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Differences in Shoulder Muscle Activation during Flexi-bar and Dumbbell Exercise : a Pilot Study

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Abstract

Background: Shoulder muscles play a crucial role in various physical activities and daily functions, with the deltoid and upper trapezius being particularly significant. The Flexi-bar is an exercise tool that uses vibrations to effectively enhance muscle strength, cardiovascular fitness, and neuromuscular coordination. This study aims to compare the effects of Flexi-bar exercises on shoulder muscle activation with dumbbell training, and to provide foundational data for the design of shoulder muscle strengthening programs.

Design: Single-group repeated-measures design

Methods: Male participants with an average age of 22.5 years took part in this study. The lateral raise and shoulder press exercises were conducted using 1 kg and 3 kg dumbbells, as well as a Flexi-bar. Surface EMG was used to measure muscle activity during each exercise condition. The average and peak muscle activation of the anterior deltoid, middle deltoid, posterior deltoid, and upper trapezius were compared and analyzed.

Results: The Flexi-bar significantly increased the maximum activation of the posterior deltoid and upper trapezius compared to the 1 kg dumbbell condition during lateral raises($p<0.05$). During shoulder presses, the Flexi-bar condition demonstrated a significant increase in upper trapezius activation compared to both 1 kg and 3 kg dumbbell conditions($p<0.05$). However, the average muscle activation levels across the exercises did not differ significantly among conditions.

Conclusion: The Flexi-bar effectively enhances muscle activation of the posterior deltoid and upper trapezius compared to traditional dumbbell exercises. These findings suggest that incorporating the Flexi-bar into shoulder strengthening routines could be beneficial for improving muscle activation and stability.

Key words: flexibar, muscle activation, shoulder, strength

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Ⅰ. Introduction

Shoulder muscles play a crucial role in various exercises and daily activities, with the deltoid muscles and the upper trapezius being particularly emphasized. These muscles are essential for shoulder stability, range of motion, and functional movements of the upper body. Even a weakening of one muscle fiber can disrupt the length-tension relationship and muscle pairings, leading to muscle imbalances and reduced endurance, which may alter the scapulohumeral rhythm(Ebaugh & Spinelli, 2010). The scapular stabilizing muscles are generally the upper trapezius and the serratus anterior. Together, these muscles work to provide stability to the scapula(J. J. Lin, Wu, Wang, & Chen, 2005). Dysfunction and pain in the shoulder joint are known to occur when there is increased activity in the upper trapezius and decreased activity in the serratus anterior(Ludewig, Hoff, Osowski, Meschke, & Rundquist, 2004). aimed at strengthening the shoulder muscles come in various forms. Typically, resistance training with weights, such as dumbbells, is used. Typical exercises for shoulder muscle activation consist of the dumbbell shoulder press, side lateral raise, bent-over reverse fly, and upright row(Campos et al., 2020). The trapezius muscle is a large muscle that spans the upper back, neck, and shoulders, and is divided into three parts: the upper, middle, and lower portions. Each part plays a crucial role in various movements and postural maintenance. The upper trapezius is involved in elevating the shoulders and moving the head and neck. The middle trapezius pulls the scapula towards the spine, while both the upper and lower trapezius contribute to the upward rotation of the scapula(J. J. Lin et al., 2005).

Flexi-bar is an exercise tool designed with a specialized vibration rod, aimed at enhancing overall muscle strength and balance. This equipment was first introduced in Germany in the 1990s and has since spread globally. Flexi-bar exercises are known for their ability to stimulate a variety of muscles through simple movements, providing effective strength and core muscle enhancement(Mileva, Kadr, Amin, & Bowtell, 2010; Kim et al., 2024). Active vibration exercises using the Flexi-bar effectively deliver vibrational stimuli to the core muscles, intensively activating muscle spindles and enhancing proprioception and core muscle activity(Bogaerts, Verschueren, Delecluse, Claessens, & Boonen, 2007; Kim et al., 2014). Numerous studies using the Flexi-bar have reported increases in muscle strength, improvements in balance and stability, enhanced cardiovascular endurance, and better neuromuscular coordination(Choi, Chung, & Shim, 2015; W. Lin et al., 2023; Mileva et al., 2010). While previous studies have examined the effects of the Flexi-bar on muscle activation under single conditions, it is necessary to investigate how muscle activation responses differ depending on the type of exercise by comparing the Flexi-bar with commonly used dumbbell exercises, particularly in terms of upper limb muscle stimulation. Therefore, this study aims to compare the effects of Flexi-bar exercises on shoulder muscle activation with dumbbell training, and to provide foundational data for the design of shoulder muscle strengthening programs.

