Effect of Toe Exercises and Toe-grip Strength on the Treatment of Primary Metatarsalgia

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Research article

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Abstract

Background

The relationship of metatarsalgia and toe function is poorly understood. We investigated the efficacy of toe exercises for the treatment of metatarsalgia.

Methods

Forty-one (56 feet) metatarsalgia patients (age mean ± SD: 63.4 ± 10.6) underwent toe strength measurement. We recorded pre- and post-treatment visual analogue scale (VAS), The American Orthopaedics Foot & Ankle Society (AOFAS) score, marble pickup, and single-leg standing time (SLST) and compared in two subgroups to evaluate impact of disease duration on treatment outcome.

Results

Post treatment, toe plantarflexion strength improved (all $p < 0.01$); VAS scores decreased ($p < 0.01$); and AOFAS scores, marble pickup, and SLST improved (all $p < 0.01$). Patients symptomatic for > 1 year had significantly lower changes in VAS scores ($p < 0.01$). Multivariate analysis showed patients with longer disease duration and larger body mass index had significantly lower improvement in VAS scores ($p = 0.029$ and $p = 0.036$, respectively). Device consistency assessed by Intraclass Correlation Coefficients (ICC) was excellent (0.89–0.97).

Conclusion

Toe function and metatarsalgia is improved by toe exercises, suggesting that they are closely related.

1. Introduction

Muscle mass decreases after the age of approximately 50 years [1]. This age-related loss of muscle mass is termed "sarcopenia" and has been a focus of constant attention because of its association with mortality [2]. Lower ambulatory performance with aging is closely related to sarcopenia [3, 4]. In the lower extremities, the toes play a crucial role and assist stability during gait and balance tasks [5]. However, elderly patients tend to have decreased toe grip strength (TGS) of approximately 30%, compared to younger patients [6]. Loss of toe-muscle strength leads to impaired balance, thereby increasing the risk of falls [5]. Furthermore, toe-grip weakness has been theorized to be associated with a range of forefoot deformities and disorders [7].

Metatarsalgia is one among the commonest conditions causing forefoot pain, characterized by pain in the front part of the foot, under the heads of the metatarsal bones. Metatarsalgia has various causes, including mechanical and iatrogenic factors [8]. Mechanical overload of the weightbearing structure is the fundamental etiology of primary metatarsalgia. Excessive forefoot loading is related to intrinsic abnormalities of metatarsal anatomy and gait mechanics [9]. Regarding gait mechanics, the toes play an important role in maintaining floor contact, which is shared with the metatarsal area during the toe-off phase in the gait cycle [10]. Therefore, the load on the forefoot is affected by the load on the toes. Thus, metatarsalgia seems to be closely related to toe function.

There have been no reports on the relationship between toe function and primary metatarsalgia. Toe function is difficult to evaluate. One of the methods to evaluate toe function is to measure the TGS. Despite a few reports on TGS measurement [6, 11], no fully validated study has yet assessed the absolute value of TGS in a clinical setting [12]. The lack of an evaluation method makes it difficult to understand complicated forefoot disorders. Horiuchi [13] developed a new device that measures TGS: a push-type toe-grip meter that can easily assess toe function.

This study was conducted to investigate TGS in metatarsalgia patients with the abovementioned novel device. Furthermore, we observed the effect of toe exercise on metatarsalgia to assess the relationship between TGS and clinical disease symptoms. We theorized that toe exercise can improve both TGS and clinical symptoms of metatarsalgia.

