Available Online at http://www.journalajst.com

ISSN: 0976-3376

ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

Asian Journal of Science and Technology
Vol. 14, Issue, 04, pp. 12455-12459, April, 2023

RESEARCH ARTICLE

EFFECTS OF FLEXI-BAR TRAINING ON MEASURES OF STRENGTH AND POWER OF UPPER LIMB MUSCULATURE IN RECURVE AND COMPOUND ARCHERS

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ARTICLE INFO

Article History:
Received 27th February, 2023
Received in revised form
10th March, 2023
Accepted 19th March, 2023
Published online 27th April, 2023

Keywords:
Biodex, Torque,
Vibration training,
Protocol, Sports.

ABSTRACT

Context: Experimental evidence suggests that mechanical vibration of low intensity (below 0.4 g) and low frequency (below 50 Hz) can be transmitted effectively through the human body. Thus, superimposition of such vibration to an active muscle has the potential to amplify the acute and chronic neuromuscular adaptations achieved during low-intensity exercise. **Aim:** To study the effects of sports specific flexi-bar training on strength and power of upper limb musculature in archers. **Methodology:** The total sample of 40 inter-university archers was selected for this study which consisted of, 20 recurve and 20 compound archers. The archers were than divided into 4 groups: Group A: Recurve Experimental, Group B: Compound Experimental, Group C: Recurve Control and Group D: Compound Control. Subjects were evaluated pre and post the training period (6 weeks) for strength and power of bilateral shoulder flexion-extension, abduction-adduction, internal-external rotation and elbow flexion-extension using Biodex system 3. **Results:** There was high statistically significant difference in the changes in strength and power of all the movements in group A v/s Group C and Group B v/s Group D with $p<0.05$. **Conclusion:** The Flexi-bar training increased the strength and power of all the movements of upper limb in both the experimental groups.

Citation: ***Amrinder Singh, Priya Gupta and Monika Sharma.*** **2023.** "Effects of flexi-bar training on measures of strength and power of upper limb musculature in recurve and compound archers", *Asian Journal of Science and Technology*, 14, (04), 12455-12459.

INTRODUCTION

Archery can be described as a comparatively static sport requiring strength and endurance of the upper body, in particular the forearm and shoulder girdle (Mann & Littke[9]). Pulling the bowstring by drawing the arm includes the elbow flexed by concentric contraction of biceps brachii and brachialis muscles, while the shoulder is extended by the strong concentric action of teres major, latissimus dorsi and posterior fibres of deltoid. The pectoral girdle is protected by concentric shortening of trapezius, rhomboid major and rhomboid minor. During the pushing movement of the bow by abduction and flexion of the shoulder, the shoulder is maintained in abduction by isometric contraction of the middle fibres of deltoid, and is then rapidly flexed by the anterior fibres of deltoid and pectoralis major, assisted by coracobrachialis and long head of biceps, all of which work concentrically (Palastanga, Field, & Soames, 2002). Experimental evidence suggests that mechanical vibration of low intensity (below 0.4 g) and low frequency (below 50 Hz) can be transmitted effectively through the human body (Rubin et al.[15]). Thus, superimposition of such vibration to an active muscle has the potential to amplify the acute and chronic neuromuscular adaptations achieved during low-intensity exercise (Milevaet al.[11]). Vibratory stimuli can be applied directly to the muscle belly (Jackson et al.[4]) or the tendon muscle (Luo et al.[6], Moran et al.[12]); indirectly applied by gripping a vibration system (Humphries et al.[3]), dumbbell (Chochrane et al.[2]), bar (Poston et al.[15]) or pulley system (Issurin et al.[4]), or whole body vibration (WBV), in which the stimuli enters via the feet while standing on a vibration platform (Mileva et al.[12]). Whatever the mode of vibration delivery or exercise, the intensity of the stimulus reaching the targeted muscle will be dependent on the transmission of the vibration stimulation through the human body (Wakelinget al.[18]). Therefore, in all vibration modalities, the proximity of vibration source to the target muscle is another important determinant of efficacy (Luoet al.[9]). To limit the impact of vibration damping, a number of training devices delivering direct or segmental low-frequency vibration have been developed. Flexi bar is 1 such device.

