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Effects of Acute Whole-Body Vibration and Flexi-Bar Training on Isokinetic Shoulder Internal and External Rotation Strength

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Abstract

In movement and training sciences, the effects of vibration treatments on acute muscle performance are popular research topics. In this study, the effects of acute whole body vibration (WBV) and flexi-bar training on isokinetic shoulder internal and external rotation strength were investigated in high performance group female handball players. Four different training protocols were applied to the study conducted with 16 healthy adult female handball players (age: 21.31 ±1.45; mass: 69.47 ±28.21). Participants took a modified push-up position and participated in bench press force treatments on a non-vibrated and vibrated (30 Hz 4 mm, 50 Hz 4 mm) surface. In addition, the participants performed the same movement form in a sitting position using a flexi bar. To determine the effects of four different protocols (30 sec × 6 sets with 30 sec rest) isolating the lower extremities on the shoulder rotator cuff muscle muscles, the strength of the shoulder rotator cuff muscles was measured with an isokinetic dynamometer at speeds of – 60 and 180°/s before and immediately after the treatment. Findings showed that 30 Hz WBV treatment decreased mean force in shoulder internal rotation muscles ($p = 0.043$), while 50 Hz WBV decreased maximum torque and mean force ($p = 0.022$, $p = 0.026$). Flexi-bar exercises were found to negatively affect the maximum torque ($p = 0.007$), work per repetition ($p = 0.006$) and mean strength ($p = 0.004$) values of the shoulder external rotation muscles. As a result, it was observed that WBV (30 Hz and 50 Hz 4 mm) and flexi-bar treatmnets caused a significant decrease in the strength of the internal rotator muscles, and WBV treatmnets had a statistically more significant effect on the external rotator muscles than the flexi-bar application.

Keywords: Whole body vibration, isokinetic strength, flexi-bar training, rotator cuff muscles.

Akut Tüm Vücut Vibrasyon ve Flexi-bar Antrenmanlarının Omuz İnternal ve Eksternal Rotasyon Kuvvetine Etkisi

Özet

Hareket ve antrenman bilimlerinde, titreşim uygulamalarının kasların akut performansı üzerindeki etkileri popüler araştırma konularındandır. Bu çalışmada yüksek performans grubu kadın hentbolculara uygulanan akut tüm vücut vibrasyon (TVV) ve flexi-bar antrenmanlarının izokinetik omuz internal ve eksternal rotasyon kuvvetine etkileri incelenmiştir. 16 sağlıklı yetişkin kadın hentbolcu (age: 21.31 ± 1.45; mass: 69.47 ± 28.21) ile yapılan çalışmada dört farklı antrenman protokolü uygulanmıştır. Katılımcılar modifiye şınav pozisyonu alarak, vibrasyonsuz ve vibrasyonlu (30 Hz 4 mm, 50 Hz 4 mm) yüzeyde bench press kuvvet uygulamalarına katılmışlardır. Bunun yanı sıra katılımcılar aynı hareket formunu oturur pozisyonda flexi bar kullanarak gerçekleştirm. Alt ekstremitelerin izole edildiği dört farklı protokolün (30 sec × 6 set with 30 sec rest) omuz rotator cuff kas kasları üzerindeki etkilerini belirlemek için protokol öncesi ve sonrası omuz rotator cuff kaslarının gücü izokinetik dinamometre ile 60 ve 180°/sn hızlarda uygulama öncesi ve hemen sonrası ölçülmüştür. Bulgular, 30 Hz TVV uygulamasının omuz iç rotasyon kaslarında ortalama kuvvet azalttığını ($p = 0.043$), 50 Hz TVV'nin maksimum tork ve ortalama kuvveti düşürdüğünü ($p = 0.022$, $p = 0.026$) göstermiştir. Flexi-bar egzersizlerinin omuz dış rotasyon kaslarının maksimum tork ($p = 0.007$), tekrar başına iş ($p = 0.006$) ve ortalama kuvvet ($p = 0.004$) değerlerini olumsuz etkilediği bulunmuştur. Sonuç olarak, TVV (30 Hz ve 50 Hz 4 mm) ve Flexi-bar uygulamalarının internal rotator kaslarında anlamlı kuvvet düşüşüne neden olduğu ve TVV uygulamalarının flexi-bar uygulamasına göre eksternal rotator kasları üzerinde istatistiksel olarak daha anlamlı bir etkisinin olduğu gözlenmiştir.