2. Methods

2.1. Patients

Between April 2012 and December 2015, all patients with metatarsalgia longer than 2 months without remission, regardless of treatment, were included in this study. Metatarsalgia was defined as weightbearing pain and/or tenderness on the plantar side of the lesser metatarsal head. Sixty patients were screened and examined according to the subject selection criteria by a single foot and ankle surgeon (KA) study investigator. A statistically powered sample size was not calculated as this was a retrospective case series. Simple radiography of the patients’ feet was carried out in the dorsoplantar view during weightbearing. The rate of patients' complications of the hallux valgus, defined as a 20-degree or greater angle of the hallux valgus, was examined. In addition, the forefoot length was assessed in the first metatarsal relative to the second metatarsal. Patients were divided into 3 groups according to this length: in index minus, the first metatarsal was shorter than the second and the following metatarsals became progressively shorter; in index plus, the first metatarsal was larger than the second; and in index plus-minus, the first and second metatarsals were approximately the same length. Furthermore, all patients underwent Magnetic resonance imaging (MRI) and were confirmed not to have rupture of plantar plates or Freiberg's disease. The exclusion criteria were as follows: patients with conditions such as rigid forefoot deformities (e.g., hammer toes, claw toes) and patients with infection, crystal arthritis, previous foot surgery, major trauma, rheumatic disease, and neurological disease (e.g., cerebral infarction, parkinsonism, radiculopathy, and Morton's neuroma). After implementing the exclusion criteria, we included 56 feet (41 patients) older than 20 years old who were not allowed to take medications or receive any insole treatment during the study period. All patients provided written informed consent.

2.2. Toe exercise

Patients received an 8-week toe functional exercise program conducted under a physiotherapist's guidance. We administered simple exercises such that elderly individuals could understand them. The patients sat in an upright position, placed a towel on the floor, and placed one foot on it, one shoulder-width apart. Then, they used their toes to scrunch up the towel, making sure to keep the rest of their foot in contact with the ground. Three sets of 15 scrunches were performed on each foot. In addition to the towel exercise, curling and spreading out of all toes was done. Patients were instructed to perform the exercises for 10 minutes twice a day for 2 months.

2.3. Toe-grip strength meter

TGS was measured using the push-type toe-grip strength meter (Fig. 1) [13]. The device measures the strength of the toes by pressing on the floor with a strain gauge attached to the cantilever. For the measurement, a foot was placed on the positioning bar of the device and strapped tightly to restrict upward motion during measurement. The measurement was started after the confirmation of zero on the device's screen. The second foot could be measured by turning the measurement board upside down. We measured all the TGS values before and after the exercise program in both upright and sitting positions. In the upright position, patients stood upright on the measurement board facing forward. Special care was taken not to lean forward, causing extra weight to be placed on the toes. During measurement in the seated position, patients sat on a chair adjusted to their height with their knee and hip joints precisely at 90 degrees. Then, the patients gripped their toes using maximal force in both positions. The highest value of force (N) with which toes were gripped was automatically recorded as the maximal peak force on the device's screen. We undertook the measurement twice on the same day. The average of the two measured values was recorded.

2.4. Assessment

Patients were also assessed by using the visual analog scale (VAS) for pain, the American Orthopedic Foot and Ankle Society (AOFAS) hallux metatarsophalangeal–interphalangeal scale (scale of 100 points), the number of marbles that the patient could pick up using their toes in 10 s while seated (Picking Up the Marbles [PUM]), and observing the number of seconds the patient was able to stand on a single leg for up to 60 s (Single Leg Standing Time [SLST]). The VAS, consisting of horizontal lines of a 100-mm length, was self-recorded. For pain intensity, the scale is anchored by "no pain" (scale of 0) and "worst imaginable pain" (scale of 100). To investigate whether the duration of disease affects the outcome of treatment, patients were divided into two groups based on disease durations of more than 1 year or less, and the average difference in the degree of improvement between the pre- and post-treatment measures was examined. Multivariate analysis was conducted to investigate which background factor correlated with the degree of improvement in the TGS in the upright and sitting positions, degree of improvement in AOFAS score, and improvements in VAS scores. The reliability of the push-type toe-grip strength meter was assessed with the Bland-Altman plot using the intra-rater correlation coefficient (ICC). During the measurement of TGS, the inter-rater reliability was not examined because the value is only read from the screen of the device.

