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EMG for the Ratio of the Vastus Lateralis and Vastus Medialis in Treadmill Running

Keiichi Tsuji[*], Hiroyasu Ishida, Yuichiro Fujihashi, Tsutomu Ueki, Yoshihito Tajima, Kaori Oba

Division of Physical Therapy, Department of Rehabilitation, Heisei College of Health Sciences, Kurono, Gifu, Gifu, Japan

Email address

k.tsuji@heisei-iryou.ac.jp (K. Tsuji)
[*]Corresponding author

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Abstract

To compare the changes in muscle activity with changes in running speed using the activity ratio of the vastus medialis (VM) and vastus lateralis (VL) muscles. The subjects performed on the treadmill at speeds of 6 km/h, 9 km/h, and 12 km/h. Their myogenic potentials were measured after 5 minutes of running for 30 seconds. The order of running speed was chosen at random. Ten running cycles in 30 seconds were selected. The measured myogenic potential data of VM were divided by those of VL (VM/VL). The average VM/VL %MVCs were compared to those during walking and during running at 6, 9, and 12 km/h, with significant differences between the average VM/VL %MVC at 6 (2.4±0.7) km/h and at 9 (1.0±0.1) and 12 (1.0±0.1) km/h. The average VM/VL %MVC values suggested that VM activity was dominant during walking and running at 6 km/h. During running at 9 and 12 km/h, there appeared to be no dominance, with equivalent VM and VL activity.

1. Introduction

Running is a simple, accessible form of exercise, but many runners have difficulty running long distances because they lack specialized knowledge and adequate training. Long distance running easily fatigues the lower limb muscles [1-3]. There are various types of running injuries; a typical example is patellofemoral pain syndrome (PFPS). According to a survey by Taunton et al., the most common injury in 2002 runners was PFPS [4] in 26 cases. The most common overuse injury was PFPS, followed by iliotibial band syndrome, planter fasciitis, meniscal injuries, and patellar tendinopathy. Although the etiology of PFPS remains unclear, an imbalance of vastus medialis (VM) and vastus lateralis (VL) muscle activity has been suggested as a possible cause. The quadriceps muscle extends the knee with an anti-gravity position supporting the weight; this is not limited to running. The VM runs from Medial lip of linea aspera through the patellar ligament and has an important role in the protection and support of the knee joint, suppressing outside excursion of the patella. Therefore, the VM likely functions to prevent failure of the knee, and proper training of the VM can likely reduce failure while running. However, the VM generally works in collaboration with the VL, making it difficult to promote selective enhancement. Therefore, since it is difficult to promote selective contractions of the VM, it is necessary to understand its movement. To determine the activities of the VM during exercise, Yagata [5] has stated that it is more important to examine activities resulting in high VM/VL activity ratios, rather than high VM activity.

VM/VL activity ratios during running have not been investigated. Since the exercise load during running varies with running speed, one must consider activity ratios at various speeds. The present study aimed to investigate VM/VL activity ratios during running at 6, 9, and 12 km/h compared to walking.

2. Methods

Fifteen male students without leg injuries (age, 20.1 ± 1.3 y; height, 171.1 ± 0.1 cm; weight, 64.4 ± 5.4 kg; BMI, 22.0 ± 1.4 kg/m^2) provided their written, informed consent to participate after receiving an oral and written explanation of the study and its purpose. The Ethics Review Board at Heisei College of Health Sciences approved this study (No. H25-53). The participants did not routinely run, but they participated in recreational sports once or twice each week. Muscle activity was measured by surface electromyography using a TELEMYO-G2 and MYO Research XP (Noraxon USA Inc., Scottsdale, AZ, USA) with disposable M-00-S Blue Sensor polymer electrodes (Ambu A/S, Ballerup, Denmark) attached to the belly of the muscle while the participants moved on a Gait Training System 2 treadmill (Biodex Medical Systems Inc., Shirley, NY, USA). Muscle output was recorded at 30 frames/sec using a video camera to synchronize the movements with the electromyographic data. Activities of the left VM and VL were assessed.

Maximum voluntary isometric contraction (MVC) was determined as manual resistance against a maximally contracted muscle. The participants walked and ran at 6, 9, and 12 km/h for 10 minutes in random order, and the myogenic potentials were measured for 30 seconds 10 minutes later. Analog signals of myogenic potential were processed using a band-pass filter (10-500 Hz) at a sampling frequency of 1000 Hz.