The flexi-bar (FB) is a double oscillating exercise device that generates vibrations and is effective in the control of nerve roots, muscle strengthening, and proprioceptive feedback (Schulte et al.[17]) It is made of an artificial material (special, reinforced glass thread), which was used in the research on flying and space flying. The grip located in the middle of the rod and the improvised weights that are placed on the ends are made of rubber (Zivkovicket al.[19]). Flexi-bar has length of 1.52 m and weighs 0.72 kg. Because of its elastic properties and weighted construction, Flexi bar is designed to resonate with a frequency of 5 Hz when vigorously moved through small amplitudes of movement, which the user has to maintain whilst remaining physically stable (Mileva et al.[11]). The vibrations are transferred to the body through the grips, along the arm and shoulder. A previous study reported that bridging exercises combined with FB exercises increases activation of the trunk muscle (Kim et al.[6]). Another study noted that this device generates higher levels of activation in the erector spinae muscle than that generated by a single oscillating device (Aroraet al.[1]).

Some of the previous studies have shown an increase in the muscle recruitment among the shoulder stabilizers while performing flexi-bar exercises. So the purpose of this study was to see the effect of sports specific flexi-bar training on the strength and power of the upper limb musculatures in archers. Flexi-bar is an easy to use device which can be implemented by the players in their training protocol and because of the mechanical vibrations caused by the flexi-bar; it has the potential to benefit the players by improving their strength and power with low intensity workout.

METHODOLOGY

Participants: Ethics approval for the study was taken from the Institutional Ethics Committee, Guru Nanak Dev University Amritsar, Punjab, India. The total sample of 40 interuniversity archers was selected for the purpose of this study. Inter-university level male and female archers were selected for the study. Subjects with "red flags" for a serious spinal condition (infection, tumors, Osteoporosis, spinal fracture, etc.); recent injuries to upper limb or spine, positive neurological sign and symptoms, suggestive of nerve root involvement (Diminished upper or lower extremity reflexes, sensations to sharp and dull and Strength); inflammatory or infective arthritis; peripheral neuropathy; upper motor neuron lesion; h/o recent upper limb or spinal surgery; systemic or psychiatric illness were excluded from the study.

Outcome Measures: Average peak torque was the measure taken for evaluation of strength while the average power was taken for the evaluation of power. Both the measurements were taken using Biodex system 3. The players were tested for strength and power of shoulder flexion-extension, abduction-adduction, and internal-external rotation and for elbow flexion extension bilaterally. For the purpose of evaluation, Biodex chair and dynamometer were arranged as per the recommendations for each movement. Isokinetic mode of testing was selected with the speed of 60° per second. The player had to perform 5 repetitions of concentric-concentric type of contractions.

Procedure: The nature of the study, procedure, benefits and potential risks were explained to the subjects in detail and those willing to participate were requested to sign a written consent form and it was ensured that the subjects were free of any musculoskeletal conditions or neurological dysfunction. Out of the total of 40 archers, 20 recurve archers were selected and 20 compound archers were selected. Convenient sampling with random allocation of subject using lottery method was used for division of archers into 2 main groups: Group 1: Experimental group and Group 2: Control group. Hence, in all 4 groups were formed: Group A: Recurve experimental (age=20.7±2.49 years, height= 172.1±8.15cm,weight= 57.9±6.5 kg),Group B: Compound experimental (age= 20.5±1.84 years, height=165.5±7.32 cm, weight=55.9±7.99 kg),Group C: Recurve control (age=21.2±1.93 years, height=169±6.48cm, weight=56.4±7.79 kg), Group D: Compound control (age= 21.9±1.1 years, height= 166.4±6.61 cm, weight= 60.1±5.21 kg) Pre readings for subjects of each group were taken within 2 week time period. While the post readings were taken within a week of completion of the training. Prior to the testing each subject was given a brief warm-up and was given time to get familiarized with the Biodex dynamometer. After that the players performed 5 repetitions of each movement at the settings mentioned above for the strength and power parameters. After this the archer was allowed to shoot some free shots at the target set at 18 meter distance (due to laboratory setting this distance was taken. It is also a standard distance for indoor shooting) to get the proper aim. The EMG electrodes were then placed on the assigned muscles along with the reflective markers. The archer then shot 3 arrows consecutively trying for the perfect aim.

