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A Comparison of the Lower Limb Muscles Activities between Walking and Jogging Performed at the Same Speed

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Abstract. [Purpose] This study compared muscle activities between jogging and walking. [Subjects] Subjects were 12 healthy, young students. Tested muscles were the vastus lateralis, vastus medialis, hip adductors, lateral head of the gastrocnemius, and soleus of the left leg. [Method] Subjects performed jogging and walking successively on a treadmill at a speed of 4.5 km/h. Subjects' myogenic potentials were measured after 10 minutes' walking or jogging for 30 seconds. The order of walking and jogging was chosen at random. The flexion angle of the knee at initial contact, mid stance, and toe off were measured. [Results] Both the average and maximum activities of the soleus and vastus medialis in jogging were significantly higher than those in walking. The knee flexion angle in jogging was greater than that in walking. [Conclusion] The activity of the soleus was not affected by knee flexion. We consider this is the reason why the soleus activity was higher than that of the gastrocnemius. In jogging, the knee was more flexed than in walking, indicating the vastus medialis was doing more work than the vastus lateralis.

Key words: Jogging, Walking, EMG

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INTRODUCTION

Among the basic movement of humans, walking and running are the means of locomotion and they require the continuous movement of the legs. Marathon running and jogging are more likely to cause disorders in the legs than walking[1)]. Koplan et al.[2)] conducted a survey of 1,423 participants in a 10 km race and their results show that 35% of them had experienced an injury of their muscle or bone. Lieberman et al.[3)] demonstrated that the vertical ground reaction forces in running are in the range of 0.58–1.89 times of a subject's weight. Recently, more people are running or jogging for pleasure and for health reasons. Public marathons have less strict entry qualification, therefore a lot of runners without adequate training exercise participate in public marathons. These runners often slow down in the latter part of the race because of increasing lower limb fatigue, and any runners slow down to a jogging pace to reach the finishing tape. In addition, runners who recover from an injury tend to use jogging exercise as a means of adjustment to their body condition. However, no research has shown that jogging is a suitable way of running for runners who are recovering from an injury, or public marathon runners who slow down due to fatigue. Taking into account the lower limb strain, walking is supposed to have a lower-impact than jogging since jogging is a slowed down form of running. Therefore it is possible that jogging produces higher output of the leg muscles than walking. Kobayashi et al.[4)] reported that even if the load of a subject's body was small, the high repetition of load cause chronic strain leading to injury. The report indicated that jogging, which is thought to have a low impact on the lower limbs, may cause injury by misuse. In addition, Sasaki et al.[5)] reported that the skeletal muscles contract to protect themselves from external stimuli and to absorb their impacts. They also reported that muscles with fatigue absorb less impact and are vulnerable. Assuming that the strain to legs in jogging is higher than that in walking, it might be better to choose walking than jogging for leg muscles with weakness or fatigue.

The present study was designed to compare the muscle activities between jogging and walking, by standardizing the exercise intensity and exercise speed and quantifying the muscle activities with electromyography.

SUBJECTS AND METHODS

The subjects were 12 male students without any injuries to their legs (age 22.3 ± 3.7, height 171.9 ± 5.7 cm, weight 61.9 ± 4.5 kg, BMI 21.0 ± 1.4). Informed consent was obtained from all subjects after explaining about the experiment and its purpose both oral and in writing. The subjects did not do running as training and did sports once or twice a week. The equipment used was a TELEMYO-G2 and Myo Research XP (NORAXON), for surface electromyography and a Gait Training System 2 (BIODEX) treadmill. The measurements of the muscle output were recorded with a video camera (frame rate: 30/sec) to synchronize the movements with the data obtained from electromyography. The tested muscles were the left vastus lateralis, vastus medialis, hip adductors, lateral head of gastrocnemius, and soleus. Disposable electrodes (Blue sensor: M-00-S, Ambu Co.) were used to detect the muscle activities. For each muscle, the electrode was attached to the belly of the muscle.

First, maximum voluntary isometric contraction, which was regarded as Maximal Voluntary Contraction (MVC) in this experiment, was measured using manual resistance and the muscles contracted at a maximum. Manual Muscle Testing (MMT)[6] was chosen for the measurements. Then after 10 minutes jogging (or walking) performed at a speed of 4.5 km/h, the myogenic potentials were measured for 30 seconds. Ten minutes jogging or walking followed by 30 seconds of measurement were repeated in the same way. The order of walking and jogging was randomly determined. The analog signals of myogenic potential were processed by a band-pass filter at a sampling frequency of 1000 Hz.

