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Effects of Sling Forearm Plank Exercises on Superficial Back Line Muscle Tone and Stiffness

Background : Although plank exercises is reported to the changes in muscle activity of the deep muscles and superficial muscles among the core muscles. However, no study has examined the effects of forearm plank exercise on tone and stiffness in the superficial back line muscle.
Objective: To compare the effects of sling forearm plank exercises and mat forearm plank exercises on the superficial back line muscle tone and stiffness.
Design: Randomized controlled clinical trial (single blind)
Methods: The subjects were randomized to sling forearm plank exercise group (N = 8) or mat forearm plank exercise group (N = 8). The measurements were taken for each research group following exercises: the muscle tone and stiffness of upper lumbar muscles, lower lumbar muscles, long head of biceps femoris, and medial part of gastrocnemius among the superficial back line muscles.
Results: Sling forearm plank exercise group Indicated statistically significant increases in stiffness of medial part of gastrocnemius ($p<.05$). However, mat forearm plank exercise group reported no statistically significant in muscle tone and stiffness of all measured muscles. No significant differences in measured variables were found between the groups.
Conclusions: These results suggest that the forearm plank exercise performed with an unstable surface in the defined sling can increase the stiffness of calf muscle, but it is unlikely to achieve increases in muscle tone and stiffness of the overall superficial back line muscles.

Key words: *Plank Exercise; Muscle Tone; Sling; Stiffness; Superficial Back Line Muscle*

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INTRODUCTION

Plank exercise is one of the most effective exercise methods used for core muscle training [1]. In general, the purpose of plank exercise is core stability [2], endurance of core muscle, alignment of body [3], and injury prevention [1]. Forearm plank induces isometric co-contraction of the body front part and back part muscle. The back muscles act on postural alignment and trunk extension and are characterized by myofascial continuity [4], which is referred to as the superficial back line. Most of the skeletal muscles of the human anatomy are attached continuously by connective tissues [5]. In particular, fascial tissues are connected throughout the body by the anatomy chain [6]. The superficial back line constitutes kinematic myofascial chain muscles that extend from plantar fascia of the foot to gastrocnemius/achilles tendon, hamstring muscle, sacrotuberous ligament, erector spinae muscles, occipitalis, galea aponeurotica, and frontalis muscle [4]. The superficial back line is thus composed of myofascial connections. This fascial line extends across the primary curve and secondary curve in the spine and affects the upright position [4].

Any tension that occurs in a specific myofascial line can affect adjacent myofascial structures [6]. However, research on the correlation between the muscle tone and stiffness of each muscle in the myofascial chain of the superficial back line is currently lacking. Myofascial continuity while

performing plank exercises is speculated to affect the muscle tone and stiffness of the muscles for this particular exercise, as well as the surrounding myofascial structures.

Movement difficulty during plank exercise varies based on the positions of the arms and legs and by the plank posture (prone, side-lying, supine) assumed [7]. The clinically used slings for core muscle training are characterized by their unstable support surfaces due to suspension. Previous studies have reported on plank exercises and the changes in muscle activity of the deep muscles and superficial muscles among the core muscles [2, 7, 8]. However, no study has examined the effects of forearm plank exercise on tone and stiffness in the superficial back line muscle. In this study, the effect of increasing body back part muscle tone and stiffness after forearm plank exercise will be very useful for physical therapist and athletic trainer.

SUBJECTS AND METHODS

Subjects

A total of 16 subjects participated and were randomly distributed into the sling forearm plank exercise group (n = 8) and the mat forearm plank exercise group (n = 8). Subject selection conditions included the absence of spine disorders, deformities, diseases, and neurological disorders. Those who performed jogging, weight training, or stretching exercises in the past five days were also excluded. Only those who sufficiently understood the purpose and method of the research and who signed the consent form were selected as subjects. The age, height, and weight of the sling plank exercise were 19.75±1.39 years, 171.13±3.23cm, and 66.63±6.16kg, respectively. The age, height, and weight of the mat plank exercise were 20.50±1.60years, 177.00±4.11cm, and 69.00±6.72kg, respectively.

Outcome measures and procedures

Sling forearm plank exercise

For the starting position, subjects flexed their elbow joints at 90 degrees with forearms supported by the floor and both upper arms spread shoulder-width apart, exhibiting scapular protraction [9, 10]. Both ankles of subject were suspended on the sling at shoulder height with subjects' knees fully extended. The subjects' exercise postures were set so that the alignment from head to foot was straight and parallel to the floor. The researchers guided the subjects to maintain exercise posture. The exercise frequency was a total of three sets performed, with one set consisting of maintenance for 30 seconds [11] and 60 seconds of resting time.

Mat forearm plank exercise

For the starting position, the subjects had the elbow joint 90 degree flexion, supporting the forearm on the floor, both upper arm spread shoulder-width apart, scapular protraction, both foot spread pelvis-width apart, pelvic neutral position, knee full extension. The subjects' exercise posture were aligned from head to foot [9, 10]. The researchers guided the subjects to maintain exercise posture. The exercise frequency for the mat forearm plank exercise was the same as that of the plank exercises using the sling forearm plank exercise.

Muscle tone and stiffness

In this study, the subjects' muscle tone and stiffness were determined using the highly reliable Myoton®PRO (MyotonAS, Estonia) [12]. All measures were performed in the dominant limb side before and after exercises.

