EFFECTS OF 12-WEEK GAIT RETRAINING ON THE MORPHOLOGY OF MEDIAL GASTROCNEMIUS

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The purpose of this study was to investigate the effects of 12-week gait retraining on the morphological properties of medial gastrocnemius. Thirty-four male habitual rearfoot strike runners were recruited and randomized divided into gait training group and control group. The medial gastrocnemius morphological properties were measured using an ultrasound device before and after training. A two-way repeated measures ANOVA (group × time) was used for analysis. The significance level was set as 0.05. The results found that after 12-week gait retraining, there was no significant group main effect and interaction effect for all parameters. A main effect of time was observed in the fascicle length (p = 0.016) and normalized fascicle length (p = 0.026). After training, the fascicle length for the GR and CON groups significantly increased by 8.5% (GR) and 2.2% (CON), and the normalized fascicle length increased by 8.8% (GR) and 2.0% (CON). It was indicated that both gait retraining and running training effectively increase the fascicle length of the medial gastrocnemius, thereby providing potential means of increasing the velocity of muscle contraction and reducing the risk of a calf strain while running.

KEYWORDS: gait retraining, medial gastrocnemius, ultrasound, morphology.

INTRODUCTION: With the vigorous development of the marathon, long-distance running has become one of the most popular sports around the world. During running, the medial gastrocnemius plays an important role. As one of the largest contributors to the propulsion stage of the stance phase, medial gastrocnemius morphology was highly correlated with running economy (Arampatzis *et al*., 2006). Meanwhile, muscle morphology (fascicle length, muscle thickness, pennation angle) was a major determinant of muscle function (Murach *et al*., 2015). The influence of fascicle length on the force-velocity relationship may lead to changes in muscle function. Timmins (2016) reported that the architectural characteristics of muscle not only affect the maximal output of force, but also the contraction velocity and risk of injury.
In recent years, foot strike patterns and gait retraining (GR) have attracted widespread attention from runners, trainers, and therapists. Compared with rearfoot strikers, the levels of muscle activation of forefoot strikers in the medial gastrocnemius and lateral gastrocnemius were higher, and the level of muscle activation of forefoot strikers in the tibialis anterior was lower (Ahn *et al*., 2014). At the same time, the preliminary study of our team showed that after 12-week GR the activation of triceps surae and Achilles tendon force significantly increased during running (Zhang *et al*., 2019). Compared to the rearfoot striker, the peak plantarflexion torque of the forefoot striker was higher during the stance phase, namely a higher triceps surae loading (Gonzales *et al*., 2019). As a result, we speculated that the increased mechanical load of gradual GR might lead to the morphological adaptation of the medial gastrocnemius to potentially improve running performance and reduce muscle damage. However, few studies have focused on the changes in muscle morphology after GR.
Thus, the purpose of this study was to explore the effects of 12-week GR on the morphology of medial gastrocnemius.

METHODS: Thirty-four healthy male rearfoot strike runners were recruited and randomly divided into the GR group (n=17) and control (CON) group (n=17).
During the first visiting, the basic information was recorded and the training plan was determined according to the group and weekly running distance. After the warm-up, the morphological properties and shank length were measured. After completion of a 12-week training intervention, the above tests were executed again.

The fascicle length, pennation angle, and thickness of the medial gastrocnemius were obtained by ultrasound device (Terason, uSmart 3300) before and after training. The participants were asked to lay prone on the treatment bed with the hip fully extended, the knee fully extended, and their ankles in a neutral position (the angle between the shank and the foot was 90°). The US probe was positioned vertically at 30% of the distance between the popliteal crease and the lateral malleolus (Geremia *et al*., 2019). Three ultrasound images of the medial gastrocnemius muscle were recorded for each participant. The ultrasound image was analyzed via ImageJ software (NIH, USA). Shank length (from medial tibial condyle to the medial malleolus of the ankle) was assessed using a measuring tape, and the participants were asked to seat with their ankle in the neutral position and their knee and hip flexed at 90° at the same time (Deng *et al*., 2021). The normalized fascicle length was the fascicle length divided by the shank length. Participants in the GR group were asked to wear minimalist shoes (INOV-8 BARE-XF 210 V2, average mass of 227 g, 3 mm total sole thickness, no midsole, and heel-toe drop 0 mm) with a forefoot strike at a moderate self-selected speed during training (Figure 1), 3 times per week for 12 weeks. The volume of running was determined by the percentage value of the participants' original weekly running volume, and the percentage value was gradually increased from 10% to 100%. The intervention training only partly substituted for the running distance, and the overall weekly running volume was consistent with the original weekly running volume. They were allowed to complete the remaining running distance outside of training with their habitual training intensity and strike pattern. Participants in the CON group were required to run in their own running shoes with the original foot strike patterns and intensities for 12 weeks.
A two-way ANOVA (group × time) was used to determine the effects of the 12-week GR on the dependent variables. When an interaction between time and group was observed, a simple effect was applied as post hoc analysis. The significance level was set as $\alpha = 0.05$.