Anahtar Kelimeler: Tüm vücut vibrasyon, izokinetik kuvvet, Flexi-bar antrenmanı, Rotator cuff kasları

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INTRODUCTION

Vibration training is a popular training tool used in sports performance development, health and rehabilitation (Cochrane et al., 2010; Rittweger, 2010). The surface vibration created by the sine waves produced by the platform oscillates in the opposite direction to the normal force. The resulting sinusoidal vibration waves cause stimulation of vibration-sensing mechanoreceptors in the nervous system. Thus, the alpha motor neuron initiates a reflex contraction known as the tonic vibration reflex, and this effect reaches throughout the body (Washif, 2019). Research shows that vibration treatments increase muscle strength and power (Verschueren et al., 2004; Colson et al., 2010; Lu et al., 2021), improve muscle strength (Torvinen et al., 2002a; Torvinen et al., 2002b), may affect hormone secretion (Di Loreto et al., 2004; Cardinale et al., 2010), may have an effect on the nervous system (Jordan et al., 2005; Mester et al., 2006), may affect postural control (Bogaerts et al., 2007; Fort et al., 2012) may have an effect on the cardiorespiratory and cardiovascular systems (Bogaerts et al., 2009; Cochrane et al., 2011), affects the performance of the shoulder rotator muscles (Hand et al., 2009; Hong et al., 2010; Grant et al., 2019).

Another training tool that creates a vibration effect on the neuromuscular system is flexi bar treatments. Active vibration exercise performed with the flexi-bar, designed to produce 270 vibrations per minute at a frequency of 5 Hz, stimulates the proprioceptive senses of the joints by creating a tonic vibration reflex in the muscles and tendons and improves muscle coordination by supporting the contraction of agonist and antagonist muscles to maintain balance (Lee and Han, 2018). It helps improve static and dynamic balance (Mileva et al., 2010; Lee and Han, 2018). Exercises using flexi-bar have been shown to be effective in reducing pain and increasing muscle activity in patients undergoing rotator cuff treatment (Kim et al., 2016). Um et al. (2015) show that young football players improve their postural alignment and balance with flexi-bar exercises.

Vibration training can be considered as an alternative exercise method to strength training (Nesser et al., 2008). It supports muscle activation through the stretch-shortening cycle with repeated eccentric-concentric muscle contractions (Cardinale and Bosco, 2003; Phanpheng and Hiruntrakul, 2020). Thus, it can help develop explosive motor skills by causing rapid mechanical changes in the muscle-tendon complex (Nicol et al., 2006). Flexi-bar treatments create reflex contractions and increase muscular activation thanks to the vibration it produces with small movement amplitude. It is known to support the cardiovascular system and have positive effects on weight management and general fitness (Phanpheng and Hiruntrakul, 2020). It provides agonist-antagonist contraction by stimulating intra-articular proprioreceptors (Lee and Han, 2018). It is reported to be effective in reducing pain and increasing muscle activity in rotator cuff treatment (Kim et al., 2016).

One of the joints most prone to injury in sports is the shoulder joint (Tummala et al., 2018). Because it has weak bone and capsule-ligament stability, it requires more neuromuscular control and stability than other joints in the human body (Hong et al., 2010). There are studies showing that vibration training helps improve shoulder external rotation strength (Ameer and Al Abbad, 2023; Gomes da Silva and Ejnisman, 2023). However, studies investigating the effects of whole-body vibration and flexi-bar training on isokinetic shoulder internal and external rotation strength appear to be insufficient. The aim of this study was to investigate the effects of acute WBV and flexi-bar training on isokinetic shoulder internal and external rotation strength in active athletes.

METHODS

Participants

Sixteen female athletes who actively play in the Eskişehir Technical University Women's Handball Team and who have not experienced any orthopedic problems in the spine or upper and lower extremities in the last six months participated in the study on a voluntary basis. Before the study, ethics committee approval was obtained from Eskişehir Technical University and participants were asked to fill out voluntary consent forms before the study.

