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Intrarater and Interrater Reliabilities for a Toe Grip Dynamometer

Daisuke Uritani, MHSc, RPT[1)], Takahiko Fukumoto, MS, RPT[1)],
Daisuke Matsumoto, MS, RPT[1)]

[1)] *Department of Physical Therapy, Faculty of Health Science, Kio University: 4-2-2 Umaminaka, Koryocho, Kitakatsuragigun, Nara 635-0832 Japan.*
TEL: +81 745-54-1601, FAX: +81 745-54-1600, E-mail: d.uritani@kio.ac.jp

Abstract. [Purpose] The aim of this study was to evaluate the intrarater and interrater reliabilities of a toe grip dynamometer. [Subjects] The subjects were 180 community-dwelling people and 20 university students. [Methods] We assigned 180 individuals to three groups based on age to determine the intrarater reliability. The groups consisted of young (age, 20 to 39 y), middle-aged (age, 40 to 59 y) and older adults (age, 60 to 79 y). Interrater reliability was investigated using 20 university students as subjects. We calculated intraclass correlation coefficients to assess the intrarater and the interrater reliability. The intrarater reliability was assessed for each group by gender. We calculated intraclass correlation coefficients for the interrater reliability by comparing the first measurements made by two testers. The Bland-Altman analysis was used to assess fixed and proportional bias. [Results] The intrarater reliability showed a substantial to almost perfect agreement in male and almost perfect agreement in female subjects. For the intrarater reliability, a fixed bias was found in most measurements, but proportional bias was not found at all. The interrater reliability showed almost perfect agreement. Fixed bias and proportional bias were not found for the interrater reliability. [Conclusion] The intrarater and the interrater reliabilities of the toe grip dynamometer were substantial, indicating its suitability for clinical use.
Key words: Toe grip strength, Toe grip dynamometer, Reliability

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INTRODUCTION

Toe flexor strength is associated with postural control while standing[1)] and with walking ability[2, 3)]. Many investigators have reported that toe flexor strength decreases with aging,[1, 4, 5)] and low toe flexor strength is an important risk factor for falls among the elderly[6–8)]. In addition, inadequate toe strength results in hallux valgus or lesser toe deformities[8–10)]. These can also negatively affect balance[6)] and increase the risk of falling among the elderly[3, 6)]. Thus, to evaluate and increase toe flexor strength is important for predicting and preventing toe deformities and falls.

Toe flexor strength has been evaluated in various ways and a standard method of measurement, such as that for determining hand grip strength, has not yet been established. Thus, standardized values of toe flexor strength vary among studies and age-related changes have not been clarified even though strength decreases with aging as noted above. Some investigators have defined toe flexor strength as pressure on the ground, which has been measured using force plates or a pressure platform[1, 4, 8)]. However, these methods may be inconvenient in terms of setup, portability and costs in the clinical setting and in field research. Although a paper grip test has been used in some studies[5, 11)], the outcome is difficult to quantify. Therefore, a portable instrument that can simply and rapidly measure toe flexor strength is required.

We therefore developed a portable toe grip dynamometer based on the hand grip dynamometer. This instrument can measure actual toe grip strength (TGS) rather than pressure force on the ground. However, its reliability has not yet been established. The aim of this study was to evaluate the intrarater and the interrater reliabilities of this custom designed toe grip dynamometer.

SUBJECTS AND METHODS

Our first study assessed the intrarater reliability of the toe grip dynamometer with 90 males (mean age 50.0 ± 17.0 years) and 90 females (mean age 49.1 ± 17.1 years) who were volunteers attending a sports events and a municipal health guidance program. Our second study assessed interrater reliability with 20 randomly selected university students (ten males and ten females; mean age 20.5 ± 0.7 years; mean height, 163.2 ± 8.7 cm; mean weight, 58.5 ± 9.5 kg). The participants of the first study were not included in the second study. None of the participants had serious ankle or foot injuries or toe deformities.

The Research Ethics Committee of Kio University (H22-21) approved this study, and each participant provided their written informed consent to participation before the study began.

Five volunteer physical therapists who have held licenses for 3 to 16 (mean 8.0 ± 5.4) years performed the measurements in the first study. All of them had experience of measuring TGS using the toe grip dynamometer before participating in the study. Two fourth-grade physical therapy students with no experience of measuring TGS using our dynamometer made the measurements in the second study. They received an explanation about how to measure TGS using the dynamometer and practiced doing so before taking measurements for the study.