II. Methods

1. Recruitment of Participants

This study was conducted with male participants in their 20s enrolled at Andong Science College. After providing comprehensive information about the study, participants who voluntarily expressed their willingness to participate were recruited. Eligible participants were healthy males in their 20s who had no issues with exercise performance due to musculoskeletal or neurological damage in the past six months, and those who were excessively underweight or obese were excluded. This study was approved by the Institutional Review Board (IRB) of Andong science college(Approval No. HR-003-01). Prior to participation, all subjects were fully informed about the purpose and procedures of the study, and written informed consent was obtained. Participants' personal information was anonymized, and all data were used solely for research purposes.

2. Experiment Methods

1) Lateral Raise Muscle Activation Comparison

Lateral raise and shoulder press exercises were selected for this study as representative multi-joint movements of the shoulder, appropriate for systematically evaluating the activation patterns of the deltoid and upper trapezius muscles. Participants had electrodes attached to their anterior deltoid, middle deltoid, posterior deltoid, and upper trapezius muscles, and then performed the lateral raise exercise. The lateral raise exercise was performed under three different conditions(figure 1).

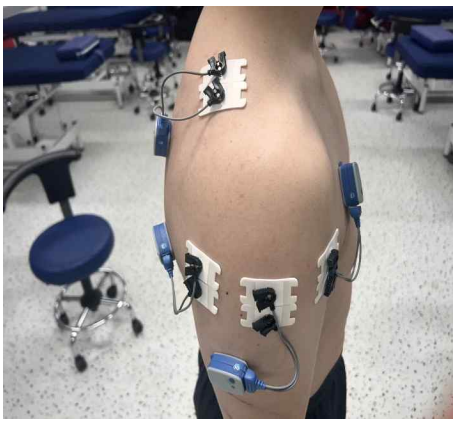

Figure1. Electromyography attachment

(1) 1 kg Dumbbell Lateral Raise

Participants stood with their feet shoulder-width apart and their bodies upright. They held a 1 kg dumbbell in their right hand and raised their arm to a position slightly below shoulder height. They

were instructed to lift their arm at a comfortable speed, ensuring it was neither too fast nor too slow, and to hold it for 3 seconds. This movement was repeated three times.

(2) 3 kg Dumbbell Lateral Raise

Participants used a 3 kg dumbbell and performed the lateral raise with the same posture and duration as in 1 kg Dumbbell. This was repeated three times.

(3) Flexi-bar Bar Lateral Raise

The Flexi-bar used in this study was 153cm in length and weighed 650g, and typically generates vibration stimulation at a frequency of approximately 5Hz during use. Participants raised the Flexi-bar to the same height as the dumbbell conditions and performed rapid, short oscillations inwards and outwards for 3 seconds. This was repeated three times. A 10-second rest was provided after each 3-second exercise period, and a 1-minute rest was given between conditions to minimize muscle fatigue(figure 2).

