Community-dwelling Older Individuals using Day Services: Prevalence and Associations Between Walking, Toe-grip Strength, and Foot Problems -Cross-sectional Study-

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Abstract

Background: Foot disorders in older individuals contribute to balance, posture, and gait instability, causing a decrease in activity of daily living and quality of life. However, the existing foot problems of older individuals in the community have not been studied well in Japan.

Method: This cross-sectional study analyzed the foot-related data of 176 frail, old-aged participants who attended day service centers in Japan. Foot conditions were assessed and measured from various aspects, as was weight distribution to the floor. Multiple regression analysis was used to find foot item variables that correlated with toe-grip strength and walking speed.

Results: Prevalence of skin dryness and suspected and existing nail fungal infection was high in both sexes regardless of care level. Prevalence rate of toe deformity and arch deformity was significantly higher in men and women requiring long-term care, respectively. The multiple regression analysis using stepwise method indicated the right toe-grip strength had a statistically significant association with the arch deformity, suspected or existing nail fungal infection, and nail thickness of the right sided foot (p-value, 0·012, 0·034, 0·040 respectively). Coefficients of all independent variables were negative. Any independent variables were not selected from the left foot. The corn, callus and toe deformity of right sided foot was significantly associated with walking test (p-value, 0·026, 0·033 respectively).

Conclusions: Our study supported that individuals requiring more long-term care tend to have more foot problems. Some specific conditions were associated with toe-grip force and walking speed. This finding contributes to future strategies to protect foot health for community-dwelling older individuals, particularly the frail population.

Trial registration: Not Applicable

Background

Studies that have investigated the prevalence of foot condition of community-dwelling older individuals are limited in Japan compared with other countries. The aging population is rapidly increasing in Japan. From 1960 to 2018, the rate of change in the aging population has increased from 5·6–28% in Japan and from 4·75% to 9·026% globally [1]. Given the fact that the rates of bedridden people and falling were high in Japan, there is a need to consider the foot issue more seriously. According to the data provided by Ministry of Health, Labour and Welfare, individuals certified for long-term care insurance accounted for approximately 18% among those aged > 65 years. Overall, 601,279 individuals were categorized into care level 5. They need full assistance in all daily activities, such as eating, excretion, bathing, changing clothes, and washing the mouth. This is equivalent to 9·06% of individuals who are certified for long-term care insurance [2].

Considering the number of ambulances transporting elderly individuals with fall accidents in the Tokyo Fire Department, the number of carriers increased for individuals ≥ 65 years. Fall accidents accounted for approximately 80% of accidents in the daily life of elderly individuals in 2016 [3]. The number of deaths due to falling has increased from 5944 in 2016 to 8803 in 2018 [4].

Foot problems of community-dwelling older people have become a growing concern worldwide. Reports from other countries indicate that 75–80% of community-dwelling people > 65 years have more than one foot problem [5, 6] and frequently complain about pain [7], although the rate varies among surveys. It is difficult for older individuals to take care of their feet [8]. Foot problems are more prevalent among frail individuals [5]. Major foot problems include toe nail disorders, lesser toe deformities, arch deformity, corn and callus, maceration between toes, skin dryness, edema, and hallux valgus [9–11]. Aging may cause further problems because of morphology and structural and functional changes. A previous study indicated that foot conditions are associated with postural stability, which lead to increase in falls [12]. Although foot problems are most prevalent in older people with chronic diseases, such as diabetes and rheumatoid arthritis, they also occur in older people without diseases.

The reason being that there is no podiatry system or systemic foot education in Japan; hence, the awareness on foot studies is low. However, toe studies involving community-dwelling older individuals have been conducted by researchers with a background in physical therapy, e.g., in Japan. Two unique medical equipments to measure toe force were developed in Japan by separate researchers. One instrument measure toe-grip strength (T.K.K.3364, Takei Scientific Instruments, Nigata city, Japan), whereas the other measures toe grasp force (Nissin Industry, Saitama city, Japan). Although both measure toe force, the targeted muscle is different. Another machine called Foot Look (Foot Look Inc. Fukuoka city, Japan) was developed to measure foot pressure on the floor and foot structure. In the present study, we initially focused on the prevalence of foot conditions from various aspects and then explored the association between foot conditions and toe force or walking speed, and lastly observed the correlation between toe force and walking speed. A previous study reported the association between toes and lower limb muscle. The lower limb muscles lead to postural stability while walking and maintaining balance [13, 14]. The association of toe exercise and cognitive function was also reported [15]. Walking speed is one of the indicators of foot functioning and has been investigated from various aspects [16–20].

The findings on the present study may lead to generate strategies for promoting foot health for older people. Therefore, the aims of the study were as follows: To evaluate (1) the prevalence of foot conditions in older people in the community, (2) foot item variables which correlate with toe-grip strength and walking speed, and (3) types of future strategies, which can be considered from the study.

Design: This study is a cross-sectional study using random cluster sampling and conformed to the STROBE statement. Data were collected from July to October in 2019.

Methods

Our target participants were older people aged > 65 years who attended day service centers; day service centers or day care centers offering professional rehabilitation programs under long-term care insurance. We assumed that participants could walk or stand even using medical appliances; therefore, majority of the participants would be categorized into support leve1 1 to care level 3.

In Japan, there are two types of insurance for healthcare of older people: medical insurance and long-term care insurance. To use long-term health insurance system, older people in Japan have to apply and obtain certification by going through certain processes, including screening. Certified older people are categorized into seven levels (support level 1 or 2, or care level 1 to 5) [21]. The long-term insurance service is divided into home-based, community-based, or facility based. Under the home-based services, day service and day care centers provide daily cares, such as hygiene, meal, recreation, and physical rehabilitation, depending on the client's plan. In general, older people using one-day service centers are frailer than those who do not use such services. The author previously described this in another study [22].

According to an estimate based on the 2015 population census, there are 36,019,000 individuals > 65 years old in Japan as of March 2020 [23].

As of March 2019, the Ministry of Health, Labour and Welfare (MHLW) conducted the survey, which revealed that nearly 18·3% of the population > 65 years of age in Japan is eligible for using long-term care insurance [24].

For those who were categorized between care level 1 and 5 1,159,200 people used the day service, whereas 436,600 used the day care service offering rehabilitation [25].

According to the sample size calculator [26], 385 was the required number per population, with 95% confidence interval and 5% margin error. The sample size was also calculated using G*power. According to Cohen's parameter for the effect size for linear multiple regression [27] fixed mode, and R2 deviation from zero, we input the effect size for f2 (medium = 0·15), a = 0·05, power = 0·08 and dependent variables 3 and finally obtained a total sample size of 119. Therefore, although we aimed to recruit 385 individuals, a total sample size of 119 satisfies the requirement of the number of participants.

To achieve the initial target number of 385, we assumed that 500 would be the ideal invitation number of clients (400 facilities × 5 participants per facility × 0·25) by considering that nearly 23% would be rejected or drop out during the study.

The MHLW provided a list of in-home service providers in the target city of prefecture A, Japan for this study. We randomly selected 400 one-day service centers via the Excel random sheet. In addition, we selected a few facilities that were introduced through the author's connection as candidates for the study. We sent an invitation mail and a postcard with a checkbox indicating the level of willingness to participate in the survey to the randomly selected facilities. Out of 400 facilities, 27 facilities responded. The author contacted the facilities with an active answer via telephone and visited majority of them to explain the study contents. Ultimately, 20 facilities participated in this study. Some of them requested to conduct the study a few times for different clients using separate dates due to a high demand from clients. Some facilities were initially eager to participate, but they declined because of staff shortage or unreadiness of preparing for the study.

The manager or staff members of the facility were willing to explain to clients and their family beforehand. Because the survey time was limited for each facility, selection of study participants was conducted by the facilities. The study included clients who understood the study contents and for those who did not fully understand, their family agreed their participation in the study. The mini-mental state exam (MMSE) score was set at ≥ 10. However, clients who obtained a score of < 10 were included if a family agreed and signed the agreement letter. Clients with foot infections, such as ulcer or wound, were excluded.

Although there were many obstacles because of limited time allocation for the field survey, 6–9 clients from each facility were able to participate the study. Each facility assisted to obtain written study permission from the family member instead of the author. Moreover, we explained and obtained written consents from study participants right before the survey. Unexpectedly, several clients could not write the letter using a pen because of hand tremor and low sight vision. In those cases, the examiner or staff signed his/her name instead of the clients themselves with the agreement. The majority of participants of both sexes were support level 1 to care level 3. There were only two participants for each sex with care level 4. There were no people with care level 5.

Study instruments

The main author created a two-page assessment sheet for data gathering for another study (submission for other paper) and this study. Appendix 1 presents the definition, measurement unit and methods of foot-related items for assessment and measurement of the item selection of the assessment sheet. Previous studies used not only the foot assessment scores but also the cumulative methods of multiple foot problems or dichotomous scales, based on the presence or absence of foot disorders [4, 28]. In this study, we employed the dichotomous method for some items. An assessment sheet was developed by the lead researcher and evaluated by a doctor with abundant foot knowledge and practical skills in this domain. With approval from a foreign researcher via mail, some of their assessment items were introduced into the assessment sheet used in this study.

We used two types of machines for measurements. One of the machines was Foot Look (Foot Look Inc.), which precisely, timely and visually measures various items, including foot length, foot width, and toe angle from the sole using a computer and scanner. It provides a visual image of soles including the hallux valgus and floating toe, and weight distribution of the body to the floor (Fig. 1). We measured toe-grip strength by using a toe-grip dynamometer (T.K.K.3364 Takei Scientific Instrument) (Fig. 2). Participants were asked to sit upright, with both the hip and knee joints at 90 degree and the ankle joints in a neutral position. While fixing the heel by a stopper, the grip bar was positioned using the first proximal phalanx. Thereafter, the participants gripped the bar with the greatest possible force for approximately 3 seconds using their toes [29, 30], and then the machine displayed the force meter. We also used a thermometer to check skin temperature of the lower extremity.

Foot-related items were classified as either items requiring clients to perform active action or do passive action at the time of foot measurement, depending on the level of participation of the clients during the examination. The items were considered passive when the participants' feet were assessed by the examiner while merely sitting down. When the participants needed to move their toes or feet or walk or step on the measurement board of the machine, the item was considered active.

Study preparation

The first author established a research team from a blueprint. First, research assistants were recruited from the university students through application indicated in a poster. Nine students participated in this research during the summer. They were educated and trained to gain knowledge of foot and practice skills for measuring foot items.

The author arranged the visiting schedule to each facility. The research team, which consisted of the main author, 3–5 research assistants, and a co-author, visited each facility during the summer of 2019.