Intervention: Once the pre readings were taken subjects of both the experimental groups i.e. Group A: Recurve experimental and Group B: Compound experimental were given a 3 days" time period to get familiarized with the flexi-bar. Following this both the groups underwent a 6 week long training program with the frequency of 3 sessions per week which consisted of vibrating the flexi-bar while holding the body and arm steady in certain postures. 3 repetitions of each posture were performed, each repetition lasting 1 min with a 30 seconds interval between 2 repetitions.

Statistical Analysis: The present study was conducted to see the effect of flexi-bar training: Group A and Group B against the control Group C and Group D on strength measured by average peak torque and power measured by average power in archers. The data was analyzed using SPSS 24 and Microsoft Excel. The data was assessed for normality using Shapiro wilk test as the sample size was below 50. The between group comparison of the outcome measures was done using Mann Whitney U test as the variables were not normally distributed. Level of significance was set at 5% with confidence interval.

Table 1. Intervention protocol

EXERCISE	BODY PART AFFECTED	BODY POSITION	SWINGING MOTIONS
Exercise 1	Chest and Back	Feet shoulder width apart. Loosely grip the flexi bar with both the hands and hold it in front of the body at roughly chest height, grasping the handle from above. Tuck chin into the throat.	Forward and backward
Exercise 2	Shoulder and upper back	Legs just more than shoulder width apart. Hold the flexi bar loosely with one hand parallel to the body, the arm stretched out from the body. Thumbs pointing forward.	Swing both in and out, while attempting to bring the arm farther behind the body [Change sides]
Exercise 3	Chest and shoulder girdle	Legs shoulder width apart. Hold flexi bar with both the hands in front of and vertical to the body	Backwards and forwards. While performing the training exercise, attempt to rotate the upper body to one side(Change side).
Exercise 4	Shoulder rotators and chest muscles	Legs shoulder width apart, hold the flexi bar with palms facing upwards (thumbs facing outwards). Keep shoulder blades low and elbows bent at 90	With a relaxed wrist, begin the movement directly in front. Forward backward movement
Exercise 5	Rotator cuff muscles – shoulder	Stand in lunge position left leg to the back, right leg to the front, heel not in contact with the floor. Hold flexi bar with hand facing outwards (thumb pointing upwards), extend the arm at shoulder height	Out and in. repeat other side (change legs as well as arms).
Exercise 6	Triceps	Left leg to the front, right leg to the back. Hold the flexi bar with both hands and straight wrists from above, thumbs pointing downward. Raise the arm above the head and bend at right angles. The thumbs pointing to the ceiling.	Up and down (keep elbows as close as possible)

RESULTS

Comparison of outcome measures between Recurve experimental and Recurve control groups: A very highly significant difference ($p<0.001$) was seen in the strength of almost all the tested movements when a comparison of changes in strength was done between Group A and Group C except, right shoulder extension which was also significant ($p=0.009$).

Table 2. Inter group comparison of changes in strength between Group A and Group C (recurve experimental v/s recurve control)

MOVEMENTS	HAND	GROUP A		GROUP C		U value	p value
		MEDIAN	IQ RANGE	MEDIAN	IQ RANGE		
Shoulder Flexion	Right	1.6	0.83	0.4	0.73	0	<0.001
	Left	1.9	0.68	0.3	0.75	0	<0.001
Shoulder Extension	Right	1.1	1.3	0.6	1.2	15.5	0.009
	Left	1.65	2.03	0.45	1.08	0	<0.001
Shoulder Abduction	Right	2.25	1.95	0	1.05	0	<0.001
	Left	2.3	1.35	0.15	0.93	0	<0.001
Shoulder Adduction	Right	2.4	1.05	0.15	1	0	<0.001
	Left	2.7	2.43	0.05	1.13	0	<0.001
Shoulder IR	Right	2.15	2.1	0.25	1.03	0	<0.001
	Left	2.85	1.9	0.35	1.13	0	<0.001
Shoulder ER	Right	2.3	2.23	0.3	0.9	0	<0.001
	Left	2.25	0.83	0.55	1.4	0	<0.001
Elbow Flexion	Right	5.45	2.03	0.25	0.73	0	<0.001
	Left	5.7	2.08	0.05	0.65	0	<0.001
Elbow Extension	Right	5.5	2.3	0.25	0.65	0	<0.001
	Left	6.25	5.13	0.15	0.48	0	<0.001