Collecting Data

The body weights of the subjects were measured using an electronic laboratory scale (Seca, Vogel & Halke, Hamburg) with a precision of ±0.01 kg. Height measurements were measured and recorded in anatomical position with a fixed stadiometer ((Holtain Ltd, UK)). A whole body vibration device (Power Plate®, Pro 5 Airdaptive Model, USA) was used for Whole Body Vibration treatments, and a flexible bar (FLEXI-BAR®Standard) was used for flexi-bar training. Isokinetic dynamometer (Humac Norm Testing & Rehabilitation System, USA) was used to measure the shoulder joint strength of the participants before and after the study.

Isokinetic Tests

Participants' shoulder rotator muscle strength was measured using an isokinetic dynamometer. After determining (Waterloo Handedness Questionnaire) the arm used dominantly by the participants, the values obtained for the dominant arm were used in statistical analysis. Tests were performed in a neutral position, performing internal (IR) and external (ER) rotation movements at angular velocities of – 60°/sec and 180°/sec, using concentric/concentric contraction. Pre- and post-test values were recorded. Participants were asked to try both types of movements (IR and ER) three times, and the best score was recorded. A familiarization session was performed before the isokinetic test. For this, participants were asked to repeat the desired movement three times at 30°/s on the pre-calibrated device. Participants were asked to maintain 45° shoulder abduction, keep the forearm in a neutral position, and ensure that the trunk and pelvis were stabilized to prevent compensations.

Study Design

The study lasted four days, as shown in Figure 1. Anthropometric measurements of the participants were taken before starting the training protocol. Participants trained on a vibration-free platform on the first day. On the second day, the participants performed isometric movements on the Power Plate device at 30 Hz 4 mm low vibration, while on the third day, they performed the specified movement at 50 Hz 4 mm high vibration. Each participant performed the protocol in a push-up position (knees on the floor) with their hands shoulder-width apart and their elbows extended, placing them in the center of either the full-body vibration platform or the non-vibration platform. The exercise consisted of six sets of 30 seconds each with 30 seconds of rest between sets. On the fourth day, the exercise duration was the same and the participants were asked to do vibration training using the flexi-bar. This flexi-bar training protocol consisted of six sets of 30 seconds each with 30 seconds of rest between sets. The strength of the participants' shoulder rotator muscles was tested before and immediately after performing internal and external rotation movements in a neutral position at two angular velocities - 60 and 180°/sec - using an isokinetic dynamometer.

Figure 1. Chart of workflow

	Day 1	Day 2	Day 3	Day 4
Pre Test	Participants' anthropometric measurements were taken. Internal and external rotation measurements were taken using an isokinetic dynamometer.	Internal and external rotation measurements were taken on the isokinetic dynamometer device.	Internal and external rotation measurements were taken on the isokinetic dynamometer device.	Internal and external rotation measurements were taken on the isokinetic dynamometer device.
Test Sessions (30 sec × 6 reps)	On Whole Body Vibration device (non-vibration)	On Whole Body Vibration device at 30 Hz 4 mm vibration	On Whole Body Vibration device at 50 Hz 4 mm vibration	Flexi-bar
Post Test Test immediately after treatments	Internal and external rotation measurements were taken on the isokinetic dynamometer.	Internal and external rotation measurements were taken on the isokinetic dynamometer.	Internal and external rotation measurements were taken on the isokinetic dynamometer.	Internal and external rotation measurements were taken on the isokinetic dynamometer.