Procedure

Each facility provided a space where we could set up the machine and chairs. Research assistants mainly measured the walking speed, floating toe, hallux valgus angles (HVAs), and weight distribution using the machine and collected the data accordingly. With the use of the assessment sheet, foot assessment, which required extensive training, was conducted by the main author.

Through this survey, safety, such as fall and injury prevention, was the primary concern. In particular, when clients participated in the walking test and in stepping up to the table of the Foot Look machine, we carefully paid attention to their movement.

The first author obtained consultation and audit from a foot care specialist with > 20 years of experience based on anonymized foot images .

Ethics

The research conformed to the Declaration of Helsinki 2000. We obtained informed consents from all participants, with the approval of facility providers and some of the families. We selected the STROBE checklist to describe the study. The study was further approved by the ethics committee of Nagoya University (approval number: 2019 – 0150).

Analysis

The demographic characteristics and foot-related assessment and measurement data were first calculated using descriptive statistics. The items were categorized as continuous variables and categorical variables. Majority of the items were analyzed by categorizing into right and left foot. Sequentially, we simply observed the histogram, calculated the mean, SD, median, maximum, and minimum values, and employed the paired *t*-test, Fisher's exact test, and Mann–Whitney U test. We compared the data by four categories, namely, men, women, support level, and care level under the long-term insurance .

We initially counted the number of toes that had certain problems, such as thickened nail and ingrown nail. However, most foot-related items for assessment were coded as 1 (problem) or 0 (no problem), In this study, "problem" refers to the detected condition of the foot, deviating from the normal known condition. For prevalence analysis, some items that were defined in numbers were changed into dichotomous scales.

In stepwise multiple regression analysis, the dependent variables included the right and left toe-grip strength and walking speed, whereas the independent variables comprised the width of opened toes, floating toe, toe deformities, corn and callus, arch deformities, nail thickness, ingrown nail, suspected or existing nail fungal infection, HVA($HVA \leq 15°$, $15 < HVA \leq 20°$, $20° < HVA \leq 40°$, and $HVA > 40°$), and weight distribution. The independent variables were selected by predicting their association with toe-grip strength and walking.

For regression analysis, the continuous variable (number of toes, etc.) was used for the width of opened toes, whereas the dischotomoous variables (problem "1" or no problem "0" data) were used for the remaining items. Data were analyzed using the SPSS Statistics 26 (IBM Corp., USA)

Results

A flow diagram of participants is shown in Fig. 3. The total number of participants was 176. However, the final number of analyzed clients on foot prevalence was 160 due to the exclusion of some missing data. The association of right and left toe-grip force with foot-related items was 136 and 135 respectively. The association between walking and foot-related items was 119. Some clients were not able to step up to the table of the Foot Look Machine because of physical limitation or were unable to grip the bar on the toe-grip dynamometer, or some other data were missing due to one-sided paralysis caused by cerebrovascular or hip problems or other issues.. Furthermore, some clients were not able to participate for measurements that required active movement, such as opening toes. Therefore, participant number for the analysis was varied as per items. The sample number was valid for multiple regression analysis, as previously mentioned.

Tables 1–3 enumerate the participants' demographic data (age, 4 m walking speed, skin temperature, degree of hallux valgus, toe-grip force, Barthel Index, widths of opened toes, and medical history).

Table 1
Characteristics of the participants

	Men								Women							
	Support level (level 1 N = 6, level 2 N = 11)			Care level (level 1 N = 2, level 2 N = 12, Level 3 N = 11, level 4 N = 2)					Support level (level 1 N = 11 level 2 N = 42)			Care level (level 1 N = 21, level 2 N = 27, Level 3 N = 13, level 4 N = 2)				
	n	Mean	SD	n	Mean	SD	p-value		n	Mean	SD	n	Mean	SD	p-value	
Age	17	83.4	4.9	27	80.4	7.1	0.137		53	83.2	6.3	63	85.5	6.1	0.049	*
4-meter walking speed (second)	16	6.0	2.2	21	8.6	4.3	0.039	*	48	5.6	1.9	51	7.9	3.8	0.000	**
Skin temperature (foot)	15	33.6	1.4	23	33.6	2.1	0.998		47	34.2	1.7	58	34.2	1.8	0.944	
Right degree of hallux valgus	16	8.8	7.6	24	8.6	5.0	0.947		53	13.5	11.9	57	12.8	9.3	0.751	
Left degree of hallux valgus	15	10.2	8.0	24	6.2	7.3	0.119		52	12.7	11.3	57	14.3	9.2	0.427	
Right toe-grip strength	16	7.0	5.1	26	4.3	3.5	0.048	*	52	4.0	2.7	62	3.6	3.6	0.509	
Left toe-grip strength	16	6.3	3.2	26	4.1	3.2	0.038	*	52	3.8	2.3	62	3.5	2.5	0.588	

Paired *t*-test, *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Those insured under the long-term insurance system include category 1 (people aged 65 years or older), and 2 (people aged 40–64 years who are covered by a health insurance program). Applicants for care services must be screened. Accepted applicants are categorized into support level 1 and 2 and care level 1–5.

Applicants in support level can perform most of the basic activities in daily life by themselves, but they need nursing care up to certain extent. Applicants in care level need some kind of assistance to do certain activities in daily life because they cannot perform them by themselves, although it is possible for them to complete most of the basic activities in daily life.

Degree of hallux valgus was measured with Foot Look (Foot Look Inc). Toe-grip strength was measured with toe-grip dynamometer (T.K.K.3364., Takei Scientific Instrument).

Table 2
Table 2. Characteristics of the participants N = 160

	Men									Women								
Item	**Support level (n = 17)**				**Care level (n = 27)**					**Support level (n = 53)**				**Care level (n = 63)**				
	n	**Median**	**25%**	**75%**	**n**	**Median**	**25%**	**75%**	**p-value**	**n**	**Median**	**25%**	**75%**	**n**	**Median**	**25%**	**75%**	**p-value**
Barthel Index	17	95	90	100	24	85	71.3	100	0.071	52	95	90	100	62	95	85	100	0.890
Widths of opening toes (1st and 2nd), right foot	17	1	0.4	2.35	27	0.3	0.2	0.7	0.014*	52	0.6	0.2	1.7	62	0.3	0.1	1	0.005
Widths of opening toes (1st and 2nd), left foot	17	0.6	0.25	2.15	27	0.3	0.2	0.5	0.048*	53	0.6	0.2	1.8	62	0.2	0.1	0.5	0.007

Mann–Whitney *U* Test, *p < 0.05; **p < 0.01; ***p < 0.001; Data are median, 25%, and 75% percentile

The Barthel Index is a simple assessment and evaluation method to measure the 10 types of movement required for daily life. Widths of opening toes were measured with changes of the length of the midpoint between the 2nd toe and the 5th toe. The examiner asked participants to open the toes to the maximum

Note: Some participants were not able to answer the questions of Barthel Index and test of widths of opening toes.

Table 3
Characteristics of the participants N = 160

	Men					Women				
	Support level		**Care level**			**Support level**		**Care level**		
Item	**n**	**Rate**	**n**	**Rate**	**p-value**	**n**	**Rate**	**n**	**Rate**	**p-value**
Diabetes	7	41.2%	5	18.5%	0.164	7	13.2%	7	11.1%	0.780
Hypertension	8	47.1%	13	48.1%	1.000	24	45.3%	22	34.9%	0.341
Kidney disease	1	5.9%	1	3.7%	1.000	1	1.9%	1	1.6%	1.000
Arteriosclerosis obliterans	0	0%	3	11.1%	0.272	1	1.9%	0	0.0%	0.457
Heart disease	3	17.6%	4	14.8%	1.000	11	20.8%	14	22.2%	1.000
Brain disease	2	11.8%	16	59.3%	0.002**	4	7.5%	9	14.3%	0.377
Rheumatism	0	0%	1	3.7%	1.000	3	5.7%	0	0.0%	0.092
Hyperlipidaemia	0	0%	1	3.7%	1.000	3	5.7%	6	9.5%	0.506
Lung disease	0	0%	1	3.7%	1.000	4	7.5%	0	0.0%	0.041*
Incontinence	1	5.9%	2	7.4%	1.000	0	0.0%	4	6.3%	0.124

Fisher's exact test, *p < 0.05; **p < 0.01; ***p < 0.001

N (%) represents the number of participants who answered which disease they have or had. (Multiple answers)

Note: We were not able to obtain data from all participants

Considering the time constraint, answering all the MMSE questions was a tremendous emotional burden for the clients and the facilities. Therefore, on reaching 10 points, we stopped them from answering the remaining questions.

Falling information was initially included but was eventually eliminated because the information provided by the clients and the staff was uncertain. Meanwhile, physical activity was measured by short physical-performance battery tests including balance, chair standing, and walking tests, which were also subsequently declined. At first visit, performing balance and chair standing tests made the clients, as well as the staff, extremely anxious because of mechanical body changes, such as heart rate elevation and instability during standing. Therefore, we only selected the 4-meter walking test. The first selected geriatric depression test was also declined because of complaints from several older clients.

Tables 1–3 present the participants' characteristics. Out of 160 analyzed participants, 44 (27·5%) were men, whereas 116 (72·5%) were women, with an average age of 81·9 and 84·35 years, respectively. In addition, 17 (39%) and 27 (61%) men and 53 (46%) and 63 (54%) women were classified into the support level and care level, respectively. The most prevalent diseases were diabetes (41·2% of men with support level), hypertension (34·9%–48·1% of men and women), and brain diseases (59·3% of men with care level).

The mean scores of walking speed were higher in care level for both men and women (6.0 ± 2.2 vs 8.6 ± 4·3 sec for men and 5.6 ± 1.9 vs 7.9 ± 3.8 sec for women with support level and care level, respectively), and right and left widths of opened toes were significantly narrow in the support level as compared to that in the care level for both men and women.

Both the right and left toe-grip strength was significantly higher for men with support level than care level. Skin temperature on lower extremity was 33·6 °C to 34·2 °C. Table 4 presents the foot assessment results. Significant differences were only observed in arch deformity between women with care level and those with support level (p-value 0·037). Skin dryness and suspected or existing nail fungal infection were highly prevalent in both men and women in general (skin dryness for men above 85·2% for right and left side, for women above 77·8% for right side and left side; suspected or existing nail fungal infection for men above 92·6% and 95·2% for women). The prevalence of nail color change (above 69·8%), arch deformity (63%) was relatively high in both sexes. However, the prevalence of nail color change was higher in men, whereas that of arch deformity was higher in women for both sexes. Meanwhile, corn and callus were relatively low for both sexes. The distribution rate of the right-side weight to the floor was higher than that of left-side weight. The HVA was categorized into HVA ≤ 15°, 15 < HVA ≤ 20°, 20° < HVA ≤ 40°, and HVA > 40°(see Appendix1). The prevalence of hallux valgus above 15° was higher in women than in men (8·3%–26·7% and 28·8%–43·1%, respectively).

