



Original Article

Associations between ankle dorsiflexion range of motion and foot and ankle strength in young adults

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Abstract. [Purpose] This study assessed the relationships between the ankle dorsiflexion range of motion and foot and ankle strength. [Subjects and Methods] Twenty-nine healthy (young adults) volunteers participated in this study. Each participant completed tests for ankle dorsiflexion range of motion, hallux flexor strength, and ankle plantar and dorsiflexor strength. [Results] The results showed (1) a moderate correlation between ankle dorsiflexor strength and dorsiflexion range of motion and (2) a moderate correlation between ankle dorsiflexor strength and first toe flexor muscle strength. Ankle dorsiflexor strength is the main contributor ankle dorsiflexion range of motion to and first toe flexor muscle strength. [Conclusion] Ankle dorsiflexion range of motion can play an important role in determining ankle dorsiflexor strength in young adults.

Key words: Dorsiflexor strength, Toe flexor, Weight-bearing lunge test

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INTRODUCTION

Limited ankle dorsiflexion range of motion (DF ROM) has been associated with several clinical manifestations such as ankle joint equinus¹⁾, patellar injuries²⁾, and ankle injuries³⁾. Restricted ankle dorsiflexion may also lead to abnormal lower extremity biomechanics during closed chain strengthening exercises⁴⁾. Backman et al.⁵⁾ showed that a low DF ROM in weight-bearing value represents a risk factor for developing patellar tendinopathy in junior elite basketball players because of load-bearing compensation in the patellar tendon. Reduced DF ROM during weight bearing may also increase the risk of patellar tendinopathy in volleyball players²⁾. Moreover, DF ROM during weight bearing was a predictor of dynamic balance in healthy adults and individuals with chronic ankle instability⁶⁾. Impaired ankle DF ROM during a squat can also result in increased knee valgus and medial knee displacement, as well as reduced activation of the quadriceps and increased activation of the soleus⁴⁾.

Muscle strength in the lower extremities is an essential element of physical therapy evaluation and can significantly impact activities involving walking ability and the prevention of sports injuries. Intrinsic foot muscles play a key role by supporting the medial longitudinal arch in static stance. Disrupting the function of these muscles through fatigue resulted in an increase in pronation as assessed by navicular drop⁷⁾. Some studies have shown that intrinsic foot flexors are important for the dynamic stabilization of the arches of the feet, enabling a more efficient exertion of extrinsic foot flexor muscle force, and thus leading to an improvement in walking performance^{7,8)}. Kibler et al.⁹⁾ compared strength of the ankle joint plantar flexor muscles and the flexibility of the triceps surae in feet with plantar fasciitis to those in feet without plantar fasciitis. These authors reported significant strength deficits and tightness of the triceps surae for the lower extremities in which plantar fasciitis was present.

Reduced toe flexor strength (TFS) is an independent predictor of falls in older people¹⁰⁾. TFS is very important for various

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movements, including standing¹¹⁾ and walking^{12, 13)}. When walking, an individual's toes are in contact with the ground for 75% of the stance phase¹²⁾ and long toe flexor muscles help control forward progression of the leg over the foot¹⁴⁾. Aging is associated with reduced plantarflexion strength (PFS) of the toes¹⁵⁾. Yun et al.¹⁶⁾ reported that toe flexor muscle strength and DF ROM are the main contributors to countermovement jump performance; however, the associations between DF ROM in weight bearing and TFS, dorsiflexion strength (DFS), and PFS, of the ankle are not well known in young adults. Therefore, the aim of the present study was to investigate the relationships between ankle DF ROM and foot and ankle strength.

SUBJECTS AND METHODS

Twenty-nine active male students (age: 21.2 ± 2.5 years, body weight: 75.9 ± 21.3 kg, height: 170.6 ± 19.9 cm) participated in this study. All participants were injury-free. Exclusion criteria were (1) any cardiovascular, respiratory, abdominal, neurological, musculoskeletal, or other chronic disease, and (2) any symptoms that could affect the musculoskeletal system. This research project was conducted according to the Declaration of Helsinki and was approved by the University Review Board for use of Human Subjects.

Participants began with a warm-up consisting of 5 minutes of low-resistance (85 W; 80 RPM) cycling on an ergometer. Ankle dorsiflexion was evaluated through the LegMotion system (*LegMotion, Check your MOtion, Albacete, Spain*)^{3, 17)}. All subjects started with their hands on the hips and placed the assigned foot on the middle of the longitudinal line just behind the transversal line on the platform. The alternate foot was placed out of the platform with the toes at the edge of the platform. While maintaining this position, subjects were instructed to perform a lunge in which the knee was flexed with the goal of making contact between the anterior knee and the metal stick. When the subjects were able to maintain heel and knee contact, the metal stick was moved away from the knee. The distance achieved was then recorded in centimeters. Three trials were performed for each ankle (i.e., dominant and non-dominant) with 10 seconds of passive recovery between trials. The third value in each ankle was selected for subsequent analysis of weight-bearing DF ROM. The participants' dominant leg was defined by their preference for kicking.