Statistical analysis

Statistical analysis of the data of our study, which was conducted to investigate the acute effects of WBV at different amplitudes and frequencies and flexi-bar treatments on isokinetic shoulder internal and external rotator muscle strength, was performed using SPSS® (Statistics version 23 for Windows) software program (IBM, Armonk, NY; 2011). In order to reveal the pre-test-post-test differences in the acute effects of each protocol performed to the participants on isokinetic internal and external rotator shoulder muscle strength on four separate days, the effects of the interaction between the factors for each parameter (maximum torque, work per repetition, average force per repetition) on the variables for each treatments were examined with One-Way Analysis of Variance for Repeated Measures (ANOVA; 4 × 3 × 2, Group ×Parameter×Time). Time (pre-test-post-test) was determined as the within-participants factor and Group (Protocol 1 (Control), Protocol 2 (30 Hz 4 mm TVV), Protocol 3 (50 Hz 4 mm TVV), Protocol 4 (Flexi-bar)) was determined as the between-participants factor. Paired Samples T-Test was performed to reveal the pre-test-post-test difference for each protocol (Table 2). To determine which protocol was superior to the other, the values obtained from the pre-test-post-test differences of the three parameters for each protocol were compared pairwise between the groups and shown in Tables 3, 4 and 5. Whether the data of the relevant variables conformed to a normal distribution was tested with the Shapiro-Wilk test and confirmed with the Skewness and Kurtosis values (Ak, 2008). Whether the variances of the series of differences between any two measurements were equal was checked with the Mauchly's Test of Sphericity. Wilcoxon Signed Rank Test was performed for intra-group and inter-group pairwise comparisons of mean differences within the group of independent variables that did not provide normal distribution. The values for all tests are given in the relevant tables, with mean and standard deviation values. Effect size values for all relevant tests were included to demonstrate the power of the statistical analysis performed (Cohen effect size d; $d < 0.2$ insignificant, $0.2 \leq d < 0.5$ small, $0.5 \leq d \leq 0.8$ medium, $d > 0.8$ large effect size; Hedge effect size $r=0.1$ small, $r=0.3$ medium, $r=0.5$ large effect size) (Salkind and Green, 2005; Morgan et al., 2004). Throughout the entire statistical analysis, the level of statistical significance was accepted as $p \leq 0.05$.

FINDINGS

The aim of our study is to investigate the acute effects of WBV with different amplitudes and frequencies and flexi bar treatments on isokinetic shoulder internal and external rotator muscle strength. For this purpose, 4 separate protocols were implemented for 16 female handball players, in which they participated on a voluntary basis. Table 1 includes descriptive characteristics of the participants.

Table 1. Descriptive characteristics of the participants.

Variable	Mean ±SD (n=16)
Age	21.31 ±1.45
Heigth	162.37 ±27.03
Mass	69.47 ±28.21
BMI	26.81 ±6.87

BMI: Body mass index; SD: Standart deviation.

In order to reveal the pre-test-post-test acute effect of the treatments detailed in the method section, pairwise comparisons were made on three different parameters (maximum torque, work per repetition, average force per repetition) (Table 2). As a result of the statistical analysis of the pre-test-post-test difference, statistically significant decreases were found in the TVV and flexible bar treatments. A statistically significant decrease was observed in the mean strength value per repetition of the muscles performing internal rotation of the shoulder girdle before and after the 30 Hz 4 mm WBV treatments ($p<0.05$). In the 50 Hz 4 mm WBV application, a statistically significant decrease was observed in the maximum torque and average force per repetition values of the muscles that perform internal rotation of the shoulder girdle before and after the treatments ($p<0.05$). In the flexi bar treatments, statistically significant decreases were found in the maximum torque, work per repetition and average force per repetition values of the muscles that perform internal and external rotation of the shoulder girdle before and after the treatments ($p<0.05$). Accordingly, it can be said that 30 Hz 4 mm WBV treatments has an effect that reduces the average force value per repetition regarding the isokinetic shoulder internal rotation strength. It can be reported that 50 Hz 4 mm TVV treatment has an effect on isokinetic shoulder internal rotation strength, reducing the maximum torque and average force per repetition. It can be said that the flexible bar treatment caused statistically significant decreases in the maximum torque and average force per repetition values regarding internal isokinetic strength values, and in the maximum torque, work per repetition and average force per repetition values regarding external isokinetic strength values (Table 2).

Table 2. Pairwise comparisons of pre-test and post-test values for treatments.