To measure the range of motion, the left knee, the greater trochanter, the knee joint space, and the lateral malleolus were marked with tape. One of the walking or running cycle of 30 seconds recorded with the video camera was chosen and the motions of initial contact, mid stance, and toe off were printed out. The range of motion of the knee flexion was measured on the prints.

The data analysis of electromyography was conducted using the average value of each muscle output and the maximal value of each muscle output in walking and jogging. Ten cycles of walking and jogging, including both the swing and stance phases, of 30 seconds were chosen to calculate the average value of the activity. These values were divided by MVC to obtain %MVC of each muscle. The maximal value of each muscle output was extracted from each cycle of the previously used 10 cycles of walking and jogging and averaged. Then, comparisons of these values and the knee flexion angles were performed between walking and jogging. The data were analyzed using the paired t test and statistical significance was accepted at value of $p<0.05$.

RESULTS

The average electromyographic activities of the soleus and vastus medialis (Table 1) were significantly different. The %MVC of the soleus was 36.3 ± 5.4% in walking and 50.2 ± 6.4% in jogging; that of vastus medialis was 31.1 ± 8.9% in walking and 40.0 ± 8.5% in jogging. The maximum electromyographic activities of the soleus and vastus medialis (Table 2) were significantly different. The %MVC of the soleus was 78.2 ± 9.2% in walking and 100.6 ± 11.2% in jogging; that of the vastus medialis was 57.6 ± 10.5% in walking and 74.1 ± 10.0% in jogging. The flexion angle of the left knee (Table 3) was significantly different in all three phases: 14.5 ± 6.7° in walking and 23.3 ± 4.5° in jogging at the initial contact, 17.6 ± 5.7°in walking and 42.4 ± 4.3° in jogging at the mid stance, and 54.1 ± 6.7° in walking and 61.7 ± 6.5° in jogging at the toe off.

Table 1. Average of %MVC for muscles (n=12)

	Walking	Jogging
Soleus	36.3 ± 5.4	50.2 ± 6.4*
Gastrocnemius	44.0 ± 8.2	44.2 ± 8.7
Vastus lateralis	34.7 ± 8.4	38.6 ± 8.3
Vastus medialis	31.1 ± 8.9	40.0 ± 8.5*
Hip adductors	41.4 ± 5.1	37.6 ± 5.7

Values are mean ± SD. *: $p<0.05$.

Table 2. Peak value of %MVC for muscles (n=12)

	Walking	Jogging
Soleus	78.2 ± 9.2	100.6 ± 11.2*
Gastrocnemius	78.4 ± 11.1	73.9 ± 12.9
Vastus lateralis	69.5 ± 14.4	69.9 ± 11.0
Vastus medialis	57.6 ± 10.5	74.1 ± 10.0*
Hip adductors	101.9 ± 10.2	95.8 ± 19.5

Values are mean ± SD. *: $p<0.05$.

Table 3. Average of left knee angle (n=12)

	Walking	Jogging
Initial Contact	14.5 ± 6.7	23.3 ± 4.5**
Mid Stance	17.6 ± 5.7	42.4 ± 4.3**
Toe Off	54.1 ± 6.7	61.7 ± 6.5**

Values are mean ± SD. **: $p<0.01$.

DISCUSSION

We conducted an electromyographical analysis to elucidate whether jogging causes as much strain of the legs for runners who slow down due to fatigue as on runners who are recovering from injury. A greater angle of knee flexion was observed in running than in walking[7], and we think the amount of muscle activity was enhanced because the muscle fibers had lengthened. In addition, enhancement of the vertical ground reaction force, the vertical movement of the center of the gravity, and the swing speed of the legs enabled stronger contraction of the leg muscles. Jogging and walking are different in their forms, which cause differences in the amount of muscle activity. Furthermore, jogging and walking are performed at different speeds, which affects the amount of muscle activity. This experiment was performed at 4.5 km/h, the same speed for both walking and jogging. In our preliminary experiments, 4–5 km/h was best walking speed of subjects.