Electromyographic data were analyzed using the average value of each muscle output and central frequency. The average activity was calculated from 30-second cycles of walking and running including both the swing and stance phases. These output values were divided by the MVC to determine the %MVC of each muscle. The data were analyzed using one-way analysis of variance and a significance level of $p < 0.05$.

3. Results

The average VM/VL ratio during running at 6, 9, and 12 km/h was compared to that during walking, with significant differences between the average VM/VL ratios at 6 km/h (2.40±0.66), 9 km/h (1.01±0.11), and 12 km/h (0.99±0.09) (Table 1). The average VM %MVC was significantly different between walking (9.29±2.34) and running at 12 km/h (20.14±2.71). The average VL %MVC was significantly different between walking (6.71±1.72) and running at 9 km/h (19.86±2.64) and 12 km/h (22.88±2.94), and between running at 6 km/h (9.98±2.15) and running at 9 and 12 km/h (Table 2).

The angle of the knee at mid stance and toe off was significantly different. The knee was more flexed during running at 6 km/h, 9 km/h, and 12 km/h than during walking, and it was more flexed at midstance at 9 km/h and 12 km/h than at 6 km/h. The knee was more flexed at toe off during running at 9 km/h and 12 km/h than during walking and running at 6 km/h (Table 3).

The average lengths of the 9 km/h and 12 km/h strides were significantly longer than those of walking and running at 6 km/h, and that of running at 12 km/h was significantly longer than that of running at 9 km/h (Table 4).

No significant differences were observed for intermediate frequencies for either VM or VL (Table 5).

Table 1. *VM/VL ratio at each velocity (n=15).*

	Walking	6 km/h	9 km/h	12 km/h
VM/VL	1.87±0.49	2.40±0.66	1.01±0.11*	0.99±0.09*

Values are means±SE. *p<0.05, vs. 6 km/h.
VL, vastus lateralis; VM, vastus medialis.

Table 2. *Average %MVC of the muscles (n=15).*

	Walking	6 km/h	9 km/h	12 km/h
VM	9.29±2.34	16.99±2.88	17.59±2.41	20.14±2.71*
VL	6.71±1.72	9.98±2.15	19.86±2.64*,**	22.88±2.94*,**

Values are means±SE. *p<0.05, vs. walking. ** p<0.05, vs. 6 km/h.
VL, vastus lateralis; VM, vastus medialis.

Table 3. *Average left knee joint angles (n=15).*

	Walking	6 km/h	9 km/h	12 km/h
Midstance	8.40±1.89	41.80±2.46*	49.20±1.09*,**	52.87±1.29*,**
Toe off	57.47±1.27	51.93±2.33	31.27±2.67*,**	23.60±2.59*,**

Values are means±SE. *p<0.05, vs. walking. ** p<0.05, vs. 6 km/h.

Table 4. *Average stride length (n=15).*

	Walking	6 km/h	9 km/h	12 km/h
Stride (m)	1.26±0.02	1.31±0.02	1.85±0.02*,**	2.38±0.02*,**, †

Values are means±SE. *p<0.05, vs. walking. ** p<0.05, vs. 6 km/h. † p<0.05, vs. 9 km/h.

Table 5. *Average central frequency of muscles (n=15).*

	Walking	6 km/h	9 km/h	12 km/h
VM	16.45±4.26	24.01±4.96	32.29±5.17	29.26±3.89
VL	30.00±5.39	34.17±4.86	33.62±5.09	30.81±4.78

Values are means±SE.
VL, vastus lateralis; VM, vastus medialis.

4. Discussion

The purpose of this study was to measure changes in VM/VL during three running velocities on a treadmill. The VM and VL of the quadriceps not only act on the lower limb during running or walking, but they also suppress damage to the knee during weight-bearing in the stance phase. Hreljac [6] reported the boundary velocity of walking and running as 2.4 m/s (8.64 km/h). The present study used velocities of 6 km/h, 9 km/h, and 12 km/h as jogging, slow running, and fast running.