Sessions	Variables		Pre test Mean ±SD (n=16)	Post test Mean ±SD (n=16)	Δ Mean ±SD	p	ES
Control	Maximum Torque	Int Rot	26.81 ±6.87	27.38 ±5.84	0,56 ±3,28	0,504	0,22[d]
		Ext Rot	17.32 ±4.90	17.31 ±4.54	0,00 ±3,40	1,00	1,05[d]
	Work per Repetition	Int Rot	45.00 ±11.11	46.19 ±12.96	1,18 ±10,38	0,654	0,25[d]
		Ext Rot	26.75 ±8.78	26.31 ±9.13	-0,44 ±6,80	0,800	0,25[d]
	Average Force per Repetition	Int Rot	20.13 ±5.48	20.56 ±4.35	0,43 ±2,87	0,552	0,18[d]
		Ext Rot	12.06 ±4.06	12.38 ±3.52	0,31 ±2,49	0,624	0,22[d]
Low WBV	Maximum Torque	Int Rot	29.56 ±9.08	28.43 ±7.85	-1,12 ±4,00	0,278	0,35[d]
		Ext Rot	18.25 ±3.68	17.88 ±4.60	-0,38 ±2,98	0,623	0,19[d]
	Work per Repetition	Int Rot	48.31 ±17.64	47.06 ±16.81	-1,25 ±8,25	0,554	0,33[d]
		Ext Rot	26.69 ±8.56	26.68 ±7.83	0,00 ±4,41	1,000	0,00[d]
	Average Force per Repetition	Int Rot	21.81 ±6.51	20.19 ±6.06	-1,62 ±2,94	0,043*	0,96[d]
		Ext Rot	12.69 ±3.05	12.37 ±2.68	-0,31 ±2,02	0,546	0,31[d]
High WBV	Maximum Torque	Int Rot	32.06 ±7.88	30.06 ±6.98	-2,00 ±3,34	0,022*	0,40[r]
		Ext Rot	16.06 ±3.25	16.37 ±2.80	0,31 ±2,18	0,575	0,27[d]
	Work per Repetition	Int Rot	55.56 ±14.55	52.37 ±12.50	-3,19 ±7,31	0,125	0,27[r]
		Ext Rot	24.37 ±7.43	24.25 ±6.70	-0,13 ±3,28	0,881	0,05[d]
	Average Force per Repetition	Int Rot	24.00 ±5.44	22.68 ±5.03	-1,31 ±2,60	0,026*	0,39[r]
		Ext Rot	11.37 ±2.82	11.37 ±2.47	0,00 ±1,41	1,000	0,00[d]
Flexi Bar	Maximum Torque	Int Rot	34.18 ±8.33	33.00 ±7.84	-1,19 ±2,16	0,045*	4,43[d]
		Ext Rot	16.68 ±4.72	13.18 ±3.58	-3,50 ±3,77	0,007*	0,48[r]
	Work per Repetition	Int Rot	59.31 ±16.73	56.31 ±13.44	-3,00 ±6,78	0,125	0,27[r]
		Ext Rot	24.06 ±10.03	19.13 ±7.53	-4,94 ±6,14	0,006*	1,05[d]
	Average Force per Repetition	Int Rot	25.75 ±6.93	24.38 ±5.30	-1,38 ±2,39	0,028*	0,39[r]
		Ext Rot	11.18 ±3.97	9.06 ±3.17	-2,13 ±2,50	0,004*	1,25[d]

SD: Standart deviation; Int Rot: internal rotation of the shoulder girdle; Ext Rot: external rotation of the shoulder girdle; Δ; absolute difference between pre-test and post-test; ES: unbiased effect size (Cohen's d; 0.2 = small, 0.5 = medium, 0.8 = large effect size Hedge's r = 0.1 small, r = 0.3 medium, r = 0.5 large effect size), WBV: whole body vibration, Low WBV: 30 Hz 4 mm WBV; High TVV: 50 Hz 4 mm TVV;
*p<0.05.

In order to determine the change in maximum torque values between treatments, the absolute differences of the pre-test and post-test values were compared pairwise and shown in Table 3. Accordingly, a statistically significant difference was found in internal isokinetic strength between the control session and the 50 Hz 4 mm WBV treatment. Accordingly, it can be said that the treatment of 50 Hz 4 mm WBV causes a decrease in the maximum torque of the internal rotator muscles. In the evaluation conducted in terms of maximum torque, a statistically significant decrease was observed between the control session and the flexible bar treatment, between the 30 Hz 4 mm TVV and the flexible bar treatment, and between the 50 Hz 4 mm TVV and the flexible bar treatment. According to this result, it can be said that the treatment of flexi bar causes a decrease in the maximum torque of the external rotator muscles (Table 3).

Table 3. Pairwise comparisons between treatments regarding maximum torque values of internal and external rotator muscles.