Table 4
Foot assessment

		Men					Women				
		Support level (n = 17)		Care level (n = 27)			Support level (n = 53)		Care level (n = 63)		
	Item	n	Rate	n	Rate	p-value	n	Rate	n	Rate	p-value
Right foot	Floating toe	9	39.1%	14	60.9%	1.000	37	47.4%	41	52.6%	0.841
	Toe deformities	8	47.1%	23	85.2%	0.015	46	86.8%	54	85.7%	1.000
	Skin lesions (Corn and callus)	1	5.9%	3	11.1%	1.000	11	20.8%	7	11.1%	0.200
	Maceration between toes	1	5.9%	2	7.4%	1.000	2	3.8%	6	9.5%	0.287
	Nail color change	15	88.2%	23	85.2%	1.000	42	79.2%	54	85.7%	0.461
	Arch deformities	12	70.6%	20	74.1%	1.000	44	83.0%	60	95.2%	0.037
	Longer nails	11	64.7%	18	66.7%	1.000	40	75.5%	53	84.1%	0.255
	Thickened nail	10	58.8%	17	63.0%	1.000	32	60.4%	42	66.7%	0.562
	Ingrown nail	4	23.5%	5	18.5%	0.716	19	35.8%	17	27.0%	0.321
	Skin dryness	15	88.2%	23	85.2%	1.000	45	84.9%	59	93.7%	0.139
	Edema	16	94.1%	27	100.0%	0.386	50	94.3%	61	96.8%	0.659
	Skin color change	17	100.0%	27	100.0%	1.000	51	96.2%	63	100.0%	0.207
	Suspected or existing nail fungal infection	16	94.1%	25	92.6%	1.000	52	98.1%	60	95.2%	0.624
	Hallux valgus										
	HVA ≤ 15°	14	87.5%	22	91.7%	0.455	34	64.2%	40	70.2%	0.863
	15° < HVA ≤ 20°	1	6.3%	2	8.3%		8	15.1%	7	12.3%	
	20° < HVA ≤ 40°	1	6.3%	0	0%		9	17.0%	9	15.8%	
	HVA > 40°	0	0%	0	0%		2	3.8%	1	1.8%	
Left foot	Floating toe	8	33.3%	16	66.7%	1.000	39	45.9%	46	54.1%	1.000
	Toe deformities	10	58.8%	18	66.7%	0.749	40	75.5%	55	87.3%	0.146
	Skin lesions (Corn and callus)	1	5.9%	1	3.7%	1.000	12	22.6%	12	19.0%	0.653
	Maceration between toes	1	5.9%	1	3.7%	1.000	1	1.9%	5	7.9%	0.217
	Nail color change	14	82.4%	22	81.5%	1.000	37	69.8%	50	79.4%	0.284
	Arch deformities	11	64.7%	17	63.0%	1.000	42	79.2%	54	85.7%	0.461
	Longer nails	10	58.8%	20	74.1%	0.334	36	67.9%	47	74.6%	0.536
	Thickened nail	10	58.8%	16	59.3%	1.000	24	45.3%	36	57.1%	0.263
	Ingrown nail	5	29.4%	12	44.4%	0.360	21	39.6%	25	39.7%	1.000
	Skin dryness	17	100.0%	25	92.6%	0.515	46	86.8%	49	77.8%	0.235
	Edema	8	47.1%	16	59.3%	0.539	21	39.6%	30	47.6%	0.454
	Skin color change	13	76.5%	18	66.7%	0.735	43	81.1%	41	65.1%	0.063
	Suspected or existing nail fungal infection	16	94.1%	25	92.6%	1.000	52	98.1%	60	95.2%	0.624
	Hallux valgus										
	HVA ≤ 15°	11	73.3%	21	87.5%	0.482	37	71.2%	33	56.9%	0.086
	15° < HVA ≤ 20°	2	13.3%	2	8.3%		2	3.8%	10	17.2%	
	20° < HVA ≤ 40°	2	13.3%	1	4.2%		12	23.1%	15	25.9%	

Fisher's exact test, *p < 0.05; **p < 0.01; ***p < 0.001

N (%) represents the number of participants whose foot conditions deviated from normal. Hallux valgus angle ≤ 15 was considered normal. Number of floating toe, hallux valgus angle (HVA), and weight distribution were measured using Foot Look (Foot Look Inc.)

		Men					Women				
	HVA > 40°	0	0%	0	0%		1	1.9%	0	0%	
Weight distribution	Left	5	31.3%	11	47.8%		17	34.0%	22	40.7%	
	Right	7	43.8%	11	47.8%	0.171	21	42.0%	28	51.9%	0.064
	Both	4	25.0%	1	4.3%		12	24.0%	4	7.4%	

Fisher's exact test, $*p < 0.05$; $**p < 0.01$; $***p < 0.001$

N (%) represents the number of participants whose foot conditions deviated from normal. Hallux valgus angle ≤ 15 was considered normal. Number of floating toe, hallux valgus angle (HVA), and weight distribution were measured using Foot Look (Foot Look Inc.)

Table 5 shows the sensitivity and vascular condition of the feet. Over 92.6% of both men and women had touch sensation, although some of them had diabetes. The rate of the palpable posterior tibial arteries was 29·6%–58·8% for men and 47·2%–57·1% for women with support level or care level.

Table 5
Sensitivity and circulation assessment for participants

Men						Women				
	Support level (n = 17)		Care level (n = 27)			Support level (n = 53)		Care level (n = 63)		
	n	Rate	n	Rate	p-value	n	Rate	n	Rate	p-value
Right foot										
Sensitivity of the first toe	16	94.1%	25	92.6%	1.000	52	98.1%	62	98.4%	1.000
Sensitivity of the third toe	16	94.1%	25	92.6%	1.000	52	98.1%	62	98.4%	1.000
Sensitivity of the fifth toe	16	94.1%	25	92.6%	1.000	52	98.1%	62	98.4%	1.000
Palpable posterior tibial arteries	10	58.8%	8	29.6%	0.068	25	47.2%	36	57.1%	0.351
Left foot										
Sensitivity of the first toe	16	94.1%	25	92.6%	1.000	53	100.0%	63	100.0%	1.000
Sensitivity of the third toe	16	94.1%	25	92.6%	1.000	53	100.0%	63	100.0%	1.000
Sensitivity of the fifth toe	16	94.1%	25	92.6%	1.000	53	100.0%	63	100.0%	1.000
Palpable posterior tibial arteries	9	52.9%	11	40.7%	0.539	26	49.1%	32	50.8%	1.000

N (%) represents the number of participants who answered "I feel it" when an examiner touched the their toe (sensitivity)

N (%) represents the number of participants whose pulse could be palpated by the examiner

Table 6 illustrates the multiple regression analysis results. Figure 4 illustrates the logical tree obtained from the regression analysis. Selected items which may associate with toe-grip strength and walking speed were input for analysis. The multiple regression analysis using stepwise method indicated the right toe-grip strength had a statistically significant association with the arch deformity, suspected or existing nail fungal infection, and nail thickness of the right sided foot (p-value, 0·012, 0·034, 0·040 respectively). Coefficients of all independent variables were negative. The highest standardized partial regression coefficient was right arch deformity. Adjusted R^2 was 0.099. Any independent variables were not selected from the left foot. The corn, callus and toe deformity of right sided foot was significantly associated with walking test (p-value, 0·026, 0·033 respectively). No significant association was found between left sided toe-grip strength and left sided foot-related items.

Table 6
Multiple regression analysis: The association between toe-grip strength, walking, and foot items

			95% Confidence Interval					
Item	Dependent variable	Independent variable	Partial regression coefficient	Lower limit	Upper limit	Standardized partial regression coefficient	P-value	
Toe-grip strength	Right toe-grip strength	Constant term	8.97	6.36	11.58		< 0.001	**
	(n = 136)	Right arch deformity	−1.87	−3.32	−0.42	−0.21	0.012	*
		R Suspected or presence of nail with fungal infection	−2.52	−4.86	−0.19	−0.17	0.034	*
		R Nail thickness	−1.14	−2.23	−0.06	−0.17	0.040	*
	Left toe-grip strength (n = 135)	Selected independent variable						
Walking speed	Walking test (seconds)	Constant value	5.16	3.79	6.52		< 0.001	**
	(n = 119)	R corn and callus	1.89	0.23	3.56	0.20	0.026	*
		Right toe deformity	1.63	0.13	3.13	0.19	0.033	*

*p < 0.05; ** p < 0.01; ***p < 0.001

Stepwise method (input: p < 0.05, output: p > 0.1)

Independent variable to put in (both of right and left sides)

Width of opening toes, floating toes, toe deformities, corn and callus, arch deformities, nail thickness

Ingrown nail, suspected or presence of nail with fungal infection

15 (HVA ≤ 20, 20° < HVA ≤ 40°, HVA > 40°)

Weight distribution

Table 7 represents the result of association between right and left side of toe-grip strength and walking speed. Figures 5 and 6 show the scatter plot indicating the association. The results indicated that a negative correlation for both feet (right foot: r=-0.184. p-value 0.035, left foot:-0.313.p-value 0.001).

Table 7
Association between toe-grip strength and walking speed

	Walking test (second)			
	n	r	p-value	
R_Toe-grip strength	131	−0.184	0.035	*
L_Toe-grip strength	129	−0.313	< 0.001	*

*p < 0.05; **p < 0.01; ***p < 0.001

Pearson correlation

Waking test measured 4 m walking speed

Toe-grip strength is measured with toe-grip dynamometer (T.K.K.3364 Takei Scientific Instrument)

Discussion

To the best of our knowledge, this is the first study to analyze the foot problem prevalence, the association between foot problems and walking, and toe-grip strength in older people attending day service and day care centers in Japan. Our target participants were frailer older people who use services under long-term care insurance but are not in a bedridden condition.

The strength of the study is that we obtained the data based on clinical assessment instead of self-reporting. In addition, the current foot problems were identified by data collection using multiple items so that the whole picture of the foot was captured. Three research questions were answered.

The prevalence of foot condition in older people

Our study target was frail older people in the community who use long-term care insurance. As frailty advances, various factors of the body may negatively affect the foot health of older people. Our investigation on foot items indicated that the rate of incidence of floating toes, toe deformities, nail color change, arch deformities, nail length, thickened nail, skin dryness, edema, skin color change, suspected or existing nail fungal infection was relatively high, whereas the rate of corn and callus were pretty low. Various factors including aging may trigger these foot problems. Physical condition varies among community-dwelling older people; hence, foot conditions also differ among them. The high prevalence of hypertension, diabetes, and brain diseases may be associated with foot conditions, leading to lower immune system, circulation impediment, and increase of muscle generation with aging.