The subjects sat with hips, knees, and ankles bent to 90 degrees in an adjustable-height chair with the tibia perpendicular to the floor and the foot resting on the floor. Each subject performed maximal voluntary isometric contraction of plantar flexion of the first metatarsophalangeal joint of the big toe (TFS) for 3 seconds to determine maximal voluntary contraction (MVC) torque. MVC torque was measured at a neutral position of the ankle and metatarsophalangeal joints. To ensure accurate positioning of the hallux onto the JTech Medical Commander™ (Midvale, UT, USA) load cell and to minimize the influence of the extrinsic muscles of the foot (ankle plantarflexors and flexor hallucis longus) and the second to fourth toes, a purpose-built wooden platform was constructed and positioned under the load cell. As shown in Fig. 1, this permitted the tested foot to be positioned such that the proximal metatarsophalangeal joint of the big toe was positioned at the edge of the platform. A strap and an examiner stabilized the foot to secure the anterior section of the foot onto the platform.

A custom-made ankle strength device was used to measure plantarflexion and dorsiflexion torque. Subjects were seated on a chair, with their trunk, thighs, lower thighs, and feet fastened to the chair and the torque meter device. DFS and PFS were calculated as the tensile and compressive force using a strain gauge (Winlaborat V4.20, Buenos Aires, Argentina) (Fig. 2).

Measured MVC torque values were normalized by body weight (kg/bw). Participants then performed three trials at maximal effort with a 1-minute rest period between trials to minimize muscle fatigue. The average of three consistent measures was then calculated. Then, we re-measured MVC torque on a different day to determine the test-retest repeatability of such measurements by calculating intra-class correlation coefficient (ICC).

Data were analyzed using PASW/SPSS Statistics 20 (SPSS Inc., Chicago, IL, USA) for Windows. The paired t-test was used to compare data between the right and left sides. Pearson correlation coefficients (r) were used to determine the strength and directionality of relationships among the different variables (DF ROM, TFS, DFS, and PFS). A correlation coefficient (r) of 0 to 0.4 was considered to represent a weak relationship, a coefficient of 0.4 to 0.7 was considered to represent a moderate relationship, and a coefficient of 0.7 to 1.0 was considered to represent a strong relationship¹⁸⁾. All data are presented as means and standard deviations. In all analyses, $p < 0.05$ was understood to indicate statistical significance.

RESULTS

The ICCs of TFS, DFS, and PFS were 0.89, 0.84, and 0.86, respectively.

Table 1 shows variables for the right and left side, along with a comparison of these data. There were no statistically significant differences ($p \geq 0.05$) between the dominant and non-dominant side for any variable tested.

Table 2 shows the Pearson's correlation coefficients between DF ROM, PFS, DFS, and TFS in the participants tested. DFS showed a moderate correlation with DF ROM ($r = 0.473$, $p < 0.001$) and with TFS ($r = 0.516$, $p < 0.001$). The linear regression equations were between DFS and DF ROM ($y = 0.0149x + 0.3019$; $y = \text{DFS}$) and DFS and TFS ($y = 0.1529x + 0.3507$; $y = \text{DFS}$). However, the relationships between PFS and TFS were weak ($r = 0.397$, $p < 0.001$).