		Internal Rotator Muscles			**External Rotator Muscles**		
Sessions		**Δ Mean ±SD (n=16)**	**p**	**ES**	**Δ Mean ±SD (n=16)**	**p**	**ES**
Control	**Low WBV**	1,69 ±4,91	0,189	0,34[d]	0,38 ±4,31	0,733	0,33[d]
	High WBV	2,56 ±4,00	0,029*	0,38[r]	-0,31 ±4,19	0,770	0,16[d]
	Flexi-bar	1,75 ±4,27	0,122	0,35[d]	3,50 ±5,81	0,044*	0,36[r]
Low WBV	**High WBV**	0,88 ±4,58	0,598	0,10[r]	-0,69 ±4,67	0,565	0,04[d]
	Flexi-bar	0,06 ±4,12	0,952	0,03[d]	3,13 ±4,84	0,027*	0,39[r]
High WBV	**Flexi-bar**	-0,81 ±3,95	0,584	0,10[r]	3,81 ±4,08	0,006*	0,50[r]

SD: Standart deviation; Δ; absolute difference between pre-test and post-test; ES: unbiased effect size (Cohen's d; 0.2 = small, 0.5 = medium, 0.8 = large effect size Hedge's r = 0.1 small, r = 0.3 medium, r = 0.5 large effect size), WBV: whole body vibration, Low WBV: 30 Hz 4 mm WBV; High TVV: 50 Hz 4 mm TVV;
*p<0.05.

To determine the change in work values per repetition between treatments, the absolute differences of the pre-test and post-test values were compared pairwise (Table 4). Accordingly, when the muscles that rotate the shoulder girdle inward were taken into consideration, no statistically significant difference was found in terms of work values per repetition when the control session and the WBV and flexi bar treatments were compared bilaterally (p>0.05). According to this result, it can be said that WBV and flexibar treatments have no effect on the isokinetic force-work per repetition variable of the shoulder girdle internal and cephalic rotator muscles. However, when comparing WBV and flexible bar treatments, it can be said that WBV treatments (both 30 Hz 4 mm and 50 Hz 4 mm) have a statistically significant effect on the isokinetic force-work per repetition variable of the external rotator muscles that rotate the shoulder girdle outward compared to the flexible bar treatment (p<0.05). According to this result, it can be said that WBV treatments are more effective on the work done per repetition by the muscles that perform external rotation of the shoulder girdle compared to the flexi bar treatment, but neither WBV nor flexi bar treatments have any effect on the internal rotator muscles that perform internal rotation (Table 4).

Table 4. Pairwise comparisons between treatments regarding work values per repetition of internal and external rotator muscles.

		Internal Rotator Muscles			External Rotator Muscles		
Sessions		Δ Mean ±SD (n=16)	p	ES	Δ Mean ±SD (n=16)	p	ES
Control	Low WBV	2,43 ±10,4	0,364	0,02[d]	-0,44 ±8,11	0,832	0,12[d]
	High WBV	4,18 ±10,88	0,105	0,29[r]	-0,31 ±8,15	0,880	0,07[d]
	Flexi-bar	1,75 ±11,06	0,195	0,23[r]	4,50 ±9,99	0,092	2,19[d]
Low WBV	High WBV	1,93 ±9,71	0,485	0,12[r]	0,13 ±4,63	0,915	0,06[d]
	Flexi-bar	-0,19 ±7,91	0,979	0,00[r]	4,93 ±7,60	0,020*	1,63[d]
High WBV	Flexi-bar	-0,19 ±7,91	0,783	0,05[r]	4,81 ±6,45	0,009*	1,30[d]

SD: Standart deviation; Δ; absolute difference between pre-test and post-test; ES: unbiased effect size (Cohen's d; 0.2 = small, 0.5 = medium, 0.8 = large effect size Hedge's r = 0.1 small, r = 0.3 medium, r = 0.5 large effect size), WBV: whole body vibration, Low WBV: 30 Hz 4 mm WBV; High TVV: 50 Hz 4 mm TVV;
*p<0.05.