A very highly significant difference ($p<0.001$) was seen in all the tested movements when a comparison of changes in power was done between Group A and Group C. Comparison of outcome measures between Compound experimental and Compound control groups:

Table 3. Inter group comparison of changes in power between Group A and Group C (recurve experimental v/s recurve control)

MOVEMENTS	HAND	GROUP A		GROUP C		U value	p value
		MEDIAN	IQ RANGE	MEDIAN	IQ RANGE		
Shoulder Flexion	Right	1.7	0.63	0.45	0.33	0	<0.001
	Left	1.45	2.35	0.3	0.95	0	<0.001
Shoulder Extension	Right	1.95	5.43	0.4	1.05	0	<0.001
	Left	2.2	4.25	0.35	0.9	0	<0.001
Shoulder Abduction	Right	2.5	1.35	0.6	1.13	0	<0.001
	Left	3.4	1.8	0.55	0.93	0	<0.001
Shoulder Adduction	Right	2.8	5.15	0.35	0.98	0	<0.001
	Left	3.6	6.78	0.6	1.43	0	<0.001
Shoulder IR	Right	1.7	1.08	0.35	0.95	0	<0.001
	Left	2.05	0.73	0.5	0.78	0	<0.001
Shoulder ER	Right	2	1.63	0.35	0.93	0	<0.001
	Left	2.3	0.73	0.35	1.05	0	<0.001
Elbow Flexion	Right	5.65	1.73	-0.25	0.5	0	<0.001
	Left	6	1.58	0.2	0.53	0	<0.001
Elbow Extension	Right	5.8	2.45	0.3	0.63	0	<0.001
	Left	6.6	3.63	0.3	0.28	0	<0.001

A very highly significant difference ($p<0.001$) was seen in all the tested movements when a comparison of changes in strength was done between Group B and Group D.

Table 4. Inter group comparison of changes in strength between Group B and Group D (compound experimental v/s compound control)

MOVEMENTS	HAND	GROUP B		GROUP D		U value	p value
		MEDIAN	IQ RANGE	MEDIAN	IQ RANGE		
Shoulder Flexion	Right	6.5	0.4	-0.25	1	0	<0.001
	Left	6.8	0.78	-0.15	1.13	0	<0.001
Shoulder Extension	Right	9.2	1.93	-0.15	0.95	0	<0.001
	Left	8.4	1.1	-0.3	0.85	0	<0.001
Shoulder Abduction	Right	2.3	1.63	0.2	0.78	0	<0.001
	Left	2.6	2.73	0.5	1.03	0	<0.001
Shoulder Adduction	Right	2.5	2.35	0.2	1.2	0	<0.001
	Left	2.6	2.35	0.5	0.98	0	<0.001
Shoulder IR	Right	2.15	1.7	0	1.03	0	<0.001
	Left	2	1.13	0.3	1.15	0	<0.001
Shoulder ER	Right	1.7	0.7	0.05	0.93	0	<0.001
	Left	2.25	1.98	0.15	1.2	0	<0.001
Elbow Flexion	Right	5.6	3.15	-0.2	0.2	0	<0.001
	Left	5.15	1.5	0	0.63	0	<0.001
Elbow Extension	Right	6.95	3.93	0.15	0.73	0	<0.001
	Left	7.5	2	-0.1	0.93	0	<0.001

A very highly significant difference ($p<0.001$) was seen in all the tested movements when a comparison of changes in power was done between Group B and Group D.

Comparison of outcome measures between Recurve experimental and Compound experimental groups: A very highly significant difference ($p<0.001$) was seen in the strength of bilateral shoulder flexion and extension, when a comparison of changes in strength was done between Group A and Group B.

There was also a high statistical significance difference in the changes in power of Group A v/s Group B with the $p<0.001$ among shoulder flexion, with $p=0.015$ and $p=0.01$ among right and left shoulder extension movements respectively and with $p=0.021$ among the right shoulder abduction movement.

