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Effects of Treadmill Walking Speed on Lower Extremity Muscle Activity Ratio in College Students

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ABSTRACT

The purpose of this study was to investigate the interaction between the activity ratio and the muscles of the lower extremity muscles according to the treadmill walking speed. The subjects measured the MVIC (Maximum Voluntary Isomeric Contraction) of the tibialis anterior, semitendinosus, medial gastrocnemius, biceps femoris using wireless surface electromyography. After walking for 1 minute at the speed of 3km/h, 4km/h, and 5km/h on the treadmill, muscle activities of the tibialis anterior, semitendinosus, medial gastrocnemius, biceps femoris. % MVIC (muscle activity/MVIC × 100) was used for the generalization of the measurements. In the treadmill walking at the speed of 3km/h, 4km/h, and 5km/h, the muscle activity ratios of the tibialis anterior, semitendinosus, medial gastrocnemius and the biceps femoris are as follows. There was a significant difference in muscle activity ($P < 0.05$) in the tibialis anterior, medial gastrocnemius and the biceps femoris at 3km/h speed, 4km/h speed, 3km/h speed and 5km/h speed. There was a significant difference ($P < 0.05$) in the semitendinosus muscle activity ratio between the 3 km/h and 4km/h speed walk, 3km/h speed and 5km/h speed walk, 4km/h speed walk and 5km/h speed walk. As the walking speed increased to 5km/h, the semitendinosus connected to the knee joint led to the gait rather than the ankle joint, so that it was found that the lower and the lower shoulder tend to walk with the tendency of bending and inner rotation.

Keywords: *Treadmill walking, Co-contraction, Muscle activity ratio, Biceps femoris*

Introduction

Walking is one of the most important functions for human beings and one of the important factors that determine the quality of life[2]. In addition, walking is the most frequently used movement in daily living, through the interaction between the flexor muscles of the hip, knee, and ankle joints[8]. A stable posture during walking is essential for performing complex motor functions, which involves complex nervous system[9]. For normal and stable walking, factors such as posture control, exercise control, and reaction time should be harmonized. Walking is a vital condition for vigorous daily life and functional activities. Walking during daily life repeats and progresses over various conditions such as slopes, plains, and stairs. Therefore, the body moves through the walking, and the interaction of the ankle muscles and the muscles around the knee joints affects the walking[19]. Particularly, to walk on slopes, stairs, and rugged areas, rather than on flat grounds, a combined contraction of functional lower limb muscles is required[20].

It has been reported that the walking speed, especially walking speed, is the most basic evaluation method for the daily life movements and functions in patients with hemiplegia due to brain damage[12]. For patients with hemiplegia, improvement in gait is an essential and essential therapeutic goal for independent living[18]. Thus, Walking is a prerequisite for the recovery rate and functional behavior of nervous system patients. Brain injured patients are mobilized by various methods of strengthening the legs for functional walking. For patients with brain damage, treadmill training is based on the central pattern generator theory in gait control and recovery[4]. This is controlled by a series of neurons located at the level of the spinal cord, and these central pattern generators are known to activate afferent input

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due to limb movement, weight shift, and posture alignment with passive or assistive assistance. This mass repetition movement training is thought to improve walking ability for brain injured patients due to neural reorganization[6]. Treadmill walking training increased the stance of the uninjured lower limb by increasing the stance of the lower limb during walking, and consequently promoted a symmetrical walking pattern. It is used for the improvement of the walking ability[17].

Also for the elderly, walking is an important factor for independent and functional daily life. Over the age of 60, the elderly average body muscle volume decreases over 60 years, especially when the muscular volume of the lower limbs is reduced further, increasing the likelihood of falls[15]. Thus, cardiovascular endurance, agility, flexibility and balance are greatly reduced making independent life impossible[13]. The weakening of leg strength and the reduction of balance ability are important causes of fall, especially weakness of lower leg strength is a major cause of falls. The weakening of leg strength leads to a decrease in balance ability[11] and a decrease in walking ability, which is a major cause of daily life disability and falls[7]. Therapeutic methods using treadmill, elastic band, etc have been applied to the elderly to prevent and maintain such lower leg muscle weakness.