To determine the change in the average strength values per repetition between the treatments, the absolute differences of the pre-test and post-test values were compared pairwise and shown in Table 5. Accordingly, when the muscles that rotate the shoulder girdle inward were taken into consideration, no statistically significant difference was found in terms of the average strength values per repetition when the control session and the WBV and flexi bar treatment were compared bilaterally (p>0.05). According to this result, it can be said that WBV and flexi bar treatmnets have no effect on the isokinetic force-average force per repetition variable of the shoulder girdle internal rotator muscles. However, when the mean values of control, WBV and flexible bar sessions were compared statistically with each other in pairs, it was seen that flexible bar treatmenst were behind control and WBV treatmenst in terms of isokinetic force-mean force values per repetition of shoulder girdle external rotator muscles (p<0.05). According to this result, it can be said that flexi bar treatmenst have a negative effect on the average strength values per repetition of the muscles that make the shoulder girdle externally rotate, compared to control and WBV treatmenst, but neither WBV nor flexi bar treatmenst have any effect on the internal rotator muscles that make the shoulder girdle internally rotate (Table 5).

Table 5. Pairwise comparisons between treatments regarding the average strength values of the internal rotator muscles per repetition.

Sessions		Internal Rotator Muscles Δ Mean ±SD (n=16)	p	ES	External Rotator Muscles Δ Mean ±SD (n=16)	p	ES
Control	Low WBV	2,06 ±3,97	0,056	$2,64^{d}$	0,63 ±3,05	0,426	$0,00^{d}$
	High WBV	1,75 ±3,69	0,077	$0,31^{r}$	0,31 ±2,70	0,650	$0,21^{d}$
	Flexi-bar	1,81 ±4,47	0,139	$0,26^{r}$	2,43 ±4,00	$0,028^{*}$	$11,4^{d}$
Low WBV	High WBV	-0,31 ±3,79	0,736	$0,06^{r}$	-0,31 ±2,27	0,590	$0,30^{d}$
	Flexi-bar	-0,25 ±2,59	0,812	$0,04^{r}$	1,81 ±3,08	$0,033^{*}$	$1,74^{d}$
High WBV	Flexi-bar	0,06 ±3,11	0,811	$0,04^{r}$	2,12 ±3,03	$0,013^{*}$	$1,45^{d}$

SD: Standart deviation; Δ; absolute difference between pre-test and post-test; ES: unbiased effect size (Cohen's d; 0.2 = small, 0.5 = medium, 0.8 = large effect size Hedge's r = 0.1 small, r = 0.3 medium, r = 0.5 large effect size), WBV: whole body vibration, Low WBV: 30 Hz 4 mm WBV; High TVV: 50 Hz 4 mm TVV;
*p<0.05.

In the light of the findings, it can be said that, in general terms, WBV and flexi bar treatments have a negative effect on isokinetic strength components (maximum torque, work per repetition, average force per repetition).

DISCUSSION AND CONCLUSION

The aim of the study was to evaluate the effects of flexi-bar and whole body vibration (WBV) exercises at different amplitudes and frequencies on shoulder internal and external rotation strength. Examining the acute effects of WBV and flexi-bar training is crucial for optimizing exercise protocols and developing rehabilitation strategies.

In this study, a statistically significant decrease was found in the mean strength values per repetition of the muscles performing internal rotation of the shoulder girdle in the treatment of 30 Hz 4 mm WBV (p<0.05). This finding shows both parallels and differences with studies in the literature. In a study conducted by Naimi et al. (2016), it was stated that 30 Hz vibration application caused a decrease in the dynamic strength of the medial rotator muscles. This study demonstrates the potential for vibration to induce muscle fatigue, consistent with our findings. Lopes and Ejnisman (2023) reported that WBV increased muscle strength in extremities with shoulder instability, but provided limited benefit in stable extremities. This suggests that WBV acutely improves muscle strength in extremities with instability.

In our study, a statistically significant decrease was observed in the maximum torque and average force per repetition values in the muscles that perform internal rotation of the shoulder girdle in the 50 Hz 4 mm WBV application (p<0.05). Hand et al. (2009) reported that 10 weeks of vibration protocols combined with dynamic resistance training in a modified push-up position increased the isokinetic total work capacity of the rotator cuff muscles. These findings show that the effect of vibration treatment on the rotator cuff muscles may vary depending on the training method, frequency, amplitude and duration. The results of our study indicate that acute vibration training can cause muscle fatigue and that protocols combining resistance training and vibration training can improve muscle performance in the long term.