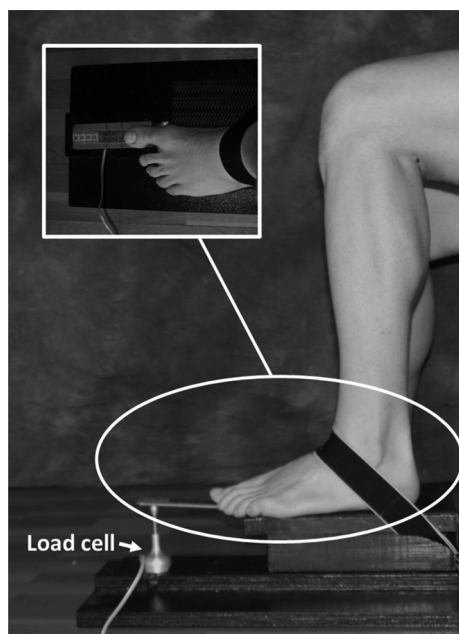


Fig. 1. Toe flexor strength setup

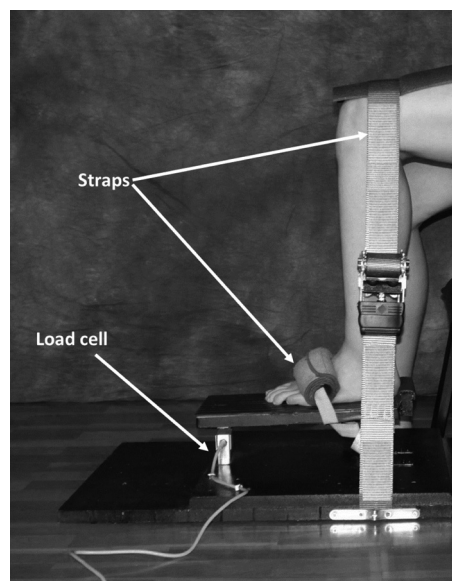


Fig. 2. Dorsiflexion and plantarflexion strength setup

Table 1. Mean and standard deviation and the comparison of dominant and non-dominant (n=29)

DF ROM_Dominant (cm)	11.41 ± 4.08	
DF ROM_Non-dominant (cm)	11.36 ± 2.90	p>0.05
TFS_Dominant (kg/bw)	0.84 ± 0.38	
TFS_Non-dominant (kg/bw)	0.82 ± 0.36	p>0.05
DFS_Dominant (kg/bw)	0.48 ± 0.12	
DFS_Non-dominant (kg/bw)	0.48 ± 0.13	p>0.05
PFS_Dominant (kg/bw)	1.42 ± 0.34	
PFS_Non-dominant (kg/bw)	1.48 ± 0.43	p>0.05

DF ROM: dorsiflexion range of motion; TFS: toe flexor strength; DFS: dorsiflexion strength; PFS: plantarflexion strength

Table 2. Correlation coefficients (n=58 limbs)

	DF ROM	TFS	DFS	PFS
DF ROM	1.0	0.279*	0.473**	-0.139
TFS	0.279*	1.0	0.516**	0.397**
DFS	0.473**	0.516**	1.0	0.153
PFS	-0.139	0.397**	0.153	1.0

*p<0.05; **p<0.001. DF ROM: dorsiflexion range of motion; TFS: toe flexor strength; DFS: dorsiflexion strength; PFS: plantarflexion strength

DISCUSSION

The main findings of the present study show a moderate correlation between ankle DF ROM and dorsiflexor strength, as well as a moderate correlation between dorsiflexor strength and flexor muscle strength in the first toe.

Another interesting finding was that none of the variables we measured showed any statistical relevance when compared between the dominant and non-dominant side. Therefore, the present study suggests that there are no important differences between the dominant and non-dominant foot and ankle in healthy subjects. In this sense, similar data were reported by van

der Harst et al.¹⁹⁾, who found no significant differences in most of the kinematic and kinetic data between the dominant leg and the contralateral leg during multi-articular movement as a single-leg hop for distance.

Ankle dorsiflexion motion is important in multi-directional running tasks to facilitate ground clearance and preparation for foot impact^{20, 21)}. Consequently, restricted performance in the ankle dorsiflexion test would suggest potential movement impairment, which could alter the mechanics of movement in multi-directional running tasks.

Kurihara et al.²²⁾ reported that maximum isometric toe flexor muscle strength was significantly correlated with the cross-sectional area of the plantar intrinsic and extrinsic muscles. In the present study, first toe flexor muscle strength was significantly corrected with DF ROM. Thus, to increase first toe flexor muscle strength, it is apparent that increases in the DF ROM are required. The specific effects of exercise training on DF ROM are unknown and further studies should now examine the effect of first toe muscle strength.

Fowles et al.²³⁾ reported that reduced force generation capacity was an important factor underlying the muscle tendon unit length-tension relationship and/or the plastic deformation of connective tissues. Low ankle DF ROM may thus change the length-tension curve of the dorsiflexor muscles and interfere with the development of dorsiflexor strength in daily life activities.

In the current study, we found no significant correlation between PFS of the ankle and DF ROM. Low ankle DF ROM may not therefore interfere with the development of PFS during regular activities.

While the results from the current study are important in the area of ankle DF ROM, literature suggests that our study is not without limitations. The main limitation of the present study was that the participants were healthy and free of major foot and ankle problems; consequently, the present data should be extrapolated to different participant populations with caution. Future studies will require a larger and more evenly age-distributed population.

In conclusion, ankle DF ROM could play an important role in determining ankle dorsiflexor strength in young adults. The implications of this research could be beneficial for both the rehabilitation and the injury prevention field.

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