The toe grip dynamometer was developed, based on a hand grip dynamometer, with technical assistance from Takei Scientific Instruments Co. Ltd (Fig. 1). The dimensions of the instrument are 200 (W) × 480 (D) × 110 (H) mm and it weighs 4 kg, which renders it quite portable. The diameter of the grip bar is 8 mm, which allows comfortable gripping by the toes. A movable heel stopper was developed to adjust for foot size when measuring TGS. The measurement range is from 0.1 to 40.0 kg, and the measurement accuracy is 0.1 kg. The peak value is measured and retained which allows recording of maximum strength after completion of the measurements.

For the measurements, the participants sat upright on a chair without leaning on the backrest, and practiced the testing procedures before actual measurements were taken. The bilateral hips and knees were flexed at about 90 degrees and the ankles were placed in the neutral position. The first proximal phalanx was positioned on the grip bar and the heel stopper was adjusted to fit the heel of each participant. The bar was then gripped with maximal effort using all the toes (Fig. 1). Testers stabilized the toe grip dynamometer while two TGS measurements were made on each side. The first side to be measured in the first measurement was randomly set, then the other side was measured. The second measurement followed the same procedure. The second measurement was performed on the same day.

Data were categorized into groups of young adults (YA; age, 20 to 39 years), middle-aged adults (MA; age 40 to 59 years) and older adults (OA; age, 60 to 79 years) and analyzed using SPSS 17.0 J for Windows (SPSS Japan, Tokyo, Japan). We calculated intraclass correlation coefficients (ICCs) and 95% confidence intervals to assess the intrarater and interrater reliabilities. The intrarater reliability was assessed for the total number of participants and for each group by gender. The ICC (1.1) and ICC (1.2) were calculated to assess intrarater reliability. We calculated the ICC (2.1) for the inter-rater reliability by comparing the first of the measurements made by two testers. The ICC scores were conventionally interpreted as: 0.0 to 0.20, slight; 0.21 to 0.40, fair; 0.41 to 0.60, moderate; 0.61 to 0.80, substantial and 0.81 to 1.0, almost perfect agreement[12]. In addition, Bland-Altman analysis[13] was used to explore systematic errors, such as fixed and proportional bias and to determine the limits of agreement. Fixed bias exists when 95% CI for the mean of differences between two measurements does not include zero, and proportional bias exists when correlation between the mean of two measurements and the difference between two measurements is significant. Lower and upper coefficient limits were calculated and the most optimistic range was adopted as the limit of agreement. A significance level of 5% was chosen.

Fig. 1. Test of toe grip strength. The first proximal phalanx is positioned on the grip bar and the movable heel stopper is adjusted to fit the heel.

RESULTS

Table 1 shows the characteristics of each group, and Table 2 shows TGS of the first and the second measurements, as well as ICC (1.1) and (1.2) for each group by gender. The TGS (mean ± SE) of males ranged from 7.3 ± 0.5 kg in the first measurement on the right in OA to 16.4 ± 1.0 kg in the second measurement on the right in YA. Those of females ranged from 5.6 ± 0.5 kg in the first measurement on the right in OA to 11.8 ± 0.8 kg in the second measurement on the right in YA. Standard errors of measurements were within 1.1 kg. For males, the ICC (1.1) ranged from 0.54 (95% confidence interval (95%CI), 0.24 to 0.75) on the right in OA to 0.91 (95%CI, 0.82 to 0.96) on the left in YA, and ICC (1.2) ranged from 0.71 (95%CI, 0.39 to 0.86) on the right in OA to 0.95 (95%CI, 0.90 to 0.98) on the left in YA. For females, the ICC (1.1) ranged from 0.76 (95%CI, 0.55 to 0.88) on the left in MA to 0.92 (95%CI, 0.84 to 0.96) on the left in OA, and ICC (1.2) ranged from 0.86 (95%CI, 0.71 to 0.93) on the left in MA to 0.96 (95%CI, 0.91 to 0.98) on the left in OA. The Bland-Altman analysis showed that fixed biases were found for all groups of both genders, on the left for males of YA, but on the right for females of YA (Table 3). Correlation coefficients between the mean of two measurements and the difference between two measurements were not significant. That is, proportional biases were not found in any group of either gender.

ICC (2.1) was 0.97 (95%CI: 0.93 to 0.99). Fixed bias was not found in measurements for interrater reliability (Table 3). Correlation coefficients between the mean of two testers and the difference between two testers were not significant. That is, proportional biases were not found in the measurements used to assess interrater reliability.