The reason of lower incidence of corn and callus may indicate that walking time is less for the frail older population; therefore, the repeated pressure on the sole is minimum. The rate of incidence of palpable tibial arteries may indicate the changes in the circulatory system based on aging. The change in the condition of peripheral blood vessels with aging is related to nail color and nail growth [31, 32]. However, as we did not use Doppler, the pressure level of the examiner may be associated with the detection of palpating the pulse. The temperature of the lower extremities indicated the condition of foot circulation because of aging, sedentary behavior, and lack of foot movement. This indicates that temperature is associated with the coldness of the feet of many older people using the service, which is observed when the examiners touch the skin and palpate the pulse of the posterior tibial artery.

The other study indicated that awake temperature of 30·6 °C (SD 2·6) at awake time and 34·0 °C (SD1.8) at sleep time also varies from 15·9 °C to 37·5 °C depending on seasons [33]. For our future study, the consistency of the targeted site of temperature measurement and time with larger number of participants, a larger number of samples, and a comparison of the data with that from younger people would provide more accurate data.

The author’s previous research demonstrated that foot skin dryness was found in 89·5–100% of frail older people who used homecare service [34]. A few studies reported that 44–45% of older people in-home care [10] and 52·6% in residents of nursing home had dry skin [35]. Both the caregiver and older people should understand the mechanism of skin barrier and apply the appropriate skin-protecting ointment.

This study assessed for possible nail fungal infection based on observation and the clinical hallmarks of onychomycosis were followed for some participants by a dermatologist. The nail with fungal infection becomes friable and appears yellowish [36]. The nail condition can be detected through mycological test, but the false-negative culture rate of this test is at least 30% [37]. Fungal infection of the foot is an indicator of lower limb cellulitis development [38]. Additionally, it may lead to psychological disorders due to its appearance [39].

Toe and arch deformity are interlinked with muscle degeneration, weakening of tendons and ligament with aging, lifestyle, walking, or the selection of shoes, or less walking. These deformities cause floating toes, leading to balance instability.

As we expected, walking speed was slower and width of opening toes was narrow and toe-grip strength was weak for people with more care. Previous studies indicated that toe-grip strength has declined with aging [40, 41].

Uritani et al [41] classified the data of toe-grip strength into six age groups and reported that women in their 70 s (men: 10·4, women: 7·3) had a significantly weaker toe-grip strength than those in their 20s–60 s. The mean age of our study participants was 83 years, which was lower than their report (70 years, [mean: 4·026, median: 3·3]). Thus, building strategies to maintain or enhance toe-grip strength in this frail population is essential.

The foot item variables correlate with toe-grip strength and walking speed

The right toe-grip strength had a statistically significant association with the arch deformity, suspected or existing nail fungal infection, and nail thickness of the right sided foot although no independent variables were selected on left foot. The corn, callus, and toe deformity of the right sided foot was significantly associated with walking test (p-value, 0·026, 0·033 respectively). The finding may be associated with a higher rate of participants represented by right distribution to the floor. However, more studies are needed to explore the finding. Although the adjusted R^2/ was 0.099 for right toe grip force and 0.067 for walking speed were week, significant P values indicated that relationship between predictors and response variables. The individual variability of foot may associate with the lower of R^2 scores. Further study will be needed to explore the generation of combination of higher adjusted R2 and lower P value.

Several reasons can be considered for the association between toe-grip strength and nail problems. The association between nail problems and toe force was previously reported [42–44]; however, the number of studies was limited in Japan and overseas. Nail abnormality including thickened, deformed or friable nails caused by fungal infection may trigger the decline of toe-grip strength because nail has the power to firmly step on the floor. Thus, nail care significantly affects the toe-grip strength. In the present study, abnormalities of the right foot arch led to a decrease in the right toe-grip strength. A few studies investigated the changes in foot shape with aging [45–47]. Deformity of arches may lead to the decline of range of motion, change in plantar loading pattern, and postural stability [48, 49], causing instability of balance.

The foot arch is known to be associated with the plantar fascia, which is also known as plantar aponeurosis [50]. In one study, Erdemir et al described the role of plantar fascia during walking [51]. The study, which evaluated the association between plantar fascia and toe force, was conducted in 20 people and found that there was no relationship between the progression of the first metatarsophalangeal (MTP) joint and the presence of plantar fascia. This study concluded that further investigation on this matter would be required [52].

Since the bar of the device measuring toe-grip strength is gripped at the MTP joint part of the foot, it is considered that an abnormality in the foot arch may lead to a decrease in the toe-grip strength. However, more data needs to be accumulated on the relationship between toe-grip strength and arch correction.

In a study, Digiovanni et al stated that adequate rehabilitation affects the stretching of the plantar fascia [53]. In another study, Mickel et al suggested “plantar fascia stretching, perception, and balance training, along with pain management and weight control” as components of rehabilitation program in order to prevent falling [54]. However, we suggest that the contents of an adequate rehabilitation program should further be assessed. For example, instead of just an exercise that moves the muscles, stretching of the foot before the exercise may prevent the generation of pain and could make the exercise more effective. Additionally, there are various auxiliary tools and pads for arch correction, and thus, further data to verify the substantial effects on the strength of toe force should be gathered.

Interestingly, the walking speed was significantly associated with the existence of corn and callus as well as toe deformities. The formation of corn and callus itself and pain caused by them may be associated with plantar pressure, leading to decline of walking speed. The association between walking speed and plantar pressure has been widely studied [55–58].

Another study reported the effect of treatment to solve the pain due to the keratosis, such as corns and callus [59, 60]. However, the association between corn and callus with plantar pressure remains unclear [61, 62]. Another study revealed that plantar pressure is higher in older people with callused regions and an intervention study indicated the removal of callus reduces planter foot pressure [63]. The lower rate of having callus and corns indicated that the walking time of study participants was less due to frailty. Simply concluding the association between corn, callus, and toe-grip strength should be avoided because the generation of corn and callus are limited for this targeted population and rate of having corn and callus are low.

Toe deformities include the hallux valgus and lower-toe deformities. Interestingly, some patients have no toe deformity, whereas others have multiple toe deformities.

Mickle et al suggest that toe deformation of the lower toes changes the load distribution during walking because such a toe condition results in the toes being pulled back into extension, thus reducing the contact areas of the toes [55].

As the presence of corn and callus trigger pain, both toe deformities, including the hallux valgus and lower-toe deformities, may generate pain [59]. Therefore, pain may greatly affect the walking speed.

Hughes concluded that toes roles as the contact portion of three-quarter of the walking cycle and weight bearing function [64]. The balance transition from the medial to the lateral side of a patient with hallux valgus is significantly delayed [65]. The toe plays an important role in maintaining the body’s balance and reflects the lower limb function. Therefore, appropriate efforts to strengthen the toe function, such as washing, nail care, stretching, and exercise are required. In the present study, no significant relationship was observed between the toe-grip strength or walking speed and the hallux valgus and floating toes.

In the present study, no significant relationship was observed between toe-grip strength or walking speed and hallux valgus and floating toes.

When the foot arch deforms, occurrence of a bunion may be inevitable. When the foot spreads laterally due to muscle degeneration or other reasons such as arch deformation, it causes the adductor muscle of the toes to be pulled outward; thus leading to the formation of the hallux valgus. Many studies have majorly focused on hallux valgus among other toe deformities [66, 67]. Further, a report also indicated an association between the degree of hallux valgus and toe-grip strength [68].

In this study, the analysis was conducted by dividing the degree of hallux valgus into three stages. Our study revealed that prevalence of hallux valgus (> 15°) in women was 29·9%–35·9%, which was higher than that in men; however, it did not reveal the angles of hallux valgus and walking speed. The small sample size may be associated with the results of undifferentiation of angles of hallux valgus.

Future studies with more samples may explore the association between the angles of hallux valgus and walking speeds. Arch deformity may prevent the toes from firmly attaching to the floor, resulting in floating toe complication, which has recently gained attention of the researchers [69, 70]. However, the number of studies remain limited both in Japan as well as overseas. Uritani et al. concluded from their study that the floating toe is associated with walking [70]; however, further studies are required to confirm this.

The study showed that negative and significant correlation between walking speed and toe-grip strength. A previous study reported the association between the decreased strength of toe flexor and slow walking [71]. However, correlation was not so strong. There is a great deal of individual variability, therefore, we were not able to conclude that individual with lower strength of toe flexor have longer walking time. Further studies will explore this association in the stratified aging group.

The foot data obtained by assessing and measuring the foot from various angles revealed the prevalence of foot disorder in frail old-aged people. Future strategies can be considered based on the foot deformities that have higher prevalence. For example, awareness regarding skin care should be spread among older people as well as care givers, which may lead to a higher usage of skin ointments and appropriate methods of skin care, leading to prevention of cracks in the skin.

The results of multiple regression analysis implicated the presence of an impaired area of foot condition, which may trigger lower walking speed and toe-grip force.

It provided insights into future strategies to prevent the foot condition from worsening as well as the possibility of effective nail care and prevention of skin lesion in maintaining the toe-grip strength or walking speed, which are key indicators of foot health. There are high chances of frail old-aged people falling and becoming bedridden in the future. According to the Ministry of Health, Labor and Welfare, fractures and falls are the third most common cause of need for long-term care for people who are certified as requiring care level 4 or 5 by long-term care insurance that requires severe long-term care [72]. Therefore, new approaches which incorporate appropriate foot care into daily practice among day service or day care would be desirable. Information on how to prevent the occurrence of nail thickness, nail fungal infection, toe and foot deformity, corn, and callus as well as information on how to appropriately provide foot care and promote the stretching of plantar fascia and exercise of foot would be key components for future strategies of preserving foot health for this age group as well as other age groups living in the community. In addition, the delivery of knowledge information and practice of foot care among the caregivers who provide care for people of this age group would be significantly helpful for preserving their foot health.

Our study has limitations with regard to the data collected. Because of the physical condition of older people, some of the participants were unable step on to the table of the Foot Look machine. Therefore, it was impossible to obtain data from all the participants. Although there are very few studies that describe the factors causing deformation of the arch and toes, there are various possible factors that need to be considered. This study, however, does not mention to them. In addition, the increased association between the decrease in skeletal muscle mass with arch and toe deformity because of aging was not evaluated in this study, although this is something that has gained much attention in the recent years.

Conclusions

In summary, the study exhibits that impaired foot area of older people by rate and key components may be associated with walking speed and toe-grip strength. This finding provides useful insight into the foot conditions of older people, in particular the frailer ones. Further studies should be conducted to target more people in this age group and to investigate strategies to prevent the development of falling and bedridden condition by incorporating foot care into routine practice at all facilities; however, we need to overcome many existing obstacles.