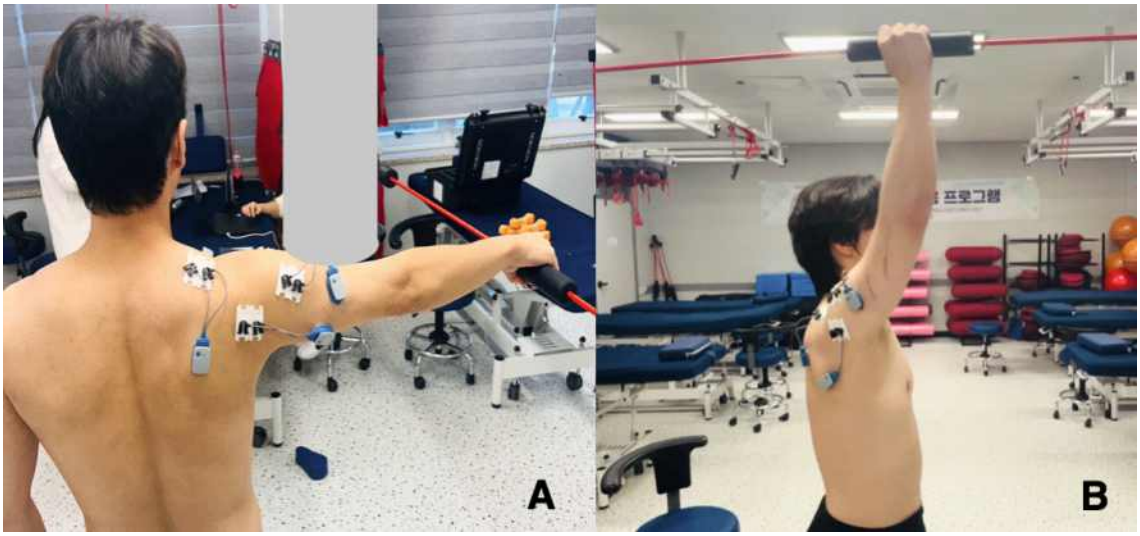

Figure 2. flexi-bar position

2) Shoulder Press Muscle Activation Comparison

Participants had electrodes attached to their anterior deltoid, middle deltoid, posterior deltoid, and upper trapezius muscles, and then performed the shoulder press exercise. The exercise was conducted under three different conditions:

(1) 1 kg Dumbbell Shoulder Press

Participants held a 1 kg dumbbell in their right hand and performed the shoulder press by lifting the dumbbell from shoulder height to overhead, extending their elbow. They completed 3 repetitions of the shoulder press, rested for 10 seconds, and performed 3 sets.

(2) 3 kg Dumbbell Shoulder Press

Participants used a 3 kg dumbbell and performed the shoulder press in the same manner as in 1 kg Dumbbell press, with 3 repetitions per set and 3 sets in total.

(3) Flexi-bar Shoulder Press

Participants used an adult Flexi-Bar, held in the right hand. They performed the shoulder press by

lifting the Flexi-bar from shoulder height to overhead while oscillating it up and down rapidly. This was done for 3 repetitions per set, with a total of 3 sets.

3. Outcome measure

Surface EMG signals were collected and directly compared between experimental conditions without normalization to a reference contraction. This approach was used to observe relative differences in muscle activity between exercise modalities, under the assumption that all measurements were conducted under consistent electrode placement, load, and posture conditions. Surface EMG signals were recorded using the Noraxon Ultium EMG 8-channel wireless system (Noraxon USA Inc., Scottsdale, AZ, USA), which provides high-fidelity muscle activity data with a sampling rate of 2000 Hz. The system offers wireless data acquisition with minimal signal noise, enabling accurate real-time monitoring during dynamic movements. The EMG equipment used in this study had a measurement range of 0–10,000 μV, with the study applying a narrower range of 0–500 μV. Although the system supported a maximum sampling frequency of 2,000 Hz, a sampling rate of 50 Hz was selected for data acquisition. The collected signals were analyzed using the MyoResearch XP EMG Analysis Suite. Electrode placements were based on the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) guidelines and were carefully aligned with the orientation of the muscle fibers. Specifically, electrodes were positioned as follows: on the anterior deltoid, approximately 2–3 cm below the clavicle over the thickest part of the muscle belly; on the middle deltoid, at the lateral aspect of the upper arm midway between the acromion and the deltoid tuberosity; on the posterior deltoid, about 2–3 cm below the spine of the scapula on the posterior surface of the shoulder; and on the upper trapezius, halfway between the acromion and the spinous process of the seventh cervical vertebra (C7), slightly oblique to the muscle fibers. In accordance with standard electromyography procedures, skin preparation—including shaving and alcohol swabbing—was performed prior to electrode attachment to ensure signal quality.