DISCUSSION

The intrarater reliability of the toe grip dynamometer was analyzed according to age group, because toe deformity

Table 1. Characteristics of participants in the intrarater reliability test

	Male			Female		
	YA (n = 30)	MA (n = 30)	OA (n = 30)	YA (n = 30)	MA (n = 30)	OA (n = 30)
Age (y)	30.6	46.6	69.7	29.7	49.0	68.6
(SD)	(5.4)	(5.5)	(4.9)	(6.9)	(6.2)	(5.2)
Height (cm)	172.8	170.0	165.4	161.8	157.0	152.9
(SD)	(5.7)	(6.0)	(5.1)	(5.1)	(5.9)	(3.5)
Weight (kg)	70.0	66.7	63.7	53.3	54.0	53.9
(SD)	(9.2)	(9.9)	(10.3)	(4.5)	(8.5)	(9.9)

Abbreviations: YA, Young adults aged 20 to 39 y; MA, Middle-aged adults aged 40 to 59 y; OA, Older adults aged 60 to 79 y. All data are expressed as means with standard deviation (SD).

Table 2. Intrarater reliability of toe grip strength*

	Right				Left			
	Mean TGS (SE) *Measurement 1	Mean TGS (SE) *Measurement 2	ICC (1,1) (95%CI)	ICC (1,2) (95%CI)	Mean TGS (SE) *Measurement 1	Mean TGS (SE) *Measurement 2	ICC(1,1) (95%CI)	ICC(1,2) (95%CI)
YA								
Male	15.4 (1.05)	16.4 (1.03)	0.90 (0.81–0.95)	0.95 (0.89–0.98)	15.7 (1.0)	15.9 (1.0)	0.91 (0.82–0.96)	0.95 (0.90–0.98)
Female	11.0 (0.8)	11.8 (0.8)	0.82 (0.66–0.91)	0.90 (0.79–0.95)	10.4 (0.6)	11.0 (0.7)	0.90 (0.81–0.95)	0.95 (0.89–0.98)
MA								
Male	12.6 (0.9)	14.3 (1.1)	0.88 (0.77–0.94)	0.94 (0.87–0.97)	12.4 (0.9)	13.3 (0.8)	0.88 (0.77–0.94)	0.94 (0.87–0.97)
Female	7.5 (0.5)	8.9 (0.5)	0.77 (0.57–0.88)	0.87 (0.72–0.94)	7.7 (0.5)	9.0 (0.6)	0.76 (0.55–0.88)	0.86 (0.71–0.93)
OA								
Male	7.3 (0.5)	9.3 (0.6)	0.54 (0.24–0.75)	0.71 (0.39–0.86)	8.0 (0.5)	8.7 (0.6)	0.87 (0.75–0.94)	0.93 (0.85–0.97)
Female	5.6 (0.5)	6.6 (0.5)	0.77 (0.57–0.88)	0.87 (0.73–0.94)	5.8 (0.5)	6.4 (0.5)	0.92 (0.84–0.96)	0.96 (0.91–0.98)

Abbreviations: TGS, toe grip strength; YA, young adult; MA, middle-age adult; OA, older adult; 95%CI, 95% confidence interval. *Toe grip strength measured in kg.

and function might be influenced by age and might affect measurement outcomes. Agreement in the intrarater reliability test for each group was substantial to almost perfect with ICC (1.2) scores ranging from 0.71 (95%CI: 0.39 to 0.86) for the right feet of males in the OA group to 0.96 (95%CI: 0.91 to 0.98) for the left feet of females in the OA group (Table 2). These findings indicate that measuring TGS with the toe grip dynamometer is highly reliable, substantial to almost perfect, regardless of age when repeated by the same physical therapist. However, ICC (1.1) in males was 0.54 (95%CI: 0.24 to 0.75) for the right feet of the MA group. This ICC score was lower than those of the other groups. The TGS values recorded from the first measurements were remarkably low for some men in the OA groups, perhaps because of unfamiliarity with the measurement procedure. In addition, some women in the MA and OA groups might have had hallux valgus or lesser toe deformities that could have influenced the test-retest reliability, though a visual inspection did not confirm significant deformities in any of the women participating in this study. Thus, we recommend that testers should repeat TGS measurements to ensure the highest reliability especially when testing middle-aged and elderly people. Fixed biases were found for almost all measurements. The largest limit of agreement was −5.4 kg (Table 3). This result indicates that the second measurement might be 5.4 kg larger than the first measurement. It also indicates that testers should repeat TGS measurements to ensure the highest reliability. In addition, to minimize the difference between two measurements, testers should sufficiently instruct subjects about the method for measuring TGS because measuring TGS is an unfamiliar procedure.