2.5. Statistical analysis

To compare the pre-exercise (pre-ex) and post-exercise (post-ex) values in relation to the parameters evaluated, the paired t-test for independent samples was used. The average difference in the degree of improvement between the pre- and post-treatment measures was also evaluated by the paired t-test. A multivariate generalized linear model, using normal distribution, was used to investigate the relationship between the background factors, including age, sex, body mass index (BMI), duration of disease, affected side, forefoot morphology, and outcomes, as well as improvement of TGS in upright and seated positions, VAS scores, and AOFAS scores. In the affected-side analysis, the right and left feet were evaluated as a comparison based on bilateral feet measurements. In the forefoot morphology, plus and plus-minus feet were evaluated as a comparison based on minus feet. To determine the inter-rater reliability of the push-type toe-grip strength meter, the Bland–Altman plot was constructed to assess the agreement. Intra-class correlation coefficients for agreement were calculated. The data were analyzed by SPSS statistical software (version 21, Chicago, Illinois). The level of significance was set at $p < 0.05$.

3. Results

Basic characteristics of the current study participants are shown in Table 1. In total, 56 feet with metatarsalgia, 32 on the right side and 24 on the left side, were included. Symptoms involved both feet in 14 patients. The average duration of metatarsalgia was 21.2 ± 33.2 (range 2–120) months. In the evaluation of forefoot morphology, index minus was present in two thirds of patients, and index plus was only present in one case. A total of 20 patients, 30.3% of whom had a hallux valgus angle of 20 degrees or more on foot x-ray. (Table 1).

In the unilateral cohort, the toe-grip strength of the affected foot was significantly weaker than that in the contralateral side in the sitting position. In the upright position, the strength of the affected foot was weaker compared to that of the unaffected foot, but this difference was not significant (Table 2). After the 8-week exercise program, all variables, including toe plantar-flexion strength, significantly increased in both standing and seated positions. Table 3 shows the change in values. The mean VAS score significantly decreased from 5.2 to 2.5 ($p = 0.00$). The AOFAS score significantly improved from 67.2 to 77.1 ($p = 0.00$) and PUM also significantly improved from 7.7 to 9.5 ($p = 0.00$).

After dividing patients into two groups according to disease duration, there were 20 patients in the more than 1-year group and 36 in the less than 1-year group. With the available numbers, no significant difference in TGS or AOFAS scores could be detected pre- and post-exercise in neither upright nor sitting positions. Only VAS scores were significantly different between the two groups. Patients with symptoms persisting for more than 1 year showed a significantly lower change in VAS scores (Table 4). The multivariate generalized linear model showed that the plus-minus foot had significant improvement in

AOFAS scores compared to that of the minus foot between the upright and sitting positions. Regarding VAS scores, improvement was worse in patients with a long history of disease and high BMI (Table 5). The results from the Bland–Altman plots indicated that there was excellent agreement among the positions, both on the affected side and the unaffected side (0.89–0.97). No adverse events were noted.

Table 1. Basic characteristics

Variables			
Age (years)	63.4	±	10.6
Sex, Male/Female	7	/	34
Height (cm)	156.6	±	7.7
Weight (kg)	52.8	±	7.3
BMI (kg/m^2)	21.5	±	2.5
The duration of having metatarsalgia (months)	21.2	±	33.2
Affected side, Left/Right/Bilateral	10/18/14		
Hallux valgus, (%)	17/56 (30.3%)		
Morphology, minus/plus-minus/plus	38/17/1		

*The valuables are presented as the mean ± standard deviation

Abbreviations: BMI, body mass index.

Table 2. TGS comparison between affected side and unaffected side.

	Affected			Unaffected			*P*
Upright TGS (N)	51.8	±	37.9	57.4	±	31.3	0.10
Sitting TGS (N)	23	±	17.2	28.8	±	18	<0.01

Table 3. Valuables pre- and post-exercise							
	Pre-ex			Post-ex			*P*
Upright TGS (N)	54.4	±	36.1	67.4	±	37.9	0.01
Sitting TGS (N)	24.7	±	16.8	32.1	±	17.9	<0.01
AOFAS score	66.7	±	16	79.9	±	12.5	<0.01
VAS	4.4	±	1.6	1.8	±	1.4	<0.01
Marble pickup (number)	5.9	±	2.9	8.6	±	2.3	<0.01
SLST (sec)	39.4	±	23.2	49.3	±	19	<0.01
The valuables are presented as the mean ± standard deviation							
Abbreviations: TGS, toe grip strength. N, newton. ex, exercise.							