Declarations

Ethics approval and consent to participate:

The research conformed to the Declaration of Helsinki 2000. We obtained informed consents from all participants, with the approval of facility providers and some of the families. The study was further approved by the ethics committee of Nagoya University (approval number: 2019-0150).

Consent for publication:

This paper does not reveal identity of any participant in any form. It is not applicable for this paper.

Availability of data and materials:

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests:

The authors declare that they have no competing interests.

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Authors' contributions:

KF designed the study and collected, analyzed, and interpreted the data. TK, TF contributed to the interpretation of the data. IH, NK, TN, YS, TF contributed for data collection. All authors have read and approved the manuscript.

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References

1. World Bank Group. Poplulation ages 65 and above,total. 2018. from https://data.worldbank.org/indicator/SP.POP.65UP.TO.ZS?end=2018&start=1960&view=chart. Accessed 25 Aug 2019.
2. Ministry of Health La W. Care insurance business status report (provisional). 2019 https://www.mhlw.go.jp/topics/kaigo/osirase/jigyo/m19/1903.html. Accessed 30 Aug 2019. (In Japanese only).
3. Tokyo Fire department. To prevent accidents in daily life of the elderly. http://www.tfd.metro.tokyo.jp/hp-kouhouka/pdf/300912.pdf. Accessed 8 July 2020.

4. Commercial Affairs Agency, Government of Japan, 2019. http://www.caa.go.jp/notice/caution/life. Accessed 30 Aug 2020. (in Japaneses)
5. Menz HB, LordThe contribution of foot problems to mobility impairment and falls in community-dwelling older people. J Am Geriatr Soc.2001;49:1651-6.
6. Muchna A, Najafi B, Wendel CS, Schwenk M, Armstrong DG, Mohler J.Foot problems in older adults: associations with incident falls, frailty syndrome, and sensor-derived gait, balance, and physical activity measures. J Am Podiatr Med Assoc.2018;108:126-39.
7. MenzChronic foot pain in older people. Maturitas2016;91:110–4.
8. MittyNursing care of the aging foot. Geriatr Nurs.2009;30:350-4.
9. Dunn JE, Link CL, Felson DT, Crincoli MG, Keysor JJ, McKinlay JB.Prevalence of foot and ankle conditions in a multiethnic community sample of older adults. Am J Epidemiol.2004;159:491-8.
10. Stolt M, Suhonen R, Puukka P, Viitanen M, Voutilainen P, Leino-Kilpi H.Foot health and self-care activities of older people in home care. J Clin Nurs.2012;21:3082-95.
11. Abdullah L, AbbasCommon nail changes and disorders in older people: diagnosis and management. Can Fam Phys.2011;57:73-81.
12. 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;61:866-70.
13. Uritani D, Fukumoto T, Matsumoto D, Shima M. The relationship between toe grip strength and dynamic balance or functional mobility among community-dwelling Japanese older adults: A cross-sectional study. J Aging Phys Act. 2016;24:459-64.
14. Yamashita K, Umezawa J, Nomoto Y, ino S, Ifukube T, Koyama H, et al., eds. The role of toe-gap force for the evaluation of falling risk on the elderly. World Congress on Medical Physics and Biomedical Engineering 2006: Springer, 405-8.
15. Tsuyuguchi R, Kurose S, Seto T, Takao N, Fujii A, Tsutsumi H, et al.The effects of toe grip training on physical performance and cognitive function of nursing home residents. J Physiol Anthropol.2019;38:1.
16. Andriacchi TP, Ogle JA, GalanteWalking speed as a basis for normal and abnormal gait measurements. J Biomech.1977;10:261-8.
17. Barbee CE, Buddhadev HH, Chalmers GR, SuprakThe effects of hallux valgus and walking speed on dynamic balance in older adults. Gait Posture2020;80:137-42.
18. Bohannon RW, Williams AndrewsNormal walking speed: a descriptive meta-analysis. Physiotherapy2011;97:182-9.
19. Jordan K, Challis JH, NewellWalking speed influences on gait cycle variability. Gait Posture2007;26:128-34.
20. Yeung PY, Chan W, WooA community-based Falls Management Exercise Programme (FaME) improves balance, walking speed and reduced fear of falling. Prim Health Care Res Dev.2015;16:138-46.
21. Ministry of Health LaW, Heatlh and welfare bureau for the eldely. Long-term Care Inusrance System of Japan. 2016. https://www.mhlw.go.jp/english/policy/care-welfare/care-welfare-elderly/dl/ltcisj_e.pdf. Accessed 25 Aug 2019.
22. Fujii K, Komoda T, Maekawa A, Nishikawa M. Foot care knowlede ange practices among Japaneses nurses and care workers in home care and adult service center: a cross-sectional study. BMC Nurs. 2020;19:75. doi.org/10.1186/s12912-020-00467-1
23. Statistics Bureau of Japan. Population estimates by Age (Five-year Groups) and Sex based on the 2015 Population Census, 2020 https://www.stat.go.jp/english/data/jinsui/tsuki/index.html. Accessed 30 Aug 2020.
24. Nursing insurance business status report 2018 summary. https://www.mhlw.go.jp/topics/kaigo/osirase/jigyo/m18/dl/1811a.pdf. Accessed 20 Sep 2020 (in Japanese)
25. Overview of actual statistics on long-term care benefits 2018. https://www.mhlw.go.jp/toukei/saikin/hw/kaigo/kyufu/18/index.html. Accessed 20 Sep 2020.
26. Sample size culculator. https://www.checkmarket.com/sample-size-calculator/#sample-size-calculator. Accessed 20 Aug 2019.
27. Cohen JA. Statistical Power Analysis for the Behavioral Sciences; Hillsdale, NJ: Lawrence Erlbaum;1988.
28. Fan L, Sidani S, Cooper-Brathwaite A, MetcalfeFeasibility, acceptability and effects of a foot self-care educational intervention on minor foot problems in adult patients with diabetes at low risk for foot ulceration: a pilot study. Can J Diabetes.2013;37:195-201.
29. Soma M, Murata S, Kai Y, Nakae H, Satou Y, Murata J, et al. Examinations of factors influencing toe grip strength. J Phys Ther Sci.2016;28:3131-5.
30. Tasaka S, Matsubara K, Nishiguchi S, Fukutani N, Tashiro Y, Shirooka H, et al. Association between floating toe and toe grip strength in school age children: a cross-sectional study. J Phys Ther Sci 2016;28:2322-5.
31. Myers JB. “Capillary band width”, the “nail (band) sign”: A clinical marker of microvascular integrity, inflammation,and age. A personal viewpoint and hypothesis. J Neurol Sci 2009;283:86–90.
32. Turner C, Quine S. Nurses’ knowledge, assessment skills, experience, and confidence in toenail management of elderly people: Why are nurses and nursing assistants reluctant to cut toenails? Geriatr Nursing. 1996;17:273-
33. Nardin RA, Fogerson PM, Nie R, Rutkove SB. Foot temperature in healthy individualseffects of ambient temperature and age. J Am Podiat Med Assn. 2010;100:258-64.
34. Fujii K. The prevalence and self-identification of foot conditions in older adults using home visiting nursing stations and their relations with walking ability. J Educ Health Sci. 2018;64:167-80.
35. Lichterfeld A, Lahmann N, Blume-Peytavi U, KottnerDry skin in nursing care receivers: a multi-centre cross-sectional prevalence study in hospitals and nursing homes. Int J Nurs Stud.2016;56:37-44.
36. Eisman S, SinclairFungal nail infection: diagnosis and management. BMJ.2014; 348:g1800.
37. Fletcher CL, Hay RJ, SmeetonOnychomycosis: the development of a clinical diagnostic aid for toenail disease. Part I. Establishing discriminating historical and clinical features. Br J Dermatol.2004;150:701-15.

