gaziantep Islam Science and Technology University, Non-Interventional Clinical Research Ethics Committee (Protocol No: 2023/266, June 2023) and registered at ClinicalTrials.gov (NCT06172244).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Declaration of Interest: The authors declare no conflict of interest

Author Contribution Statement: ÇM: conceptualization, methodology, data curation, formal analysis, writing original draft, project administration, writing review, and editing. DGK, GE: conceptualization, methodology, writing, review, and editing. FBK, HY, MG: investigation, data curation, resources, writing, review, and editing. SY: methodology, supervision, writing – review, and editing.

Declaration on the use of AI: None.

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