Table 5. Inter group comparison of changes in power between Group B and Group D (compound experimental v/s compound control)

MOVEMENTS	HAND	GROUP B		GROUP D		U value	p value
		MEDIAN	IQ RANGE	MEDIAN	IQ RANGE		
Shoulder Flexion	Right	6.3	0.45	-0.05	1.05	0	<0.001
	Left	6.85	0.73	0	0.8	0	<0.001
Shoulder Extension	Right	6.6	2.73	0	1.05	0	<0.001
	Left	6.5	2.28	-0.25	0.75	0	<0.001
Shoulder Abduction	Right	1.8	0.85	0	1	0	<0.001
	Left	2.55	0.9	-0.1	1.03	0	<0.001
Shoulder Adduction	Right	2.6	0.95	0.15	0.85	0	<0.001
	Left	2.25	0.92	0.3	0.98	0	<0.001
Shoulder IR	Right	2.15	1.9	0.35	0.93	0	<0.001
	Left	2.3	1.33	0.5	1.35	0	<0.001
Shoulder ER	Right	2.1	0.78	0.1	0.98	0	<0.001
	Left	1.9	0.63	0.15	0.95	0	<0.001
Elbow Flexion	Right	5.6	2.05	0.05	0.6	0	<0.001
	Left	5.1	1.9	0.05	0.7	0	<0.001
Elbow Extension	Right	8	4.4	-0.1	0.73	0	<0.001
	Left	7.5	1.93	0.05	0.63	0	<0.001

Comparison of outcome measures between the recurve and compound experimental groups

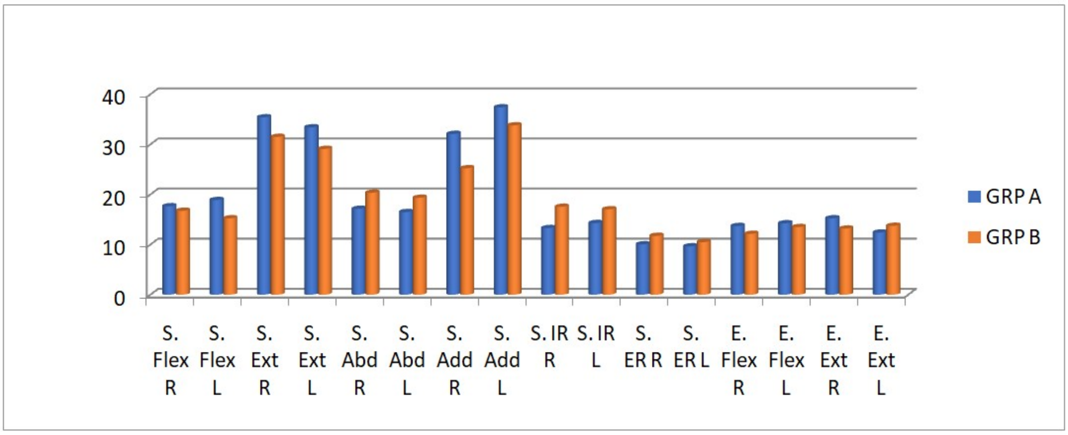

Figure 1. Comparison of change in strength between Group A & B

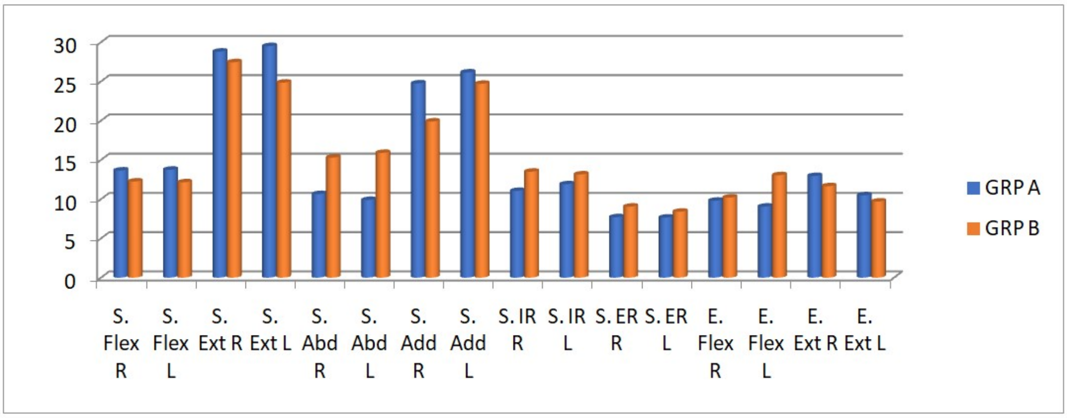

Figure 2. Comparison of change in power between Group A and B

DISCUSSION

Strength: When considering the inter group comparison across groups a highly statistical significant difference in the changes in strength was seen in all the movements in Group A v/s Group C and Group B v/s Group D ($p<0.01$). A high statistically significant difference was found in the changes in strength of bilateral shoulder flexion and extension movement in Group A v/s Group B comparison ($p<0.001$). Here, the median of the movements was higher in Group B.