Table 4. Mean difference between the pre- and postoperative measures in two groups with disease duration							
Values	Over 1 year (n=20)			Less than 1 year (n=36)			p
Upright TGS	15.9	±	26.8	11.3	±	30.3	0.56
Sitting TGS	9.2	±	8.6	6.3	±	15.2	0.35
VAS	1.5	±	1.19	3	±	1.5	<0.01
AOFAS score	11.7	±	10.9	14.1	±	10.6	0.42
The valuables are presented as the mean ± standard deviation							
Abbreviations: TGS, toe grip strength. N, newton. ex, exercise.							

Table 5 Multivariate generalized linear model for coefficients among the variables									
outcomes		age	gender	BMI	duration of disease	right foot	left foot	plus-minus	plus
upright TGS change	coef	-0.09	11.17	-2.04	-0.09	2.48	-14.9	4.87	2.17
	[95% Conf. Int]	[-0.90, 0.718]	[-11.50, 33.93]	[-5.22, 1.14]	[-0.34, 0.15]	[-21.59, 6.55]	[-37.43, 7.63]	[-12.69, 22.42]	[-56.16, 60.50]
	P value	0.827	0.336	0.208	0.437	0.84	0.195	0.587	0.942
sitting TGS change	coef	-0.08	3.98	0.11	-0.02	4.21	-0.97	8.48	9.33
	[95% Conf. Int]	[-0.46, 0.30]	[-6.80, 14.76]	[-1.40, 1.61]	[-0.14, 0.09]	[-7.18, 15.61]	[-11.64, 9.70]	[0.17, 16.80]	[-18.29, 36.96]
	P value	0.679	0.469	0.888	0.682	0.469	0.858	0.046*	0.508
VAS change	coef	0.01	0.04	-0.17	-0.01	-0.06	-0.93	0.57	-0.43
	[95% Conf. Int]	[-0.32, 0.05]	[-1.12, 1.21]	[-0.33, -0.01]	[-0.027, -0.01]	[-1.30, 1.17]	[-2.08, 0.23]	[-0.33, 1.47]	[-3.42, 2.56]
	P value	0.669	0.942	0.036*	0.029*	0.918	0.115	0.212	0.777
AOFAS change	coef	0.06	-2.71	-0.23	<0.01	-0.63	-1.36	9.06	7.69
	[95% Conf. Int]	[-0.24, 0.36]	[-11.15, 5.74]	[-1.41, 0.95]	[-0.09, 0.10]	[-9.56, 8.30]	[-9.73, 7.00]	[2.54, 15.57]	[-13.97, 29.34]
	P value	0.701	0.53	0.7	0.927	0.89	0.749	0.006*	0.487
*Coeficient is significant at the 0.05 level									
Abbreviations: Coef, β coeficient. 95% Conf. Int, 95% confidence intervals. TGS, toe grip strength									

4. Discussion

The unique findings of this study provide objective evidence confirming the effects of toe exercise on metatarsalgia. Insole was the standard treatment for metatarsalgia, and its effect was reported to improve VAS by an average of 1 point [14]. In this study, the average improvement was 2.7 points, which indicates less pain than that associated with insoles. Previous reports have evaluated TGS between the sitting and upright positions [15]. They found that there was no difference in the TGS between the upright and sitting positions. Contrary to the previous report, TGS in the sitting position was significantly lower than that in the upright position. The push-type toe-grip strength meter in the current study measures the pressing force applied to the ground by the toes, whereas the pull-type meter used in the previous study measures the toes' pulling force in the proximal direction, similar to the hand-grip dynamometer. As the shape of the toes is different for each person, it is questionable whether the pulling bar of the pull-type device fits all foot shapes. Furthermore, we placed emphasis on the force that presses or steps on the ground as a function of the toes. In that sense, we believe that the push-type device reflects the function of the toes more clearly.

The current study also demonstrated that the affected foot has significantly weaker TGS in the sitting position compared to that in the unaffected foot, but no significant difference is observed in the upright position. It is unclear why the difference in the upright case is not manifested; it may possibly be due to some compensatory function working in the upright position to maintain the TGS.