38. Bristow IR, SpruceFungal foot infection, cellulitis and diabetes: a review. Diabet Med.2009;26:548-51.
39. ScherOnychomycosis is more than a cosmetic problem. Br J Dermatol.1994;130 (Suppl. 43):15.
40. Suwa M, Imoto T, Kida A, Iwase M, YokochiAge-related reduction and independent predictors of toe flexor strength in middle-aged men. J Foot Ankle Res.2017;10:15.
41. Uritani D, Fukumoto T, Matsumoto D, ShimaReference values for toe grip strength among Japanese adults aged 20 to 79 years: a cross-sectional study. J Foot Ankle Res.2014;7:28.
42. FujiiEffect of foot care interventions for older adults using day care services. Nurs Open.2019; 6:1372-80.
43. Imai A, Takayama K, Satoh T, Katoh T, YokozekiIngrown nails and pachyonychia of the great toes impair lower limb functions: improvement of limb dysfunction by medical foot care. Int J Dermatol.2011;50:215-20.
44. Yamashita T, Yamashita K, Rinoie C, akase Y, Sato M, Yamada K, et al. Improvements in lower-limb muscle strength and foot pressure distribution with foot care in frail elderly adults: a randomized controlled trial from Japan. BMC Geriatr.2019;19:83.
45. Scott G, Menz HB, Newcombe L. Age-related differences in foot structure and function. Gait Posture 2007;26:68-75.
46. Ansuategui Echeita JA, Hijmans JM, Smits S, Van der Woude LH, Postema K.Age–related differences in women's foot shape. Maturitas2016;94:64-9.
47. Menz HB, Morris ME. Clinical determinants of plantar forces and pressures during walking in older people. Gait Posture 2006;24:229-36.
48. Anzai E, Nakajima K, Iwakami Y, Sato M, Ino S, Ifukube T, et al. Effects of foot arch structure on postural stability. Clin Res Foot Ankle.2014;2:1-5.
49. Hagedorn TJ, Dufour AB, Riskowski JL, Hillstrom HJ, Menz HB, Casey VA, et al. Foot disorders, foot posture, and foot function: the Framingham foot study. PLoS One 2013;8:
50. Japaneses Society for Surgery of the Foot. Terminology of Foot & Ankle Surgery, 3rd ed., Tokyo. Japan. 2017.
51. Erdemir A, Hamel A, Fauth A, Piazza SJ, Sharkey NA. Dyanamic loading of the Plantar Aponeurosis in walking. J Bone Joint Surg. 2004,86:546-52.
52. Rachel LCDR, PT Allen, Gross M. Toe flexor strength and passive extention range of motion of the first metatarsophalangeal joint in indivisuals with plantar fasciitis. J Orhtop Sports Phys Ther. 2003;8:468-78
53. Digiovanni B, Nawoczenski D, Malay D, Plantar fascia-specific stretching exercise improves outcomes in patients with chronic plantar fasciitis. et al. Plantar fascia-specific stretching exercise improves outcomes in patients with chronic plantar fasciitis. J Bone Surg. 2006;88:1775-81.
54. Mickle K, Munto B, Load S, Menz HB, Steele JR. ISB clinical biomechiancs award 2009. Toe weakenss and deformity increase the risk of falls in older people. Clin Biomech. 2009;24:
55. Mickle KJ, Munro BJ, Lord SR, Menz HB, Steele JR. Gait, balance and plantar pressures in older people with toe deformities. Gait Posture 2011; 34: 347-51.
56. Rosenbaum D, Hautmann S, Gold M, Menz HB, Steele JR.Effects of walking speed on plantar pressure patterns and hindfoot angular motion. Gait Posture1994;2:191-7.
57. Taylor AJ, Menz HB, Keenan A-M.The influence of walking speed on plantar pressure measurements using the two-step gait initiation protocol. Foot2004;14:49–55.
58. Menz HB, MorrisClinical determinants of plantar forces and pressures during walking in older people. Gait Posture2006;24:229-36.
59. Balanowski KR, FlynnEffect of painful keratoses debridement on foot pain, balance and function in older adults. Gait Posture2005;22:302-7.
60. Potter J, PotterEffect of callus removal on peak plantar pressures. Foot2000;10:23–6.
61. Springett KP, Whiting MF, MarriottEpidemiology of plantar forefoot corns and callus, and the influence of dominant side. Foot2003;13:5-9.
62. Menz HB, Zammit GV, Munteanu SE. Plantar pressures are higher under callused regions of the foot in older people. Clin Exp Dermat. 2007;32:375-80.
63. Young M, Cavanagh P, Thomas G, Johnson M, Murray H, Boulton A. The effect of callus removal on dynamic plantar foot pressures in diabetic patients. Diabet Med. 1992; 9: 55-7.
64. Hughes J, Clark P, Klenerman L. The importance of the toes in walking. J Bone Joint Surg Br. 1990;72:245-51.
65. Wen J, Ding Q, Yu Z, Sun W, Wang Q, Wei K.Adaptive changes of foot pressure in hallux valgus patients. Gait Posture2012;36:344-9.
66. Nix S, Smith M, VicenzinoPrevalence of hallux valgus in the general population: a systematic review and meta-analysis. J Foot Ankle Res.2010;3:21.
67. Nix SE, Vicenzino BT, SmithFoot pain and functional limitation in healthy adults with hallux valgus: a cross-sectional study. BMC Musculoskelet Disord.2012;13:197.
68. Uritani D, Fukumoto T, Matsumoto D, Shima M. Associations between toe grip strength and hallux valgus, toe curl ability, and foot arch height in Japanese adults aged 20 to 79 years: a cross-sectional study. J Foot Ankle Res. 2015;8:
69. Saito R, Okamoto S, Nakazawa R, Sakamoto M. Relationship between foot alignment and floating toes classified in static and dyanmic conditions in females. J Phy Ther Sci. 2019;31:282-6.
70. Uritani D, Sakamoto C, Fukumoto T. Effect of floating toes on knee and trunk acceleration during walking: a preliminary study. J Phy Ther Sci. 2017;29:361-4.
71. Misu S, Doi T, Asai T, Sawa R, Tsutsumimoto K, Nakakubo S, et al. Association between toe flexor strength and spatiotemporal gait parameters in community-dwelling older people. J Neuroeng Rehabil.2014;11:143.
72. Ministry of Health, Labor and Welfare. Summary of the National Lifestyle Survey 2016. https://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa16/dl/16.pdf. Accessed 2 Sep 2020.(in Japansese only)

Figures

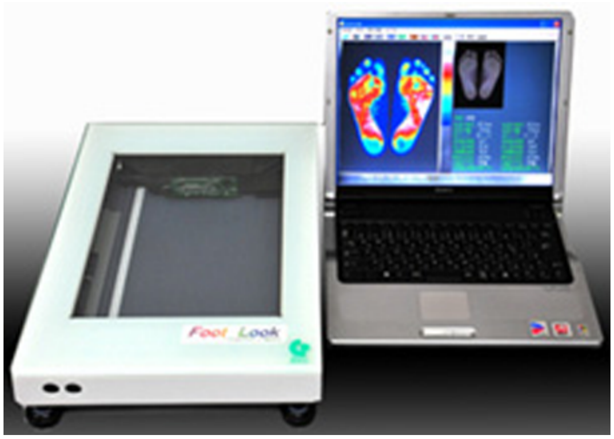

Figure 1

Foot look Using a computer and a special scanner, the foot is measured and the balance of the foot is visually analyzed to find problems, such as loating toes and the degree of hallux valgus..

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Figure 2

Toe-grip dyamometer measures toe force. Researchers developed the macine with assistantce from Takei Scientific Insturment Inc. Participants gripped the bar for approximatly 3 seconds using their toes with the greatemet force as much as they can.

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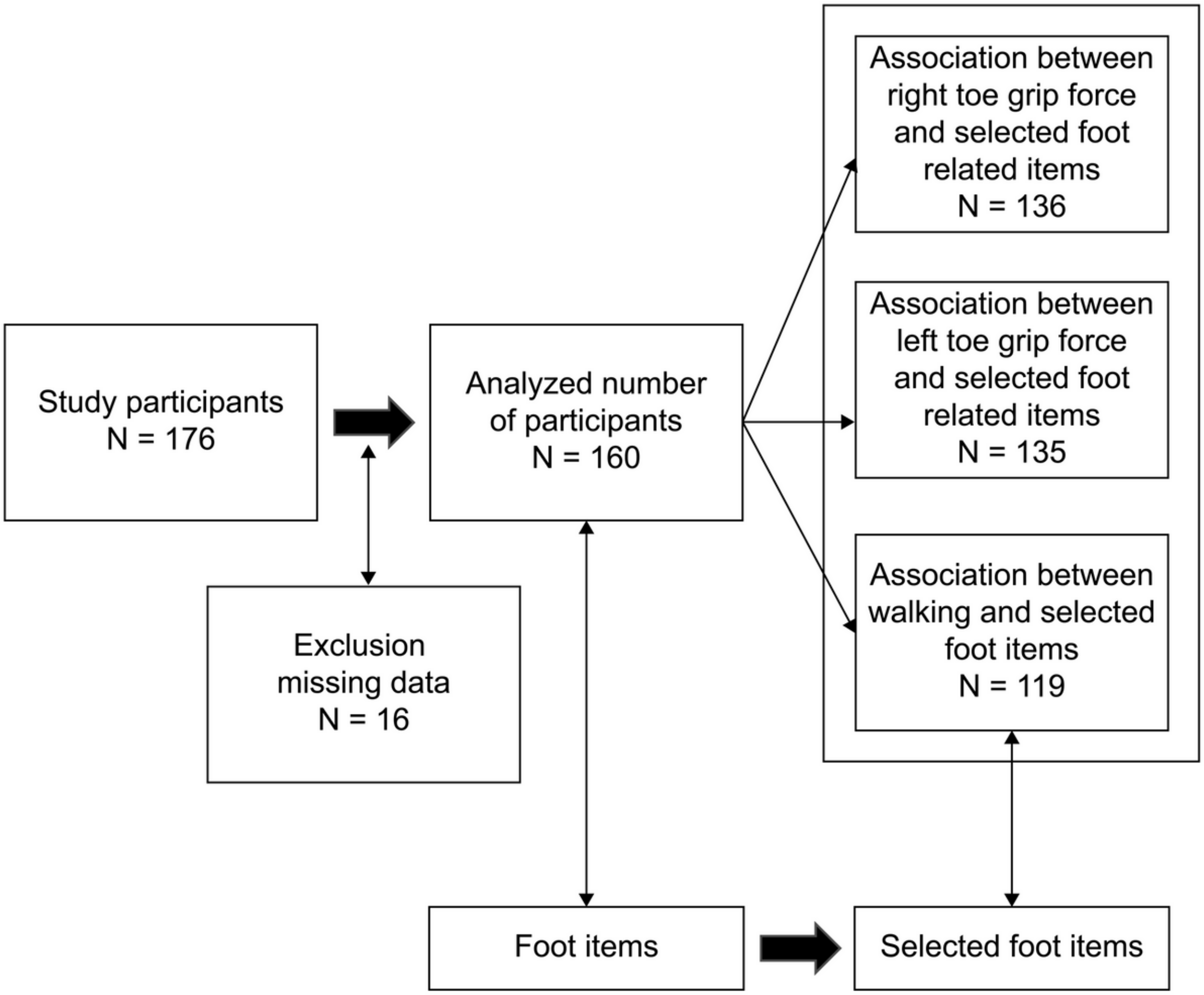
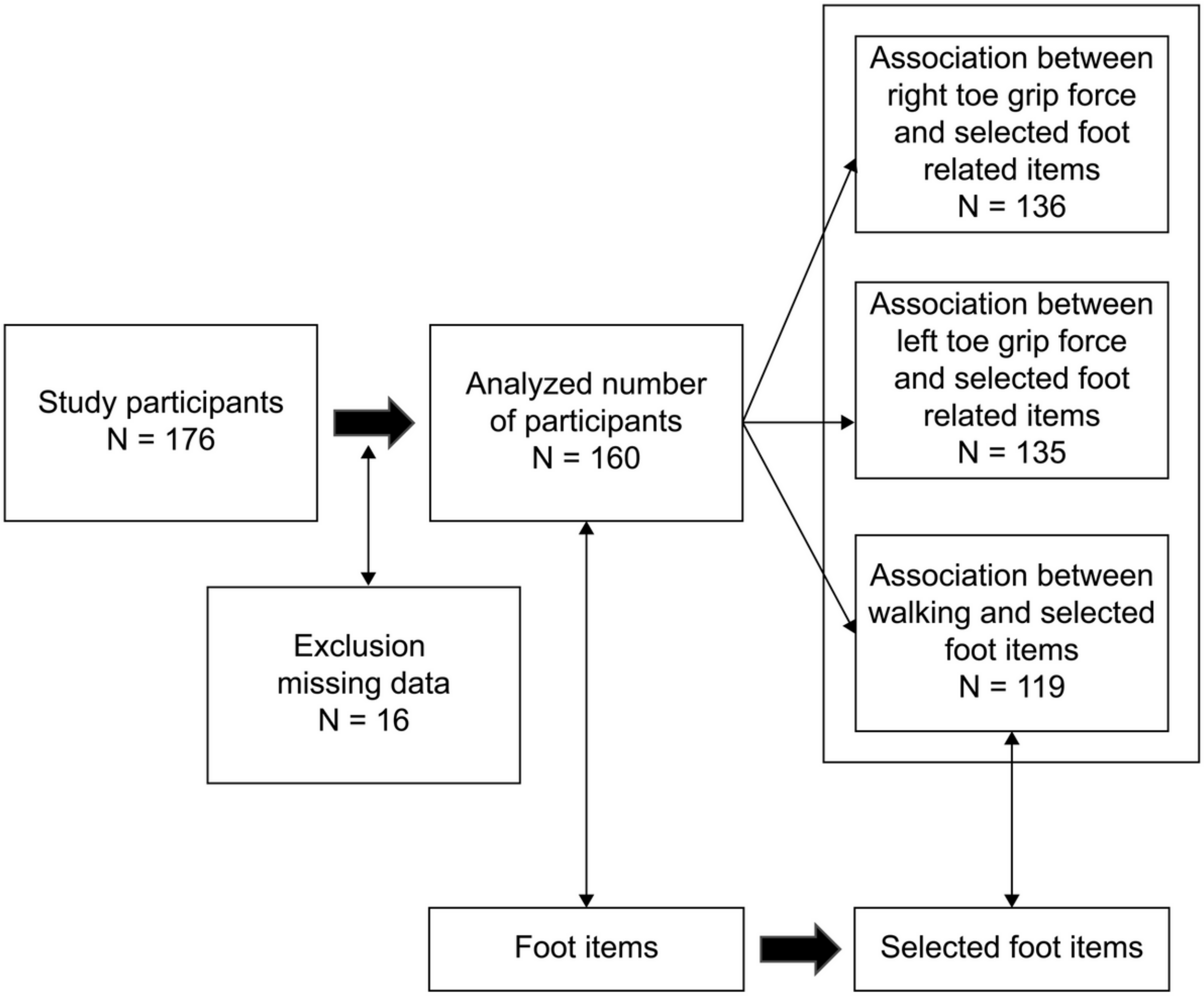


