



Original Article

## Correlation between ankle plantar flexor strength and leg extensor torque

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**Abstract.** [Purpose] The purpose of this study is to consider the correlation between ankle plantar flexor strength and leg extensor torque in order to investigate whether the leg extension torque can be expected to increase as the triceps surae muscle strength is increased. [Participants and Methods] Healthy adults of 30 males and 22 females were recruited. Hand Held Dynamometer was used to measure ankle plantar flexor strength. Strength Ergo 240 was used to measure leg extensor torque. After measurement, a correlation between these factors was investigated by gender. [Results] For both males and females, a significant positive correlation between the left and right ankle plantar flexor strength and leg extensor torque was observed. [Conclusion] Actively performing muscle strengthening exercises for ankle plantar flexor by physical therapists was found to be meaningful in increasing leg extensor torque.

**Key words:** Closed kinetic chain, Ankle plantar flexor strength, Leg extensor torque

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### INTRODUCTION

In physical therapy, there are many opportunities to perform exercises for patients who have difficulty standing up or walking. Since standing up and walking are exercise patterns for closed kinetic chain (CKC), leg extensor torque is needed to extend the entire leg<sup>1, 2)</sup>. Consequently, considering the relationship between leg extension torque and leg strength is important. In addition, the triceps surae is a major leg muscle group. The triceps surae is the collective term for calf muscles and the soleus. When these muscles are simultaneously worked in open kinetic chain (OKC), the ankle will be plantar flexed<sup>3)</sup>. Furthermore, calf muscles function to bend the knee joint in CKC<sup>4)</sup>. However, when the angle of knee joint approaches the extended position, the knee joint itself becomes extended<sup>5-7)</sup>. In this case, in standing and walking, which are CKC movements, the triceps surae muscle is involved in knee joint extension.

Physical therapists have many opportunities to perform muscle strengthening exercises for the lower extremities, including the triceps surae muscle. If an increase in leg extension torque can be expected by strengthening the triceps surae muscle, usability of muscle strengthening exercises of ankle plantar flexor (APF) muscle will also increase. Exercise using Strength-Ergo (SE) is considered to be a CKC, since it involves a compound joint. However, studies that consider its correlation with APF strength are few. Consequently, the purpose of this study is to examine the correlation between APF strength measured by Hand Held Dynamometer (HHD), and leg extension torque measured by SE.

### PARTICIPANTS AND METHODS

Fifty two healthy adults with no leg problems (30 males/average age 21.1 ± 3.8 years, and 22 females/average age 21.6 ± 4.8 years) were recruited. The purpose of this study, measurement methods, handling method of the results, presentation

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of the study results, anonymity of personal names during presentations and deletion of data after the study were thoroughly explained in advance. Only persons who signed the consent form were set as study participants. In addition, this study was carried out with the approval of the ethical committee of Fukuoka Wajiro Rehabilitation College (Approval No. FW-20-09).

APF strength was measured using HHD ( $\mu$ Tas F-1: Anima Co., Ltd.). Body position was set as laying on a mat, knee extended, and planar dorsiflexion  $0^\circ$ . Muscle strength by body weight ratio (N/kg) was measured. The HHD sensor was attached to the top of middle toe joints, in contact with the wall. In addition, the physical therapist manually held the ankle to keep the heel on the mat. In this condition, approx. 3 seconds of isometric contraction at maximum strength was promoted. APF strength was measured three times and average value was calculated. A 30 second break was taken between each operation.

The SE by Mitsubishi Electric Engineering Company Limited was used for leg extensor torque, and measurement was carried out five times continuous drive at a speed of 50 rotation/min. Peak torque by the body weight for both the left and right sides during leg extension motion (Nm/kg) was measured. Here, body position during measurement was set as sitting, and the angle of the back rest was set at  $110^\circ$ . Seat position was set as the knee joint at  $30^\circ$  in the flexed position, ankle joint  $0^\circ$  dorsiflex posture, at bottom dead center (greatest extension of the leg), which is the transition point between left and right pedaling. Furthermore, regarding measurement methods for APF strength and leg extensor torque, previous studies were consulted<sup>8)</sup>.

For statistical analysis, difference between genders was considered, as well as calculation the interclass correlation coefficients (ICC) for each measurement. Next, correlation between APF strength and leg extensor torque was considered by gender using Spearman's rank-correlation coefficient. Furthermore, SPSS Statistics V22.0 was used for statistical analysis, and significant difference was set at 5%.