Primary metatarsalgia is considered an abnormality that is related to the anatomy of the metatarsal bones as well as to the relationship between metatarsal bones and the rest of the foot which leads to overload [9]. Metatarsal bone-length discrepancy has received the most attention so far [16]. The present study showed that patients with index-minus accounted for most of the participants, suggesting that the second metatarsal was relatively long, and the metatarsal length seemed to be involved in the onset of metatarsalgia. However, as the length of the metatarsal bone cannot be changed except for surgery, another viewpoint is required for conservative treatment.

During walking, the load increases to about 2 times the body weight before toe-off at the MTP joints [17] due to the combined effect of forward-falling and ground reaction force loads applied to the forefoot. When the toes lose the ability to functionally push off the ground, it puts an increased load on the metatarsal area. This repetitive overloading in the metatarsal area causes metatarsalgia.

We observed an improvement in PUM, indicating that exercise not only improves strength but also enhances toe function. Therefore, metatarsalgia may be relieved because of an improvement in toe function.

Patients with long durations of metatarsalgia (more than one year) did not have improved VAS scores to a great extent in this study. The multivariate generalized linear model showed that the foot with plus-minus morphology had a significant improvement in AOFAS scores compared to that in the foot with minus morphology in the upright and sitting positions. Regarding VAS scores, improvement was worse in patients with a long history of disease and high BMI. In terms of the long duration of metatarsalgia, chronic pain is generally considered difficult to cure. Although there is an opinion that it is difficult to create a temporal boundary in terms of the difference between acute and chronic pain, generally, pain lasting 12 weeks or more is regarded as chronic pain [18]. The cause of pain in metatarsalgia is unclear, but it is presumed that the acute phase involves nociceptive pain. The improvement in pain was worse in chronic cases, suggesting that mixed pain, involving nociceptive, nociplastic, and neuropathic pain, is involved in chronic disease [19]. For patients with hallux valgus, waiting for elective surgery has been associated with less improvement in physical function outcomes following surgery [20], which supports our findings. Our results suggest that a different treatment strategy may be needed for chronic pain in metatarsalgia lasting more than 1 year.

We found that an increased BMI positively correlated with worse improvement in VAS scores. Moreover, previous reports showed a high BMI was positively correlated with elevated opioid consumption rates [21]. However, this result may stem from doctors prescribing a high number of opioids because of the patient being obese. The relationship between obesity and pain is still unclear.

The strength of this study is in the assessment of the toes using reproducible absolute values of TGS, showing that weak toes tend to promote metatarsalgia. This device measures TGS by measuring the strength used to press the toes into the floor. The force of toe plantar-flexion is the strength of sustaining one's weight, shared with the ball area in the toe-off phase. Therefore, this movement directly reflects the power of the toe-off phase by pressing off the ground. This push-type toe-grip strength meter is a useful device to detect toe weakness in the clinical setting.

The current study has certain limitations. First, the participants were recruited from a single institution; hence, the results may not be generalizable. Second, we have no objective proof of overloading in the metatarsal area in people with weak toe grip. Proper walking not only needs a certain level of plantar-flexion strength but also the ability to move the toes in order to work effectively. The ability of toes to control the loading warrants further investigation. Third, pain may deteriorate due to the natural course of metatarsalgia progression. Since we did not include a control group, further investigations in the form of randomized controlled studies, are required to investigate the effectiveness of toe exercises in metatarsalgia.

5. Conclusion

We investigated TGS in metatarsalgia patients by using a new device. To our knowledge, this is the first observational study to determine the relationship between TGS and clinical symptoms. Our results provide objective evidence confirming the effect of toe exercises. Patients with metatarsalgia tend to have a weaker TGS. Regaining toe strength could ease the pain caused by metatarsalgia; however, patients with minus morphology feet are likely to develop metatarsalgia, resulting in difficulty in healing, and patients with chronic metatarsalgia for more than 1 year show a significantly lower improvement in VAS scores. The push-type toe-grip strength meter is highly reproducible and a clinically useful device.