The point of measurement for each muscle was set to the highest point of the muscle belly of the erector spinae, which is parallel to the dominant side, based on the spinous process of upper lumbar (UL) and lower lumbar (LL) muscles as measurement points for each muscle [13]. The measurement points for biceps femoris (BF) muscle [14] and medial part of gastrocnemius (MG) muscle [15] were also set to the highest points of the muscle belly for each one. The researcher indicated the measurement points of each muscle measured using a mark on the skin.

The measurement positions of each muscle were adjusted to prevent unnecessary expressions of muscle tone or stiffness by supplying a pillow for support below the ankles in the prone position. Furthermore, the researcher placed Myoton®PRO vertically over the skin marker [12]. Each measurement was performed twice for each muscle, and the mean of the data was used in the results. All measurements were performed by a single physical therapist.

Data and Statistical analysis

In this study, The Windows version of SPSS 23.0 was used for statistical data analysis. The subjects' general characteristic was independent t-test was conducted to verify homogeneity between the two groups. The Kolmogorov-Smirnov test was employed to test the normal distribution in each group. The

paired t-test was conducted to analyze differences in superficial back line muscle tone and stiffness of each muscle measured after exercise in each group. The independent t-test was used to analyze inter-group differences. All statistical significance levels in this study were set at $\alpha = .05$.

RESULTS

After exercise, sling forearm plank exercise group Indicated statistically significant increases in stiffness of MG muscle ($p<.05$). However, mat forearm plank exercise group reported no statistically significant in muscle tone and stiffness of all measured muscles (Table 1). No significant differences in measured variables were found between the groups.

Table 1. Change of muscle tone and stiffness on the superficial back line muscles in each group

Variable		Sling forearm plank exercise		Mat forearm plank exercise	
		Before	After	Before	After
Upper lumbar muscle	Muscle tone(Hz)	15.21±1.19	14.88±1.66	15.79±1.42	15.94±1.80
	Stiffness(N/m)	278.50±43.42	266.94±45.66	288.75±49.38	302.63±61.84
Lower lumbar muscle	Muscle tone (Hz)	14.10±1.04	15.24±1.19	14.54±.94	14.74±1.51
	Stiffness(N/m)	220.81±32.75	296.19±93.41	242.81±55.61	252.31±67.49
Long head of biceps femoris muscle	Muscle tone(Hz)	15.36±1.08	15.58±1.37	15.31±1.53	15.90±2.40
	Stiffness(N/m)	276.38±29.20	284.31±37.29	268.50±35.86	278.31±50.09
Medial part of gastrocnemius muscle	Muscle tone(Hz)	15.33±1.84	15.86±1.89	16.66±2.00	16.84±1.52
	Stiffness(N/m)	273.56±33.95	277.63±33.52*	280.19±41.82	280.69±36.48

Values are means ± standard deviation
*Significant difference between before and after exercise in each group ($p < .05$)

DISCUSSION

The human's muscle tone and stiffness can increase or decrease according to the exercise methods [13, 16]. A previous study reported that the close chain exercise increased muscle tone and stiffness [16] but decreased the muscle tone of the lumbar region during static prone suspension of the whole body [13].

In this study, the stiffness of MG muscle was significantly increased after completing the sling forearm plank exercise ($p < .05$). The muscle tone and stiffness of all muscles measured increased after mat forearm plank exercise, but these results, however, were not statistically significant. This study assumed that the muscle tone and stiffness of the myofascial structures in the superficial back line would extend to the adjacent myofascial structures following forearm plank exercise, but no significant change was observed. This result suggests that use of the sling increases MG muscle stiffness more than use of the mat does and that it improves postural instability due to suspension. Mat forearm plank exercise supports the body with both the forearm and toes on a stable surface, but sling forearm plank exercise requires more stiffness of MG muscle than the stable surface because it suspends both ankles with the sling. To compare muscle activity in the healthy superficial back line, the LBP patient has less muscle activity for the erector spinae of the lower back region during active plantar flexion and active neck extension [17]. The muscle tone and stiffness of rectus femoris muscle and vastus medialis muscles on the injured area in a patient with a knee injury may increase depending on the pain released [18]. This study cannot verify muscle tone and stiffness results of the superficial back line in patients with musculoskeletal conditions because the subjects of this study were all healthy males.

Ekstrom et al. [2] determined the muscle activity of each muscle in the superficial back line in subjects performing mat forearm plank exercise and found no significant change in the muscle activity of longissimus thoracis muscle, lumbar multifidus muscle, or hamstring muscle following the completion of the

exercise. This study similarly found no significant changes in muscle tone or stiffness for any of the muscles measured after mat forearm plank exercise performance. Similar results produced in previous studies confirm that performing plank exercises in the static position does not increase muscle tone or stiffness in any of the muscles in the superficial back line.

In contrast, Carlson et al. [19] did find a correlation in tension between the plantar fascia and achilles tendon in the dorsiflexion of the metatarsophalangeal joint. From this, it can be conjectured that the muscle tone and stiffness of each muscle in the superficial back line can be changed if the arms or legs are engaged in active movement during mat forearm plank exercise.

Expanding the interpretation of the study by Carlson et al. is somewhat limited, however, because the present study does not measure the muscle tone and stiffness of those performing the exercises in an active range of motion, but rather only in the resting position.

The present study does verify that plank exercises are able to improve muscle tone and stiffness by differentiating from previous studies that instead focus on muscle activity.

CONCLUSION

Based on the results of this study, performing forearm plank exercise with a sling suspension on an unstable support surface can increase the stiffness of MG muscle. However, it is unlikely to produce an increase in muscle tone and stiffness of the upper and lower lumbar segments in healthy subjects.

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