In our study, when flexi bar treatments were compared with control and WBV treatments (30 Hz 4 mm and 50 Hz 4 mm), it was seen that the shoulder girdle external rotator muscles were behind the control and WBV treatments in terms of isokinetic force-average force values per repetition ($p<0.05$). According to this result, flexi-bar treatments had a negative effect on the mean strength values per repetition of the muscles that perform external rotation of the shoulder girdle compared to control and WBV treatments, but neither WBV nor flexi-bar treatments had any effect on the internal rotator muscles that perform internal rotation of the shoulder girdle.

Lopes and Ejnisman (2023) evaluated the effects of acute WBV training on rotator cuff muscles in 10 athletes who underwent surgery for shoulder instability. Muscle strength in internal and external rotation movements was measured using isokinetic dynamometry at two different angular velocities (60°/s and 180°/s) in three different time periods (before, immediately after, and 10 minutes after WBV treatment). Participants were exposed to 30 Hz vibration for 30 seconds for 5 sets. Measurements were made on both unstable and stable extremities, and significant strength increases were observed in both movements and speeds in the unstable extremity, while increases were recorded only at certain speeds in the stable extremity. Lin et al. (2023) examined the effects of shoulder vibration exercises and traditional elastic resistance exercises on shoulder muscle strength and function. Both groups showed a significant increase in muscle strength, but no difference was found between the groups. The flexi-bar group increased throwing distance, but this did not create a significant difference between the groups. The findings suggest that shoulder vibration exercises may be an alternative option to traditional resistance exercises. Kim et al. (2021) examined the immediate effects of flexi-bar exercises on joint position sense and muscle activities in individuals with scapular winging. In a total of 18 participants, passive and active joint ositiın sense errors decreased significantly after KPP (knee push-ups) and FPK (knee push-ups and flexi-bar) ($p<0.05$). Surface electromyography measurements showed that serratus anterior and lower trapezius muscle activities were selectively increased during FPK, but there were no significant changes in the upper trapezius and pectoralis major muscles. These findings demonstrated that flexi bar exercises improved both passive and active proprioceptive control in individuals with scapular winging and supported scapular stabilization by increasing the activity of the serratus anterior and lower trapezius muscles. Kim et al. (2016) analyzed the effect of active vibration stimulus exercise on shoulder functionality and stability according to shoulder joint angles. Thirty male students were given exercises with flexi-bar at shoulder joint angles of 90° (Group I), 130° (Group II) and 180° (Group III). In the study, shoulder stability was evaluated using the Functional Reach Test and the Y-Balance Test. According to the analysis results, Group I showed more improvement than Group III in the Functional Reach Test; while Group II achieved better results than Groups I and III in the Y-Balance Test. In conclusion, flexi-bar training has been shown to be an effective tool for improving shoulder functionality and stability. These findings indicate that flexi-bar exercises are effective in improving shoulder stability and functionality and that exercise treatmnets can be optimized according to different joint angles. Flexi-bar exercises can be considered as an effective equipment in shoulder rehabilitation and sports performance development programs.

WBV applications (30 Hz and 50 Hz, 4 mm) were observed to cause significant decreases in strength in the internal rotator muscles of the shoulder girdle. This result supports the potential of vibration to induce muscle fatigue.

In flexi-bar treatmnets, lower performance was observed in the isokinetic strength of the shoulder girdle external rotator muscles compared to the WBV and control groups. However, flexi-bar training has been shown to support scapular stability and improve passive and active proprioceptive control. Flexi-bars can be considered effective equipment for long-term use in shoulder rehabilitation and sports performance enhancement programs.

The number of participants and the testing of only acute effects can be cited as limitations of the study.

In conclusion, the effects of WBV and flexi-bar training vary depending on frequency, amplitude, and duration of treatment. Both methods offer different potential for shoulder stability, muscle strength, and functionality.

Conflict of Interest: There is no conflict of interest between the authors.

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3.Author: %25

Information about the Ethics Committee Permission: Responsibility for any violations that may arise in the work done belongs to the author. Ethics committee approval of the article was obtained with the decision of Eskisehir Technical University Ethics Committee dated 29.04.2024 and numbered 19973.

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