Interventions for functional walking are being applied not only to patients with brain injuries and the elderly, but also to healthy people who want to live life. The study for enhancing walking ability of women in their twenties through core muscle strengthening[14] claims that improving walking ability improves posture balancing ability and posture control ability regardless of sex and age. However, it is still the most preferred method for the brain damage patients, the elderly, and the normal people to increase the walking ability safely is the walking training using the treadmill. Walking with a treadmill is safe and has the advantage of taking individual characteristics into consideration, and healthy people use a lot of strengthening of leg strength. In this study, we investigate the speed at which the lower extremity muscles can be activated most effectively during treadmill walking and the interaction of the muscles according to their speed.

Method

Subjects: Subjects participated in the experiment were 17 students (male = 11, female = 6) who were 20 to 24 years old and had normal orthopedic and neurological problems. The subjects were informed about the overall progress and safety of the experiment, asked for consent for personal information, and written consent was obtained from the subjects who indicated their willingness to participate voluntarily. The experiment of this study was based on the Helsinki Declaration of Medical Research Ethics Principles.

Research Design: The subjects measured the MVIC (Maximum Voluntary Isomeric Contraction) of the tibialis anterior, semitendinosus, medial gastrocnemius, biceps femoris using wireless surface electromyography. After walking for 1 minute at the speed of 3km/h, 4km/h, and 5km/h on the treadmill, muscle activities of the tibialis anterior, semitendinosus, medial gastrocnemius, and biceps femoris. % MVIC (muscle activity/MVIC × 100) was used for the generalization of the measurements. % MVIC were measured and the muscle activity ratios of 4 muscles were compared at 3km/h, 4km/h, and 5km/h velocities.

Intervention: The subjects first measured MVIC of four muscles using wireless surface electromyography. The subjects first measured MVIC of four muscles using wireless surface For the MVIC measurement of the tibialis anterior, ankle flexion and inversion were performed to find the most active muscle position of the tibialis anterior. After that, electrodes were attached to the most active site 2/3 of the proximal side of the tibia bone body, 7 cm below the lateral surface of the tibia tuberosity. The sole was fixed on the floor while sitting comfortably in the chair. After that, 5 exercises were performed to allow dorsi flexion and inversion of the foot, followed by dorsi flexion and inversion for a maximum of 5 seconds. Measurements were taken for 3 seconds except 1 second for each of the front and back, and the mean value was measured 3 times in the same way and rested for 1 minute between measurements. For MVIC measurements of the semitendinosus, the knee was flexed and internal rotated in the prone position. In this state, the electrode was attached to the middle part of the midline between the femur and the ischial tuberosity, which is the most active region with resistance. After attaching the electrode, the knee joint flexion and the internal rotation posture were taken in the prone posture, resistance was given, and after 5 exercises, resistance was measured and the resistance was measured for 5 seconds. Resistance was given in the prone posture with knee flexion and lateral rotation for biceps femoris(long head) MVIC measurements. After that, electrodes were attached to the distal two-thirds of the fibular head and ischial tuberosity, which is the most active part of the biceps femoris(long head). After attaching the electrode, the knee joint flexion and the lateral rotation were put in the prone position, resistance was given, and after exercising 5 times, the resistance was measured and the resistance was measured for 5 seconds. Measurements were taken for 3 seconds except 1 second for each of the front and back, and the mean value was measured 3 times in the same way and rested for 1 minute between measurements. In order to measure the MVIC of the gastrocnemius(medial side), the foot was flexion at the prone position and the electrode was attached 9 cm below the medial epicondyle, the most active site[3]. After the electrodes were attached, they were allowed to resist the planter flexion in the prone position and then exercised 5 times so as to withstand and measured for 5 seconds with the maximum resistance. After this, the subjects walked at a speed of 3km/h, 4km/h, and 5km/h on the treadmill. At this time, the order of the speed was determined randomly and the walking was performed. Subjects performed treadmill walking for 1 minute. EMG signals of 15 ~ 20 seconds, 20 ~ 25 seconds, and 30 ~ 35 seconds after gait were collected and 3 seconds values were used except 1 second before and after. The average value was used after three measurements in this way.