Abbreviations

AOFAS

American Orthopedic Foot and Ankle Society, BMI:Body mass index ICC:Intra-rater correlation coefficient, PUM:Picking up the marbles, TGS:Toe grip strength, SLST:Single leg standing time, VAS:Visual analog scale.

Declarations

Ethics approval and consent to participate

This single-center study was approved by the institutional review board (approval no. 17-R069), and conducted in accordance with the tenets of the Declaration of Helsinki.

Consent for publication

Not applicable

Availability of data and materials

The authors confirm that the data supporting the findings of this study are available within the article.

Competing Interests

The authors declare there are no conflicts of interest.

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Authors contributions

K. A. involved in making the conception and design of research and carried out drafting of the article. K. A. and T. A. collected the data and analyse and prepared the paper. N. K. provided the advice about the experimental condition. All authors read and approved the final manuscript.

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References

1. Janssen I. The epidemiology of sarcopenia. Clin Geriatr Med. 2011;27(3):355–63.
2. Roubenoff R. Sarcopenia: effects on body composition and function. J Gerontol A Biol Sci Med Sci. 2003;58(11):M1012–7. http://www.ncbi.nlm.nih.gov/pubmed/14630883.
3. Hida T, Harada A. Fall risk and fracture. Diagnosing sarcopenia and sarcopenic leg to prevent fall and fracture: its difficulty and pit falls. Clin Calcium. 2013;23(5):707–12.
4. Hida T, Shimokata H, Sakai Y, Ito S, Matsui Y, Takemura M, et al. Sarcopenia and sarcopenic leg as potential risk factors for acute osteoporotic vertebral fracture among older women. Eur Spine J. 2016;25(11):3424–31.
5. Menz HB, Morris ME, Lord SR. Foot and ankle characteristics associated with impaired balance and functional ability in older people. J Gerontol A Biol Sci Med Sci. 2005;60(12):1546–52.
6. Endo M, Ashton-Miller JA, Alexander NB. Effects of age and gender on toe flexor muscle strength. J Gerontol A Biol Sci Med Sci. 2002;57(6):M392–7.
7. Menz HB, Morris ME, Lord SR. Foot and ankle risk factors for falls in older people: a prospective study. J Gerontol A Biol Sci Med Sci. 2006;61(8):866–70.
8. Espinosa N, Brodsky JW, Maceira E. Metatarsalgia. J Am Acad Orthop Surg. 2010;18(8):474–85.
9. Espinosa N, Maceira E, Myerson MS. Current concept review: metatarsalgia. Foot Ankle Int. 2008;29(8):871–9.
10. Mann RA, Hagy JL. The function of the toes in walking, jogging and running. Clin Orthop Relat Res. 1979;142(142):24–9.
11. Soma M, Murata S, Kai Y, Nakae H, Satou Y. An examination of limb position for measuring toe-grip strength. J Phys Ther Sci. 2014;26(12):1955–7.
12. Soysa A, Hiller C, Refshauge K, Burns J. Importance and challenges of measuring intrinsic foot muscle strength. J Foot Ankle Res. 2012;5(1):29.
13. Horiuchi K, Handa S, Aoki K. A design and evaluation of a push type toes flexion strength meter, Japanese. J Wellbeing Sci Assist Technol. 2008;8:15–22.
14. Männikkö K, Sahlman J. The effect of metatarsal padding on pain and functional ability in metatarsalgia. Scand J Surg. 2017;106(4):332–7. https://doi.org/10.1177/1457496916683090. [Epub 2017 Mar 1].

