

Original Article

An Examination of Limb Position for Measuring Toe-grip Strength

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Abstract. [Purpose] The purpose of the present study was to investigate the limb position at which the maximum toe-grip strength could be exerted as well as measurement reproducibility. [Subjects] Twenty healthy young women were selected. [Methods] We measured toe-grip strength under three conditions: 90° hip and knee flexion while sitting, 90° hip flexion and knee extension while sitting, and a standing position. [Results] We found that toe-grip strength was significantly lower in the 90° hip flexion and knee extension sitting position than in the 90° hip and knee flexion sitting position and standing position. Moreover, the 90° hip and knee flexion sitting position produced the best intraclass correlation coefficient ($r = 0.813$). [Conclusion] The results suggest that 90° hip and knee flexion while sitting is the most suitable limb position for measuring toe-grip strength, as this position allows maximum strength to be exerted and allows measurements to be repeated.

Key words: Toe-gripping strength, Reproducibility, Healthy females

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INTRODUCTION

Toe grip is a complex motion involving several muscles. In the toes, these muscles include the intrinsic flexor pollicis brevis, flexor pollicis longus lumbrical, flexor brevis, and flexor longus¹. Toe-grip strength is measured while sitting with the trunk in the vertical position, the hip and knee joints at 90°, and the ankle joint in a neutral position^{1–5}. Toe-grip strength is a useful index for evaluating an individual's risk of falling^{6, 7}, and toe-grip strength interventions are used to prevent falls^{1, 5}. However, limb position during these measurements has not been sufficiently investigated. To make this a reliable evaluation index, it is necessary to examine which limb positions elicit maximum muscle strength and investigate reproducibility.

Finger-grip strength is reported to be greater when measured in a standing position than when measured in a sitting or supine position⁸. Grip strength is also said to be maximized when the wrist joint is in slight dorsiflexion⁹ and the elbow joint extended¹⁰. Reproducibility in the different limb positions has also been examined, with measurements in the standing position with the elbow flexed at 90° exhibiting the best reproducibility¹¹. For toe-grip strength, a similar level of muscle strength can be exerted in both the

currently use measurement position—sitting with the hips and knees flexed to 90°—and the standing position¹². It was also reported to be easier to exert maximum strength when the ankle is in dorsiflexion or a neutral position compared with plantar flexion¹³. Although these reports suggest that the current neutral ankle position is optimal for measurement, it remains unclear which hip and knee joint positions are best suited for measurement. Thus, we believe it is necessary to verify the effect of changing the hip and/or knee joint angle. In addition, limb positions for measuring toe-grip strength have not been examined from the standpoint of reproducibility.

The current study focused on changes in the knee joint angle in a sitting position. Toe-grip strength was measured in a sitting position with the hip and knee joints flexed at 90°, sitting position with the hip flexed at 90° and the knee extended, and in the standing position as reported in previous studies. We investigated the limb position at which the maximum toe-grip strength could be exerted and also examined the reproducibility of these measurements.

SUBJECTS AND METHODS

The subjects were 20 healthy women with no known orthopedic impairments. Their age, height, and body weight (mean \pm SD) were 20.8 ± 1.0 years, 159.2 ± 5.4 cm, and 51.9 ± 5.4 kg, respectively. The present study was approved by the Ethics Committee for Human Research of Tohoku Fukushi University (RS1211022). The subjects provided informed consent for participation in the study.

Toe-grip strength was measured using the dominant foot, and measurement was performed using a toe-grip dy-

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Table 1. Toe-grip strength and intraclass correlation coefficients (ICCs) (n=20)

	90° hip and knee flexion sitting position	90° hip flexion and knee extension sitting position	Standing position
First (kg)	19.5 ± 3.7 (11.2–24.5)	17.1 ± 3.1 (8.1–21.7)	18.4 ± 2.5 (12.3–21.5)
Second (kg)	19.2 ± 3.3 (12.1–24.3)	16.2 ± 3.3 (9.6–21.6)	18.8 ± 2.9 (12.8–23.2)
Average (kg)	19.4 ± 3.4*	16.7 ± 2.8	18.6 ± 2.6*
ICC (1,1)	0.813	0.494	0.78
95%CI	0.592–0.921	0.086–0.762	0.530–0.906

Mean ± standard deviation (SD). * $p < 0.05$ versus the 90° hip flexion and knee extension sitting position

namometer (T.K.K. 3360; Takei Co Ltd, Niigata, Japan). The handle of the force meter was set on the first metatarsophalangeal joint. After a sufficient number of training trials and adequate rest, toe-grip strength was measured twice, and the mean value was used in the analysis. The right toe was dominant (defined as the toe used to kick a ball) in all the subjects.