Agreement in the interrater reliability test was almost perfect, even though the operators were physical therapy students with no experience of measuring TGS using the toe grip dynamometer. These findings suggest that the toe grip dynamometer could yield similar outcomes regardless of the operator. The procedure of measuring TGS using the toe grip dynamometer is simple and straightforward. Therefore, even examiners who have never used the device can measure

Table 3. Assessment of fixed bias

		Mean of difference (SEM)	95%CI for mean of difference	Fixed bias	Limits of agreement
Intrarater reliability					
YA					
Male	R	–1.01 (0.43)	–1.89, –0.13	Yes	–4.10, 2.09
	L	–0.13 (0.43)	–1.00, 0.74	No	–3.21, 2.95
Female	R	–0.80 (0.47)	–1.76, 0.16	No	–4.18, 2.58
	L	–0.61 (0.28)	–1.19, –0.03	Yes	–2.64, 1.42
MA					
Male	R	–1.74 (0.37)	–2.49, –0.99	Yes	–4.39, 0.91
	L	–0.90 (0.40)	–1.71, –0.09	Yes	–3.76, 1.96
Female	R	–1.36 (0.25)	–1.88, –0.85	Yes	–3.17, 0.45
	L	–1.29 (0.31)	–1.93, –0.65	Yes	–3.53, 0.96
OA					
Male	R	–2.02 (0.47)	–2.98, –1.06	Yes	–5.41, 1.37
	L	–0.67 (0.26)	–1.21, –0.14	Yes	–2.55, 1.20
Female	R	–1.00 (0.27)	–1.56, –0.44	Yes	–2.97, 0.96
	L	–0.65 (0.18)	–1.01, –0.29	Yes	–1.92, 0.62
Interrater reliability		0.16 (0.32)	-0.51, 0.61	No	-2.37, 2.69

SEM, standard error of mean; 95%CI, 95% confidence interval for mean difference, YA, Young adult group; MA, Middle-aged adult group; OA, Old adult group

TGS with high reliability. In addition, systematic error was not found because fixed bias and proportional bias were not found by Bland-Altman analysis. However, as well as subjects, testers need to understand the measurement method for TGS, and use the toe grip dynamometer properly to attain reliable measurements.

The reliability of measurements obtained using the hand grip dynamometer is high and agreement is almost perfect[14]. A hand grip dynamometer is easy to use in clinical practice. On the other hand, TGS has been measured using various ways, without a standard method[1, 4, 5, 8, 11]. In addition, some methods of measuring TGS are inconvenient in the clinical setting,[1, 4, 8] and some use qualitative assessments[5, 11]. Accordingly, our toe grip dynamometer will be useful in the clinical setting, because it is easy to use and its mesurements can be compared.

We measured toe flexor strength as grip strength in this study. In clinical practice, toe gripping is prescribed as a muscle strengthening exercise for toe flexor muscles. Our method follows the same way. Thus, the toe grip dynamometer can be used to assess treatment effect, and our method of measuring TGS is clinically relevant.

One limitation of this study was that the results were obtained from adults aged 20 to 79 years. Therefore caution is required when extrapolating our results to individuals who are younger than 20 and older than 79 years of age. Furthermore, an extremely powerful TGS of over 40.0 kg cannot be determined. Therefore, the reliability of the toe grip dynamometer for individuals aged less than 19 and more than 80 years will require investigation. Since the toe grip dynamometer was designed based on adult feet, its value for lower elementary school or kindergarten children should be investigated in a future study, since foot size might influence the reliability of this device. Another limitation of our study was that our results were obtained from healthy individuals without discernable foot pathology. TGS of patients with severe toe deformities or with diabetes might be measured in the clinical setting. Therefore, care is required when measuring TGS in the presence of severe toe deformities or other foot pathologies, the influence of which requires further study.

As stated above, although toe flexor strength has been measured using various methods, controversies have arisen regarding settings and quantitative values, and the comparison of results among studies has been difficult. The toe grip dynamometer used in this study is portable and very reliable. Further applications of toe grip strength or function measured using the toe grip dynamometer will be developed in the future.

In conclusion, the intrarater and interrater reliabilities of the new toe grip dynamometer, based on handgrip dynamometer, is substantial making it suitable for clinical use. The toe grip dynamometer will be useful in the clinical setting and in field research, because it is portable, simple to use and relevant to adults aged between 20 and 79 years.

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