Hence, it can be said that though both the experimental groups improved in strength when compared to their respective control groups, there was a greater effect of the training on Group B (compound experimental) in comparison to Group A (recurve experimental) in some movements. The findings of the present study are in agreement with a previous study conducted by Mileva et. al.[12]. They observed that after low-intensity exercise dynamic strength only increased after the superimposition of vibration. Therefore, it seemed that superimposing a vibration like stimulus during low-intensity exercise simulates the response induced by higher-intensity exercise.
Contradicting the results of the present study, Mileva et al.[11], in their previous study observed no change in the isometric elbow flexion or

extension strength after Flexi-bar exercise and implied that the Flexi-bar stimulus alone was not strong enough and/or the duration of the exercise was not long enough to result in significant residual changes in the post exercise performance of the arm muscles. However, a significant post exercise reduction in knee extension isometric strength was observed. It seems that the combination of unstable posture induced by the 1-legged squat and Flexi-bar exercise was sufficient to induce acute residual changes in leg muscle activation and performance. But in opposition to these results, the current study shows increase in strength of upper limb movements as result of flexi bar exercises. This may be due to the fact that in the present study the intervention was given for 6 weeks while in previous study acute effects were observed. It must also be noted that the present study evaluated the isokinetic strength of the movements (dynamic strength) while the previous study had taken isometric strength (static strength) as an outcome measure.

Power: During inter group comparison across groups a high statistically significant difference was observed in the changes in power of all movements in Group A v/s Group C and Group B v/s Group D ($p<0.001$). A statistical significance was found in the changes in power of bilateral shoulder flexion ($p<0.001$), bilateral shoulder extension and right shoulder abduction ($p<0.05$) in Group A v/s Group B comparison. Here the median of bilateral shoulder flexion and extension was higher in Group B while that of right shoulder abduction was higher in Group A archers. Hence, it can be concluded that though both the experimental groups improved in power as a result training when compared to their respective control groups, there was a greater improvement in power of some movements in Group B (compound experimental) and of some movements in Group A (recurve experimental) when compared to one another. The effects of the vibration training application (upon several weeks of persistent training) on explosive strength were demonstrated in many studies, whether they investigated jump height, stamina in explosive strength or mechanical power (Paradisis & Zacharogiannis 2007[14]). These studies show the positive effects of applying different exercises on the vibratory platform as opposed to the same exercises that are performed without the platform. The augmented power found, agrees with results of Issurin et. al.[4] who also found that acute superimposed vibration bilateral bicep curl increased peak power by 8% in male amateur athletes. Zivkovic et. al.[19], in their study indicated that vibration training does not give statistically significant effects on any of the analyzed values for the explosive strength of the lower limbs. The reason could be the insufficient frequency of 4.6 Hz produced by the Flexi-bar, because to activate the muscles most effectively, the frequency should be in the range of 30 to 50 Hz (Luo et. al.[8]). This study contradicts with the result of the present study but it should also be noted that the vibrations to the lower limbs muscles were applied indirectly, which in turn can influence the effects of the vibration training (Luo et. al.[8]) in the previous study, while in the current study the vibrations are being transmitted directly through the hand holding the flexi-bar.

CONCLUSION

The impact of these types of training on motor abilities, as well as on strength and power as one of the most frequently studied areas, have not been extensively explored. In particular, this refers to vibration training with low frequency, as with the Flexi-bar. The exercises that are performed during this type of training are of the isometric type, and rightfully there are doubts as to whether the frequency of 4.6 Hz is sufficient to achieve adequate muscle stimulation. The analysis of the obtained results shows that the use of vibration training with the Flexi-bar increases the strength and power of all the movements of upper limb in both the experimental groups. This means that the applied vibration muscle stimulation at 4.6 Hz with the use of flexi-bar does produce the expected effects. This also gives the possibility for new research to examine the effects of muscle vibration stimulation by the Flexi-bar, using different exercises, as well as a chance to explore the effects of longer interventions.

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