## RESULTS

Measurement results of APF strength and leg extensor torque for males and females are as shown in Table 1. Regarding left and right leg extensor torque between genders, a significantly large difference was observed for males. Regarding APF strength, no significant difference was observed.

Correlation of APF strength and leg extensor torque is shown in Table 2. For both males and females, a significant positive correlation between the left and right ankle plantar flexor strength and leg extensor torque was observed.

## DISCUSSION

This study considered the correlation between APF strength and extensor torque. ICC (1.3) for each measurement in this study was 0.94–0.98. For measurement of leg extensor torque and degree of sway carried out in this study, all matters are considered to have reliability.

Leg extensor torque is exercised by compound motion of leg joint. For leg extension torque, a significant difference between genders was observed. Moreover, regarding leg extensor torque, relative muscle strength of females as shown by body weight ratio of isokinetic leg press is reported to be 74% of males<sup>9)</sup>. This result was roughly the same in this study also. In APF strength, no significant difference in gender was observed. This may be due to APF being an exercise for only a single

**Table 1.** Measurement results of ankle plantar flexor strength and leg extensor torque

		Males	Females
Ankle plantar flexor strength (N/kg)	(Right)	3.7 ± 0.7, 0.94	3.3 ± 1.1, 0.97
	(Left)	3.9 ± 0.9, 0.96	3.4 ± 1.2, 0.98
Lleg extensor torque (Nm/kg)	(Right)	2.4 ± 0.5**, 0.93	1.9 ± 0.3**, 0.98
	(Left)	2.4 ± 0.4**, 0.97	1.9 ± 0.3**, 0.98

Mean ± SD, ICC of ankle plantar flexor strength and leg extensor torque for males and females  
\*\*p<0.01.

**Table 2.** Correlation between ankle plantar flexor strength and leg extensor torque

		Leg extensor torque (Nm/kg)			
		Males		Females	
		(Right)	(Left)	(Right)	(Left)
Ankle plantar flexor strength (N/kg)	(Right)	0.41*	-	0.80**	-
	(Left)	-	0.45*	-	0.65**

Correlation between ankle plantar flexor strength and leg extensor torque for males and females \*p<0.05, \*\*p<0.01.

joint, decreasing the influence of difference in relative muscle strength between males and females.

In this study, a positive correlation was observed between the left and right ankle plantar flexor and leg extensor torque in both males and females. This is thought to be caused by APF strength related to the leg extension torque exercise. Calf muscles, which are APF mainly start at the medial epicondyle of the femur and lateral epicondyle, and the soleus muscles start at the head of the fibula and medial border of the tibia, and both end at the calcaneus<sup>10</sup>. During OKC, both the calf muscle and the soleus muscle function to plantarflex the ankle<sup>11</sup>. However, during CKC, since the ankle is fixed, the knee joint angle is close to the extension position, so the calf muscles act on the femur in the posterior direction. In the same manner, the soleus muscle pulls tibia and fibula in the posterior direction. As a result, during OKC, both the calf muscle and the soleus muscles function to extend the knee joint<sup>5-7</sup>. This is considered to be why a positive correlation between ankle plantar flexion and leg extensor torque was observed.

Omori et al.<sup>12</sup> reported that the walking speed increases as leg extension torque increases. Therefore, in cases where obtaining standing movement and walking speed are set as the goal, usefulness of an approach addressing leg extension torque is considered to be high. In addition, leg extension torque is strongly related to standing movement<sup>13</sup>. However, when performing standing practice, there is an increased risk of falling in the patients which display weakened leg muscle strength and have difficulty maintaining a standing position. In these cases, performing APF muscle strengthening exercises in order to increase leg extensor torque based on the result of this study, can be considered. APF muscle strengthening exercises can be performed in the lying, sitting, and standing in stable condition while holding on the handrail, etc. positions with hardly any risk of falling. Sumita et al.<sup>14</sup> stated that APF muscle could be strengthened by encouraging concentric and centrifugal contraction through manual resistance of the triceps surae muscle in the lying position. Hence, according to the results of this study, actively performing muscle strengthening exercises for ankle plantar flexor by physical therapists in order to increase leg extensor torque was found to be meaningful.

Regarding limitations to this study, participants were young healthy adults, but most persons targeted for general exercise therapy are aged. A decrease in muscular tension and change of muscle morphological characteristics are observed due to aging<sup>15</sup>. Hence, determining the correlation between APF strength and leg extension torque in similar methods in the future is desired.

### *Conflicts of interest*

None.

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