The following three limb positions were used to measure toe-grip strength: sitting with the trunk in the vertical position and the hip and knee joints flexed at 90° (90° hip and knee flexion sitting position); sitting with the trunk in the vertical position, the hip joint flexed at 90°, and the knee joint extended (90° hip flexion and knee extension sitting position); and the standing position. The pelvic girdle and joints were in a neutral position during the 90° hip flexion and knee extension sitting position. Toe-grip strength during the sitting position was measured on a treatment table that could be adjusted for height. The test administrator checked the postures with a goniometer and stabilized the toe-grip dynamometer while measurement was taken on the side. In the standing position, the feet were placed shoulder-width apart, and the ankle was in a neutral position with regard to inversion, eversion, dorsiflexion, or plantar flexion with the arms hanging down at the sides of the trunk. To compensate for the height of the toe-grip dynamometer, the height of the leg not being measured was adjusted using a supplemental platform. Toe-grip strength measurements were also taken again on another day using the same procedure. The order of the three measurement conditions was randomly determined.

We used the SPSS software (version 12.0 for Windows, SPSS Inc., Chicago, IL, USA) for the statistical analysis and performed repeated measures analysis of variance and Dunnett's test for multiple comparisons to compare the toe-grip strength under each condition. The level of significance was set at 0.05. The reproducibility of each toe-grip strength measurement condition was statistically analyzed using intraclass correlation coefficients (ICC1, 1).

RESULTS

The mean ± SD values for toe-grip strength were 19.4 ± 3.3 kg in the 90° hip and knee flexion sitting position, 16.7 ± 2.8 kg in the 90° hip flexion and knee extension sitting position, and 18.6 ± 2.6 kg in the standing position. These

values were significantly different. Multiple comparisons found that the toe-grip strength was significantly lower in the 90° hip flexion and knee extension sitting position than in the other 2 positions ($p < 0.05$).

The ICC values for each position were 0.83 for the 90° hip and knee flexion sitting position, 0.49 for the 90° hip flexion and knee extension sitting position, and 0.78 for the standing position, and the 90° hip and knee flexion sitting position showed the best intraclass correlation coefficient ($r = 0.813$) (Table 1).

DISCUSSION

The current study measured toe-grip strength during 90° hip and knee flexion while sitting, 90° hip flexion and knee extension while sitting, and while standing to examine which limb position allowed for the exertion of maximum muscle strength and to investigate measurement reproducibility. The analyses found that toe-grip strength in the 90° hip flexion and knee extension sitting position was significantly lower than those in the 90° hip and knee flexion sitting position and the standing position. Moreover, the 90° hip and knee flexion sitting position produced the best intraclass correlation coefficient ($r = 0.813$). This finding indicates that 90° hip and knee flexion while sitting is the most suitable limb position for measuring toe-grip strength in terms of reproducibility and the ability to exhibit maximum strength.

Our results showed that the positions able to elicit maximum toe-grip strength were the standing position and 90° hip and knee flexion while sitting, which is in agreement with the findings of previous studies. The ankle, a talocrural joint, exhibits a convex shape on the surface of the lower leg joint, which acts as a wedge when moving from the neutral position to dorsiflexion and provides stability¹⁴. In both the 90° hip and knee flexion sitting position and the standing position, stability during measurement is provided by the subject's own body weight, which is thought to enable the exertion of maximum muscle strength.

Measuring toe-grip strength in the 90° hip and knee flexion sitting position had the best reproducibility, followed by the standing position and then the 90° hip flexion and knee extension sitting position. Reproducibility interpreted via intraclass correlation coefficients¹⁵ was "almost perfect" for the 90° hip and knee flexion sitting position, "substan-

tial” for the standing position, and “moderate” for the 90° hip flexion and knee-extension sitting position. We believe 90° hip and knee flexion while sitting was the most reproducible because measurements in this position were not accompanied by shifts in the center of gravity and there was little effect from anatomical restrictions due to extension of biarticular muscles such as the gastrocnemius and hamstring. When measuring toe-grip strength in the standing position, the center of gravity can shift posteriorly as toe-grip strength is exerted, which tends to cause compensative movements such as anteversion of the trunk or to require postural strategies to maintain balance. Moreover, for measurements in the 90° hip flexion and knee extension sitting position, biarticular muscles such as the gastrocnemius and hamstring extend to flex the toes when exerting toe-grip strength, which can easily lead to anatomical restrictions. Therefore, it is believed that these two measurement positions would likely produce variations during the exertion of toe-grip strength.

The present study had certain limitations. First, it is difficult to extend our findings to the general population because only healthy young women participated in the study. Future studies should involve healthy young men and individuals from different age groups.

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