The average and maximum activities of the soleus in jogging significantly higher levels than in walking. The cross-sectional area of the soleus is larger than that of the gastrocnemius[8]. According to Fukunaga et al.[9] the muscle fibers of the soleus are longer than those of both the lateral and medial gastrocnemius, and they are heavier too. Therefore, the soleus activity was higher than that of the gastrocnemius, which contributes much to plantar flexion of the ankle. The soleus, which is a monarthric muscle, arises from the proximal part of the tibia and fibula, leading to the Achilles tendon[10]. The angle of the knee doesn't change the length of is soleus. Daikuya et al.[11] reported that the vertical movement of the center of gravity in running is wider than that in walking, because one of the legs is always in contact with the ground in walking, while in running, there is a moment when neither leg is in contact with the ground. Furthermore, Saibene et al.[12] reported that the vertical movement of the center of mass of the body in walking while the center of the mass of the body in jogging sank in the step period and then moved forward in reaction. In jogging, the degree of leg-grounding is different depending on the speed. However, its form is similar to running and the center of gravity is likely to move vertically. The activity of the soleus is not affected by the angle of the knee and the soleus activity is easily enhanced compared to the gastrocnemius. In other words, we think that the soleus activity increased to generate stronger kicking power.

In this experiment, the peak value of %MVC for muscles was occasionally larger than 100%. According to Yamada et al.[13], MVC is affected by the exercise experience. Subjects who have exercise experience or have greater muscle strength appear to have high voluntary activation. Therefore, the subjects of this experiment were persons with low voluntary activation. Accordingly, we consider that this explains why the peak value of %MVC for muscles was occasionally larger than 100%.

No significant difference was observed between walking and jogging in the average and maximum activities of the gastrocnemius, a biarticular muscle arising from the distal femur. Therefore, muscle length is influenced by the flexion angle of the knee. According to Rose et al.[14], the gastrocnemius contracts from the start of loading (when weight is carried on the sole) to toe off in the stance phase. In the latter half of the stance phase in running, the knee of the stance leg extends and the ankle of the stance leg exhibits plantar flexion which allows the stride to elongate. However, in the stance phase of jogging, which is slowed-down running, the knee of the stance leg doesn't extend enough to enhance the muscle activity resulting in a shorter stride than in running. Our present experiment showed that the angle of knee flexion in jogging is significantly greater than that in walking at the toe off phase. Therefore, we consider the amount of soleus activity is enhanced, strengthening the kicking power. Since the gastrocnemius is not fully extended, the vastus medialis and vastus lateralis, which are part of the quadriceps, act as knee stabilizers in the stance phase, preventing the knee from giving way, not only when swinging the legs forwards in but also when running. The stronger the vertical ground reaction force becomes, the greater their activities increase. In addition, their activities are enhanced by higher running speeds allowing the lower leg to swing more rapidly. The vastus medialis works at the very end of knee extension[15], while the initial extension is generated by the vastus lateralis. No significant difference was seen in both maximum and average activities in walking or jogging, which indicates that there are no significant differences in the vertical ground reaction force and the speed of lower leg swing between walking and jogging.

On the other hand, both maximum and average activities of the vastus medialis in jogging were higher than those in walking. The vastus medialis works in the very last part of knee extension. The magnitude of the knee flexion angle in jogging was significantly greater than that in walking (23.3 ± 4.5° in jogging, 14.5 ± 6.7° in walking). Altenburg et al.[16] demonstrated that the best knee flexion angle for exerting the maximum torque of the vastus lateralis id around 55°, and in the present study electromyography also showed the highest value for the vastus medialis at around this angle.

The more the knee extends from 55°, the less its torque becomes; thus the vastus medialis was thought to around 23.3 ± 4.5°. Furthermore, the eccentric contraction of the vastus medialis is supposed to keep the knee from giving way between the initial contact and mid stance phase. For all these reasons, the activity of the vastus medialis was enhanced.

There was no significant difference between walking and running both in the maximum and average activities of hip adductors. The hip adductors decrease the mediolateral movement of the leg in combination with muscles of the lateral side of the hip joint, such as the gluteus medius, and stabilize it in the neutral position. A stronger vertical ground reaction force appears to indicate stronger hip adductors activity. We consider this is the reason why no significant difference was observed between walking and jogging at the same speed.

Leg muscle activity was measured with electromyography while subjects performed jogging and walking on a treadmill at a speed of 4.5 km/h. The results show that both average and maximum activities of the vastus medialis and soleus in jogging were significantly higher than those in walking. It indicates that a greater strain is taken by the vastus medialis or soleus in jogging when runners slow down from fatigue or are recovering from injury. Therefore, jogging should be chosen depending on the site of the injury or accumulated fatigue to prevent the runners from worsening their leg condition.

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