Measurement of Muscle Signals: For the purpose of this study, myoRESEARCH 3 (Noraxon, Arizona USA) was used for wireless surface EMG (Fig. 1). The surface EMG electrode was attached with two disposable electrodes of 40 mm width and 20 mm length, one of the active electrodes and one of the reference electrodes. When the electrode was attached, the surface of the skin was shaved cleanly, then wiped with alcohol cotton, and the electrode was attached. Two active electrodes of the tibialis anterior, semitendinosus, medial gastrocnemius and the biceps femoris were attached to the attachment site at intervals of 2 cm, and the reference electrode was attached to the 3 cm side of the active electrode. The sampling rate of EMG signal was set to 1,000 Hz and the frequency bandwidth was 10 ~ 350 Hz. The RMS values were measured by smoothing the rectified raw data.

Figure 1: Wireless surface EMG

Statistical Processing: We used repeated measures analysis of variance to measure treadmill walking at speeds of 3 km/h, 4 km/h, and 5 km/h. The statistical program was SPSS 12. 0 (SPSS Inc., USA). Statistical significance was 0.05.

Result

Subject Characteristics: The subjects were 11 men and 6 women. The average age of male was 22.09 old, the average weight was 69.45kg, the average height was 175. 28cm, the average age of female was 21.33, the average weight was 57.66kg, And the average height was 160.83 cm. Result of the subject characteristics in table 1 below:

Table 1: Subject characteristics

	Age (old)	Height (cm)	Weight (kg)
Male (n = 11)	22.09 ± 2.21	175.28 ± 5.71	69.45 ± 12.06
Female (n = 6)	21.33 ± 0.81	160.83 ± 4.62	57.66 ± 6.28
Total (n = 17)	21.82 ± 1.84	170.17 ± 8.81	65.29 ± 11.70

Comparison of Muscle Activity Ratio of Lower Extremity Muscle: In the treadmill walking at the speed of 3km/h, 4km/h, and 5km/h, the muscle activity ratios of the tibialis anterior, semitendinosus, medial gastrocnemius and the biceps femoris are as follows. There was a significant difference in muscle activities ($P < 0.05$) in the tibialis anterior, medial gastrocnemius and the biceps femoris at 3km/h speed, 4km/h speed, 3km/h speed and 5km/h speed. There was a significant difference ($P < 0.05$) in the semitendinosus muscle activity ratio between the 3 km/h and 4km/h speed walk, 3km/h speed and 5km/h speed walk, 4km/h speed walk and 5km/h speed walk. Result of the comparison of muscle activity ration in table 2 below:

Table 2: Comparison of muscle activity ratio

%MVIC

	3km/h	4km/h	5km/h	F
Tibialis anterior	13.13 ± 9.81[ab]	15.35 ± 11.01[a]	18.02 ± 7.06[b]	5.868
Medial gastrocnemius	27.62 ± 14.07[ab]	30.54 ± 15.49[a]	35.47 ± 15.14[b]	7.766
Biceps femoris	8.88 ± 7.90[ab]	10.40 ± 9.55[a]	12.08 ± 9.09[b]	6.299
Semitendinosus	12.92 ± 6.89[abc]	15.60 ± 9.62[abc]	23.02 ± 12.53[abc]	10.279

$P<0.05$

Discussion

Treadmill walking training has been shown to be a useful way to improve endurance for brain damage patients with low levels of aerobic capacity and improve energy metabolism during walking[10]. It is also used to maintain the strength of the elderly and to control dynamic and static balance. It is widely used for the normal exercise of the normal people and the activation of the lower extremity muscles. The purpose of this study was to investigate the walking speed of the lower extremity muscles for the most efficient co-contraction. Appropriate joint contractions of the leg muscles in gait can produce functional gait. In this study, we measured the muscle activity ratio of the tibialis anterior and medial gastrocnemius corresponding to the dorsi flexion and planter flexion of the ankle joint, and measured the muscle activity ratio of the semitendinosus and the biceps femoris involved in flexion and rotation of the knee joint.