Figure 1: INOV-8 Bare-XF 210 V2

RESULTS: Twenty-nine participants completed the intervention and met the inclusion criteria, with a dropout rate of 14.7%, the basic information of the participants completing the training program was shown in table 1.

Table 1: Mean±SD data for basic information of participants.

Group	n	Age (years)	Height (cm)	Weight (kg)	Weekly running volume (km)
GR group	14	34.43±8.34	173.36±6.73	70.39±8.33	39.29±14.26
CON group	15	32.27±9.87	172.97±5.28	67.77±9.70	40.73±23.45
P value		0.531	0.863	0.443	0.844

All parameters had no significant interaction between time and group. However, a significant time effect was observed in the fascicle length ($p = 0.016$) and normalized fascicle length ($p = 0.026$). After training, the fascicle length significantly increased by 8.5% (GR) and 2.2% (CON), and the normalized fascicle length increased by 8.8% (GR) and 2.0% (CON), there was no significant effect of group (p = 0.108). There were no significant main effects for group or time observed in pennation angle and thickness (Table 2).

Table 2: Mean±SD data for the morphological difference of medial gastrocnemius before and after training.

Parameter	GR group		CON group		*P* value		
	Pre	Post	Pre	Post	Time main effect	Group main effect	Interaction effect
FL (cm)	6.51± 0.67	7.04± 0.73*	6.27± 0.95	6.36± 0.88*	0.016	0.108	0.076
PA (°)	18.90± 1.95	18.23± 1.94	18.57±2 .77	18.09±2 .31	0.098	0.762	0.792
TK (cm)	1.83± 0.28	1.83± 0.26	1.75± 0.29	1.68± 0.25	0.363	0.217	0.415
Normalized FL	0.19± 0.03	0.21± 0.03*	0.19± 0.03	0.19± 0.03*	0.026	0.291	0.105

Note: * indicates a significant difference between before and after the training (p < 0.05). MG is the medial gastrocnemius, FL is the fascicle length of the MG, PA is the pennation angle of the MG, TK is the thickness of the MG.

DISCUSSION: In this study, the effects of 12-week GR on the morphology of the medial gastrocnemius were investigated. Fascicle length and normalized fascicle length of the medial gastrocnemius had a main effect of time. However, no significant interaction and main effect were found in pennation angle and muscle thickness.

The medial gastrocnemius is one of the important contributors to the propulsion during the extension phase of running. Its muscle bundles rotate around the starting point, and the muscle bundles shorten while the pennation angle becomes larger (Narici *et al*., 1996). This study found a significant increase in fascicle length in both groups after training. Specifically, the fascicle length and normalized fascicle length increased by 8.5% and 8.8% in the GR group, while it increased by 2.2% and 2.0% in the CON group. It was reported that fascicle length is a major factor in dictating muscle contraction velocity (Wickiewicz *et al*., 1984), the longer the fascicle length, the greater the maximum velocity of contraction (Abe *et al*., 2000). It suggested that adaptive changes in the medial gastrocnemius after training may play an important role in increasing the velocity of contraction, yet this may require further investigation. Moreover, possessing shorter fascicles increased the likelihood of microscopic muscle damage during the repetitive eccentric actions of running (Timmins *et al*., 2016). Therefore, from the perspective of muscle morphology, GR could reduce the probability of calf strain caused by lengthening fascicles. Moreover, there was a tendency for the pennation angle to decrease after training in this study (p < 0.1). The pennation angle of the muscle negatively correlates with the transmission efficiency of muscle force. Thus, we speculated that GR is beneficial to improve the force transmission efficiency during the running, reduce the loss of energy consumption, and thus improve the running economy.

CONCLUSION: In this study, the effects of 12-week GR on the morphology of the medial gastrocnemius were investigated. The results showed that the fascicle length of the medial gastrocnemius for both groups increased after training. The result indicated that GR and running training could effectively increase the fascicle length of the medial gastrocnemius and provide a potential means of increasing the velocity of muscle contraction and reducing the risk of a calf strain during running.

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