15. Handa S, Horiuchi K, Aoki K. A study on the measurement of toes grasping strength and effect of standing postural control. Jpn J Ergon. 2004;40:139–47. (in Japanese).
16. Mann RA, Chou LB. Surgical management for intractable metatarsalgia. Foot Ankle Int. 1995;16(6):322–7.
17. Al-Munajjed AA, Bischoff JE, Dharia MA, Telfer S, Woodburn J, Carbes S. Metatarsal loading during gait-A musculoskeletal analysis. J Biomech Eng. 2016;138(3):4032413.
18. Johnson MI. The landscape of chronic pain: broader perspectives. Medicina. 2019;55(5).
19. Freynhagen R, Parada HA, Calderon-Ospina CA, Chen J, Rakhmawati Emril D, Fernández-Villacorta FJ, et al. Current understanding of the mixed pain concept: a brief narrative review. Curr Med Res Opin. 2019;35(6):1011–8.
20. Sutherland JM, Wing K, Younger A, Penner M, Veljkovic A, Liu G, et al. Relationship of duration of wait for surgery and postoperative patient-reported outcomes for hallux valgus surgery. Foot Ankle Int. 2019;40(3):259–67.
21. Kvarda P, Hagemeijer NC, Waryasz G, Guss D, DiGiovanni CW, Johnson AH. Opioid consumption rate following foot and ankle surgery. Foot Ankle Int. 2019;40(8):905–13.

Figures

Figure 1

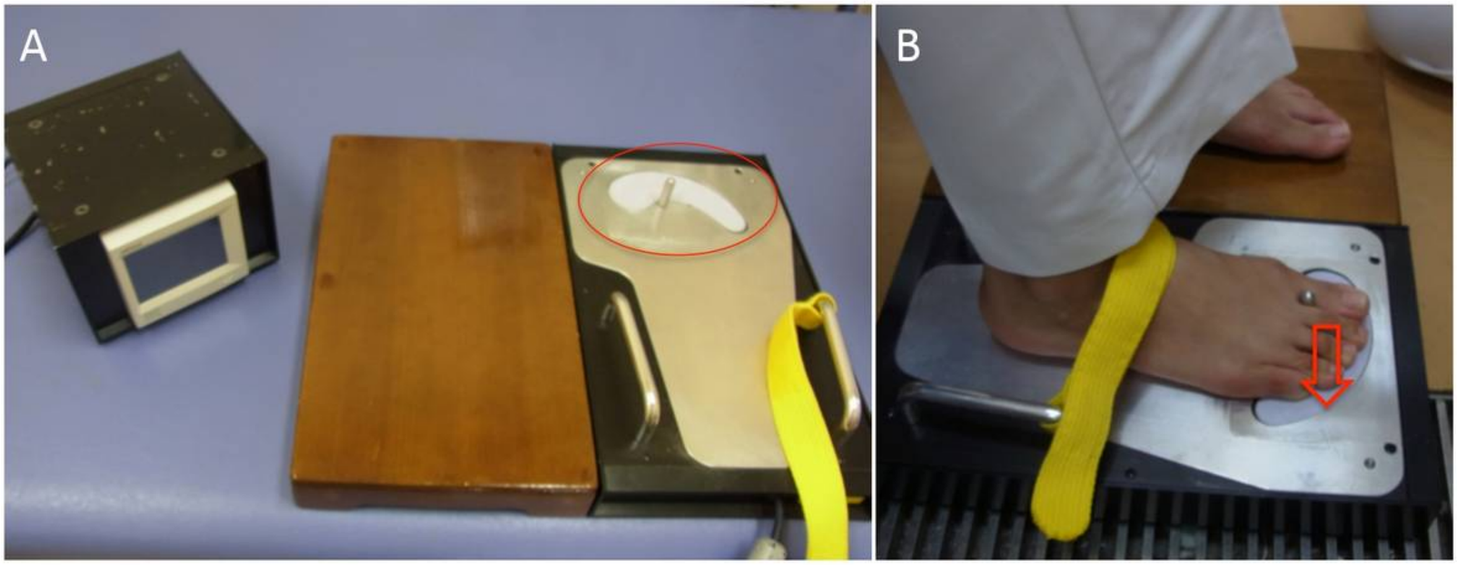

Figure 1

The push-type toe-grip strength meter A: Toes press the floor face with the strain gauge installed in the cantilever (red circle). The greatest value (Newton: N) while the toes are gripping is automatically recorded as the maximal peak force on the black box screen. B: The foot is placed on the positioning bar and strapped tightly to the device to restrict upward movement during measurement. Then, the floor face is pressed as firmly as possible with the foot.