The muscle activity ratios were significantly increased in the tibialis anterior, the medial gastrocnemius, and the biceps femoris at 3km/h-4km/h, 3km/h- 5km/h. In the semitendinosus, the muscle activity ratio increases in both 3km/h-4km/h, 3km/h -5km/h, 4km/h-5km/h. These results show that the angular velocity of the ankle joint and the knee joint increases as the walking speed increases. In particular, the increase of the muscle activity rate in each case of the 1-km/h increase in the velocity of the semitendinosus indicates that the semitendinosus are most affected by the increase in the walking speed. The other three muscles increased muscle activity ratios at 3km/h-4 km/h, but did not show significant muscle activity ratios at 4km/h-5 km/h. Thus, tibialis anterior, medial gastrocnemius and biceps femoris are all activated until the walking speed is increased to 4km/h, but when the speed is increased to 5km/h, only the activity rate of the semitendinosus is significantly increased.

In a study by Cho & Kim[1], we studied 4km/h of treadmill walking at 3km/h, 4km/h, and 5km/h in normal young people using four video cameras. As a result, the angular velocity of the ankle increased with the increase in the treadmill walking speed, but there was no difference in the angular velocity between the knee joints. The increase in the angular velocity of the ankle joint as the walking speed increases can be deduced as a result of this study. The increase in muscle activity when the velocity of the tibialis anterior and medial gastrocnemius increased from 3km/h to 4km/h means that the angular velocity of the ankle joint was increased as a result. The study of Cho & Kim[1] is the result of motion analysis through a video camera. In this study, the result is the same as the study of muscle activity using wireless EMG. In addition, the result of the difference in angular velocity between the knee joint and the knee joint was not different from the result of this study. However, if there is any correlation between angular velocity and joint angle, it is uncertain what these associations and muscle activity mean.

In the study of Yi & Kim[21], the treadmill walking is similar to the general ground walking type, and the vertical repulsive force generated when walking on the treadmill is also similar to the normal walking. The result of this study is the result of treadmill walking, but it is thought that similar muscle activity ratio will appear when walking on the ground. Walking exercises or walking exercises through a treadmill are used for patients with brain lesions, the elderly, and the normal people. There was no difference in the angle of the ankle joint and the angle of the knee joint as the speed of the treadmill increased during treadmill walking in the 60-70 age group. These results suggest that the elderly tend to use sufficient flexion of the knee joint to reduce the impact on the joints as the walking speed increases by the study of Eun & Lee[5]. In this study, the muscle activity ratio of the muscles of the ankle joint and the knee joint was increased as the walking speed was increased. When the walking speed is increased more, the semitendinosus that affect the knee joints lead the walk to the leading edge rather than the ankle joints. However, this result could be different according to age and function difference.

According to the results of this study, as the walking speed increases in young normal subjects, the semitendinosus connected to the knee joint lead the gait rather than the ankle joint. It should be noted that the semitendinosus, which are connected to the knee joint but have flexion and internal rotation, lead to the pace of gait rather than the flexion and lateral rotation of the biceps femoris. However, since the speed of this experiment is limited at 5 km/h, the results may differ for further increased speeds and further studies are needed. The relationship between the angular velocity of the joints, muscle activity ratio, and range of motion should be studied and the fatigue of each muscle should be reinforced.

Conclusion

The purpose of this study was to measure the muscle activity ratio of the tibialis anterior and medial gastrocnemius of the ankle joint with 3km/h, 4km/h and 5km/h treadmill walking in young normal subjects. We also measured the ratio of muscle activity of the semitendinosus and biceps femoris of the knee joint. As the walking speed increased to 5km/h, the semitendinosus connected to the knee joint led to the gait rather than the ankle joint, so that it was found that the lower and the lower shoulder tend to walk with the tendency of flexion and internal rotation.

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Conflict of Interest: The authors declare no conflict of interest.

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