4. Statistical Analysis

The general characteristics of the study participants were described using means and standard deviations. To compare the differences in muscle activity under various experimental conditions, one-way analysis of variance (ANOVA) was used. Post-hoc comparisons were conducted using the LSD test. The statistical significance level was set at 0.05 or less.

III. Results

1. General characteristics of paticipants

The average age of the participants was 22.5 years, with an average height of 173.3 cm, an average

weight of 67.3 kg, and an average BMI of 22.3.

2. Comparison of shoulder muscle activation in lateral raise

Compared to the 1 kg dumbbell side lateral raise, the Flexi-bar condition resulted in a significantly higher maximum activation of the posterior deltoid(p<0.05). However, there were no significant differences in the activation of the anterior deltoid, middle deltoid, or upper trapezius between the two conditions.

Table 1. Participants' General Characteristics (n=14)

	Mean	SD
Age (year)	22.5	0.84
Height (cm)	173.3	4.88
Weight (kg)	67.3	1.93
Body mass index	22.3	1.93

Table 2. Comparison of Muscle Activation between Flexi-Bar and Lateral Raise Conditions (n=14)

		1kg dumbell raise (A)	3kg dumbbell raise (B)	Flexibar lateral raise (C)	f	p	Post hoc
mean amplitude	ant deltoid	26.83±8.86[a]	41.49±18.87	26.82±9.43	5.124	0.011*	B>A,C
	mid deltoid	27.42±12.01	42.33±19.75	36.54±17.18	2.859	0.069	B>A
	post deltoid	15.70±13.07	24.75±17.84	31.20±16.95	3.282	0.048*	C>A
	upper trapezius	38.82±19.56	71.44±36.82	48.16±25.39	4.972	0.012*	B>A
max amplitude	ant deltoid	80.10±35.72	115.76±52.50	107.55±62.24	1.770	0.184	
	mid deltoid	80.45±41.90	119.63±64.19	133.60±72.03	2.882	0.068	C>A
	post deltoid	48.62±41.85	76.46±55.59	142.87±77.23	9.112	0.001*	C>A,B
	upper trapezius	120.08±56.90	201.25±99.81	181.66±95.45	3.377	0.044*	B>A

[a]M±SD, *p<.05

3. Comparison of shoulder muscle activation in shoulder press

In comparison to the 1 kg and 3 kg dumbbell shoulder press conditions, the Flexi-bar press condition showed a significant difference in the maximum activation of the upper trapezius(p<0.05). Although the

analysis of variance did not reveal significant differences in the activation of the posterior deltoid, there was a significant difference between the 1 kg dumbbell shoulder press and the Flexi-bar press(p=0.027). There were no significant differences in the average muscle activation during the training period among the conditions.

Table 3. Comparison of Muscle Activation between Flexi-Bar and Shoulder Press Conditions (n=14)

		1kg dumbell raise (A)	3kg dumbbell raise (B)	Flexibar lateral raise (C)	f	p	Post hoc
mean amplitude	ant deltoid	46.81±22.67	52.84±39.11	51.72±41.06	0.084	0.920	
	mid deltoid	18.18±11.65	19.47±12.37	20.44±12.43	0.122	0.885	
	post deltoid	6.58±3.62	7.16±3.73	9.11±4.58	1.524	0.231	
	upper trapezius	43.23±26.46	49.65±20.95	51.55±27.35	0.418	0.661	
max amplitude	ant deltoid	154.73±106.63	178.23±110.44	285.00±188.63	3.119	0.056	C>A
	mid deltoid	66.24±31.17	69.03±43.24	95.52±45.02	1.945	0.157	
	post deltoid	18.85±8.59	21.07±14.60	42.82±27.87	5.845	0.006*	C>A
	upper trapezius	131.95±68.95	145.78±70.71	197.92±87.30	2.900	0.067	C>A

[a]M±SD, *p<.05

IV. Discussion

The exercise using the Flexi-bar significantly increased the maximum activation of the posterior deltoid and the upper trapezius in this study. This suggests that the Flexi-bar may enhance muscle activation by providing instability during exercise(Chung, Park, Kim, & Park, 2015; J. H. Kim et al., 2014). Unlike traditional dumbbells, the Flexi-bar requires the user to continuously adjust their balance during exercise, which emphasizes the stabilizing role of the muscles. As a result, the posterior deltoid and upper trapezius may exhibit higher activation compared to dumbbells. This can be explained by the mechanism where muscles exert more force in response to instability(Behm, Muehlbauer, Kibele, & Granacher, 2015).