Since no significant differences were observed at intermediate frequencies, the effects of fatigue could be excluded. Average VM/VL %MVC values suggested that VM activity was dominant during walking and running at 6 km/h. During running at 9 and 12 km/h, there appeared to be no dominance, with equivalent VM and VL activities (Figure 1). Average VM %MVC values indicated that the VM was active during both walking and running, while average VL %MVC values suggested that VL activity increased gradually with speed. Brownstein et al. [7] reported that VM activity is greater during knee joint flexion than when the knee is extended. Therefore, even at the slow speed, long-time running imposes a burden on the VM. Furthermore, in a previous study [8], we compared the muscle activity during jogging and walking at the same velocity. In this study, the activity of the VM during jogging was significantly higher, and the knee joints showed significant flexion during jogging. On the other hand, VL muscle output does not fall off as the knee joint is extended. Since the VM and VL muscles are single-joint muscles, they are affected by the range of motion of the knee joint. When the velocity of running is increased, the hip and knee joints are more extended in the latter half of the stance phase, which makes it easier for the VL to work. Furthermore, as a result of the stride becoming longer, the muscles of the lower limbs must produce greater output.

With respect to the cause of PFPS, Fredericson et al. [9] said that a variety of factors was involved, including generalized ligamentous laxity, mobilization of the patella, position of the patella, decreased flexibility of the iliotibial band and quadriceps, and weakness of the quadriceps and muscles around the hip joint. The patella moves up and down with flexion and extension of the knee. Christou [10] said that the patellar pain is likely to occur when it is pulled to the lateral side at this time. Therefore, the activity of the VM is important.

Slow running, such as jogging, seems to impose less of a burden on the lower limbs. However, it was found that there is a bias in the activity ratio of the VM and VL muscles in this experiment. It is considered that PFPS is caused by fatigue of the VM. Especially in a novice runner who has not achieved strengthening of the quadriceps muscle, VM fatigue can be noted.

Identification of the characteristics of muscle activity during running in the present study may contribute to elucidation of the mechanism of onset of PFPS.

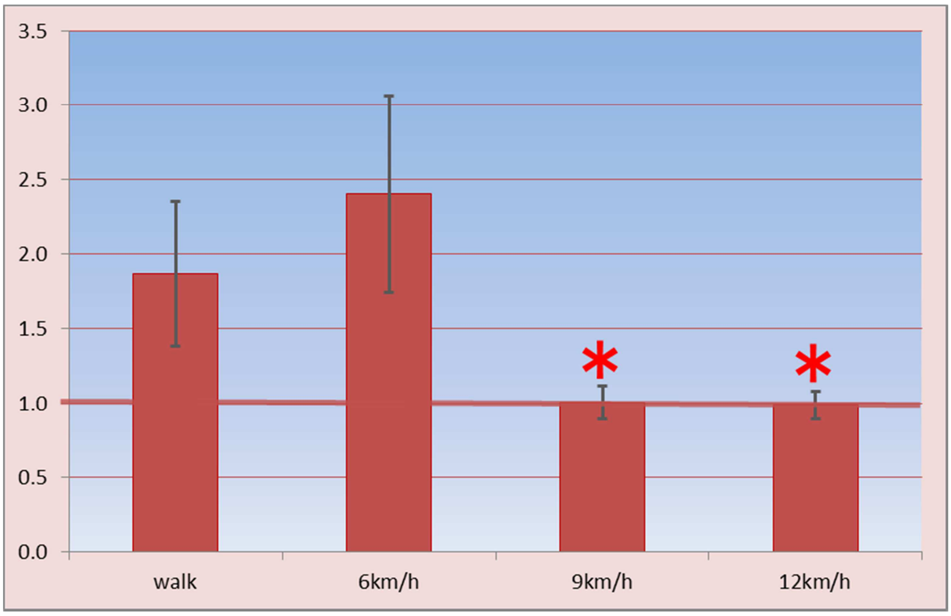

Figure 1. *Average %MVC of VM/VL.*

Average ± SE. Walk was 1.9±0.5, 6km/h was 2.4±0.7, 9km/h was 1.0±0.1 and 12km/h was 1.0±0.1.
* was VS. 6km/h, P<0.05.

5. Findings

The average VM/VL ratio biased toward VM at 6km/h, but 9km/h and 12km/h was not biased any side. Slow running seems to impose less of a burden on the lower limbs.

Identification of the characteristics of muscle activity during running in the present study may contribute to elucidation of the mechanism of onset of PFPS.

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