Figure 3

A flow of diagram of participants Initial study participants were 176. Due to the missing data, 160 were on analysis for assessing foot items. For the association between right or left grip force and selected foot items which may associate with the strenght, 136 and 135 parcitipants were on analysis. For the association between walking speed and seletected items were 119.



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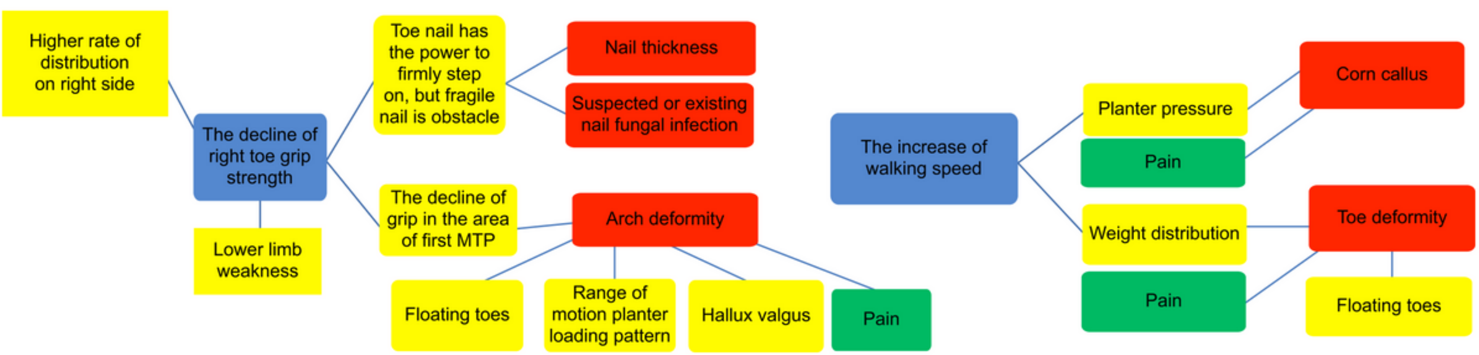
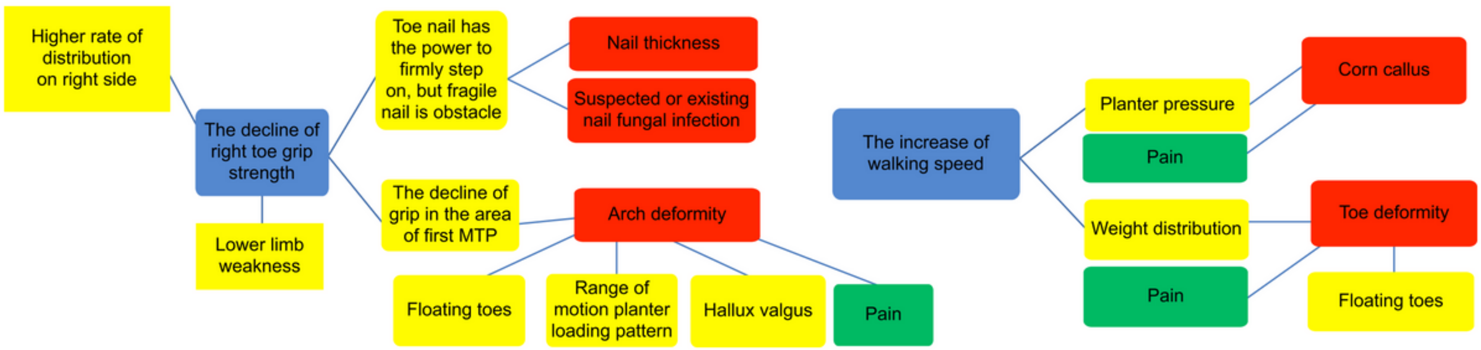


Figure 4

Logic tree obtained from the regression analysis Logic tree indicated foot items which is associated with dependent variables as right or left toe grip force, walking speed by breaking down the items.



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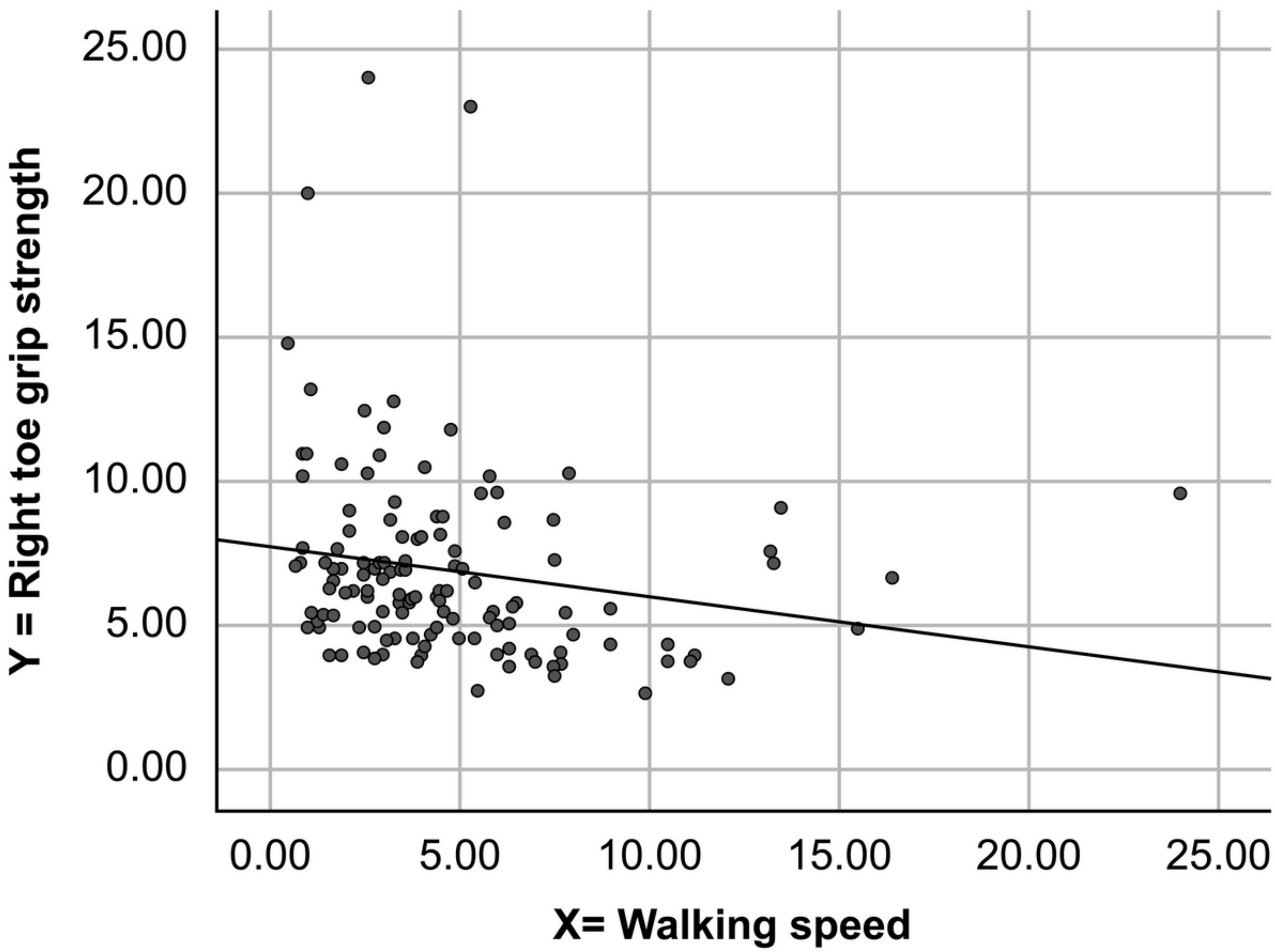
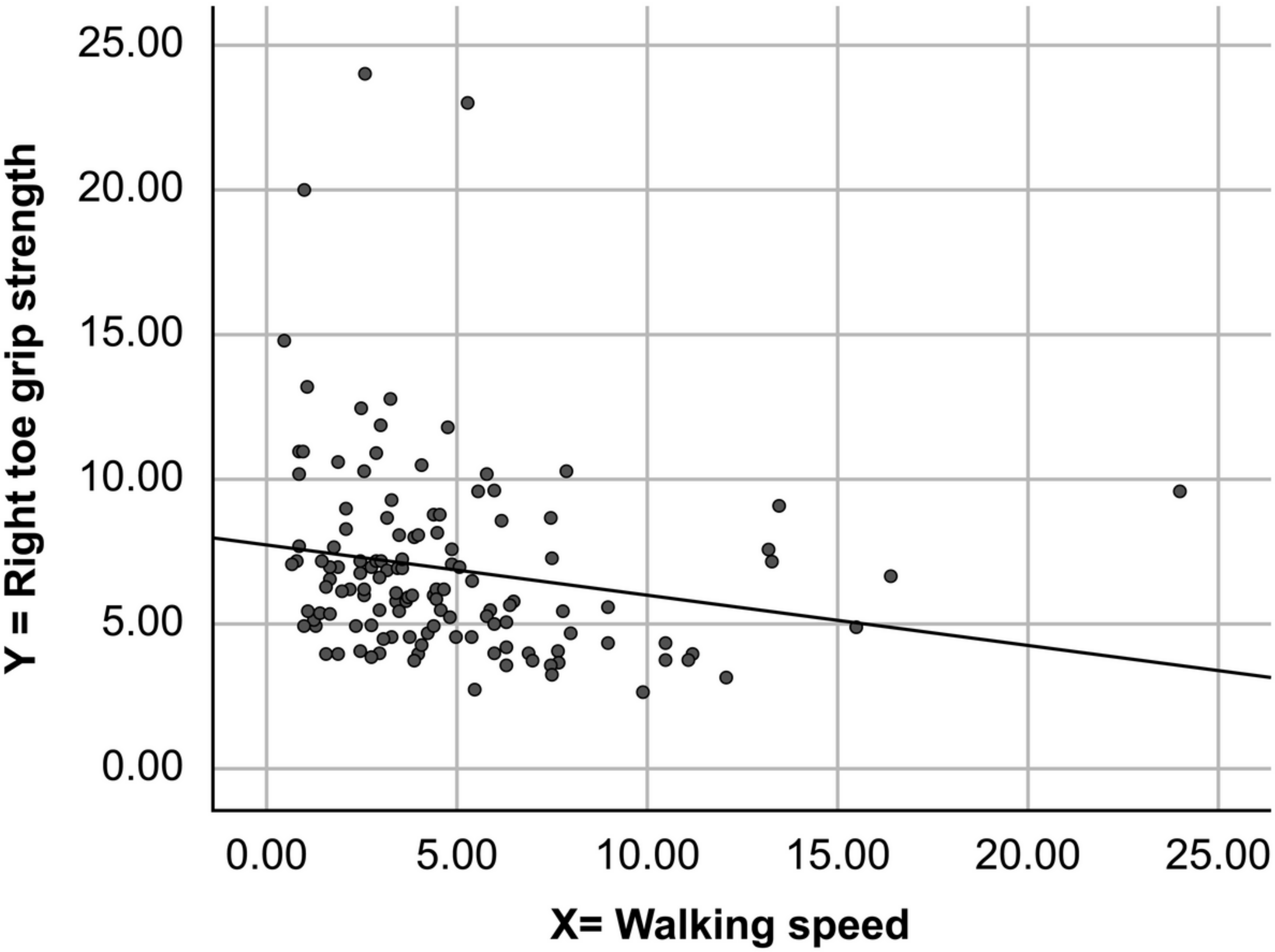