The anterior deltoid and middle deltoid are primarily activated during forward arm raises and lateral abductions (Ebaugh & Spinelli, 2010). However, in the lateral raise condition of this study, no significant differences in activation were observed between the Flexi-bar and dumbbell exercises. This may suggest that the anterior and middle deltoid are either less sensitive to the instability introduced by the Flexi-bar or that the functional demands placed on these muscles do not significantly differ be-

tween the two exercise modalities. Another plausible explanation is the relatively low load intensity applied in both conditions. Since both the Flexi-bar and light dumbbells provide submaximal resistance, the stimulus may not have been sufficient to elicit distinguishable levels of muscle activation in the anterior and middle deltoid (Schoenfeld et al., 2016).

In contrast, the posterior deltoid plays a crucial role in shoulder external rotation and horizontal abduction, especially during movements that involve scapular stabilization and posterior chain engagement. Similarly, the upper trapezius contributes to maintaining shoulder stability (E. K. Kim & Kim, 2016). In the present study, the vibration stimulus provided by the Flexi-bar appears to have increased the neuromuscular demands for joint stabilization, resulting in greater activation of these muscles. Notably, the posterior deltoid exhibited significantly higher activation during Flexi-bar exercises compared to dumbbell exercises. This may be attributed to its role in dynamically counteracting the multidirectional instability generated by the vibrating bar. Unlike traditional dumbbell movements that primarily generate linear resistance, the oscillatory nature of the Flexi-bar likely required increased recruitment from posterior stabilizers to maintain movement control and shoulder joint integrity (박재철과 이동규, 2025).

The second experiment revealed that the Flexi-bar shoulder press significantly increased the maximum activation of the posterior deltoid and upper trapezius compared to both 1 kg and 3 kg dumbbell shoulder presses. This suggests that the Flexi-bar increases stabilization demands during the shoulder press exercise, thereby contributing to heightened activation of these muscles. The instability introduced by the Flexi-bar likely required additional neuromuscular control, particularly from the posterior deltoid and upper trapezius, to maintain shoulder and scapular stability (E. K. Kim & Kim, 2016; Lee, Kim, Park, & Park, 2018; Stanković et al., 2024).

On the other hand, it is interesting to note that no significant differences were observed in average muscle activation across conditions. While the Flexi-bar appears to elicit greater peak activation, this effect may be transient and not sustained throughout the entire movement. One possible explanation is that the momentary increases in activation caused by vibration were diluted when averaged over the duration of the exercise. Moreover, the number of repetitions and the relatively short measurement period in this study may have been insufficient to detect subtle but meaningful differences in average muscle activity across conditions.

Several limitations should be noted in this study. First, the relatively small number of participants used in the study may limit the generalizability of the results. As this study was conducted as a preliminary experiment, data was collected from a relatively small sample size. Second, this study was limited to healthy male participants in their twenties, which may reduce the generalizability of the findings to other populations. Third, there is a lack of analysis regarding long-term training effects, thus further studies on the long-term effects and adaptations to the Flexi-bar are necessary. Therefore, future studies should include participants with more divers age group and genders, and investigate long-term effects to improve the applicability and external validity of the results.

V. Conclusion

The Flexi-bar was effective in increasing the maximum muscle activation of the posterior deltoid and upper trapezius compared to lateral raises and shoulder presses using dumbbells. If the goal is to enhance the activation of overall shoulder muscles rather than targeting specific muscles, using the Flexi-bar should be considered as a priority.

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