Figure 5

Association between right toe-grip strength and walking speed The graphic image indicate the associaction between both variables. The result showed a negative correlation between them (Right foot: r = -0.184(p=0.035)



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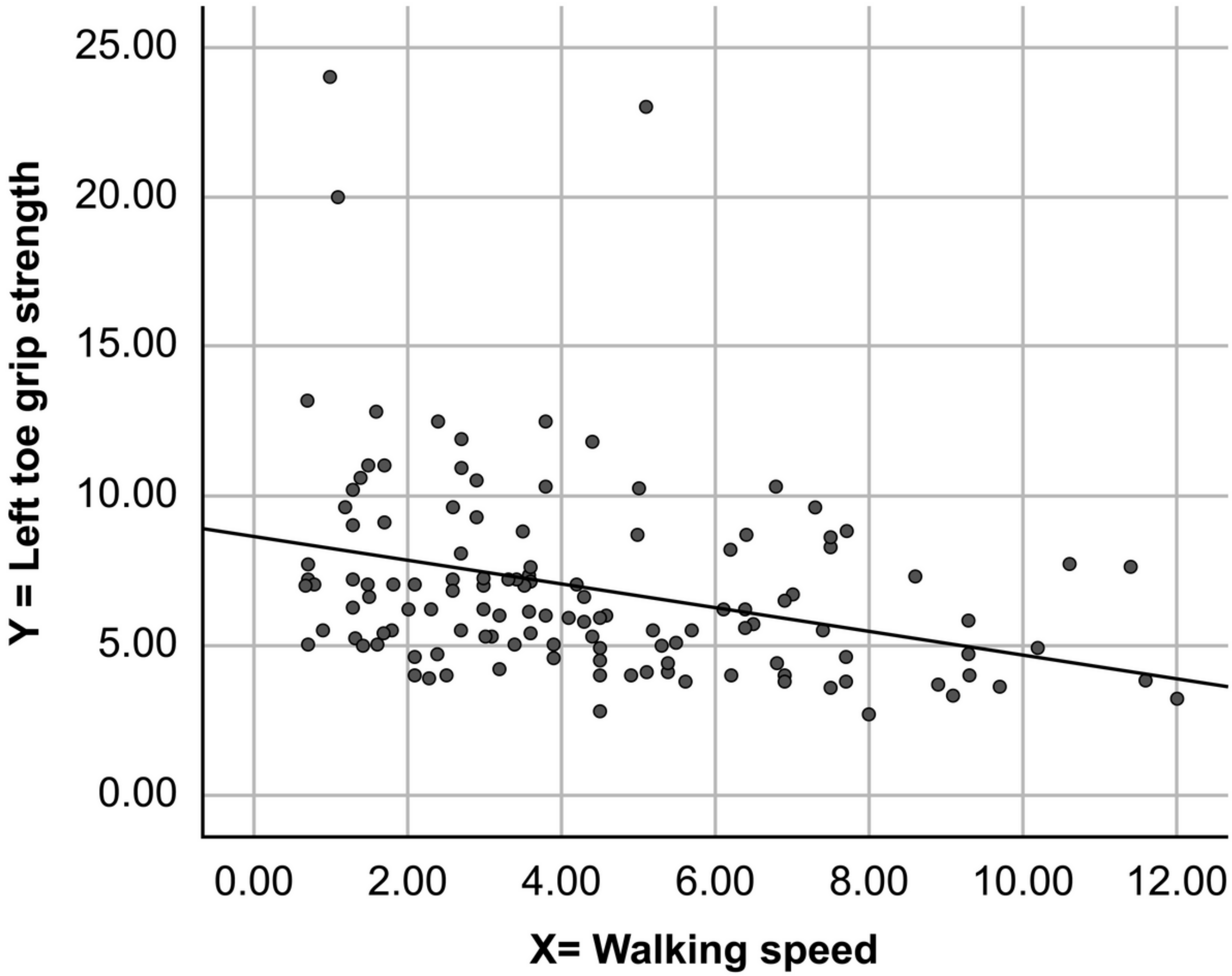
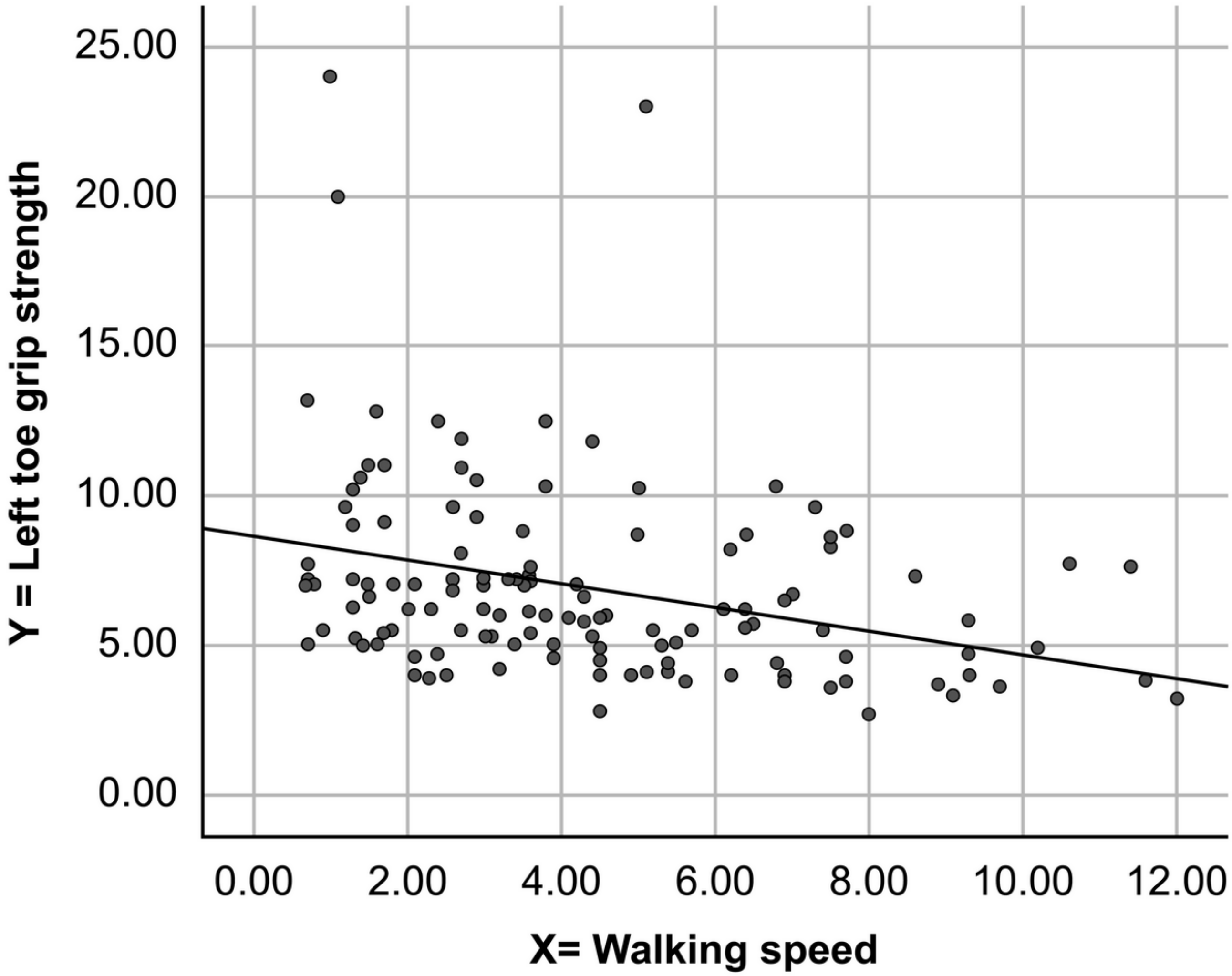


Figure 6

Association between left toe-grip strength and walking speed The result showed a negative correlation between them (Left foot: r = -313(p=0.001) The graphic image indicate the associaction between both variables.



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