－原著－

地域在住後期高齢者の転倒予測因子としての残存歯数：１年間のコホート研究

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Number of remaining teeth as a predictor of prospective falls in Japanese community-dwelling late older population: a 1-year cohort study

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〈抄録〉
背景：本研究の目的は，地域在住後期高齢者を対象とした１年間の前向き研究において，残存歯数と転倒の発生率との関連を評価することである。
方法：2017 年に握力，歩行速度，TUG（Timed Up & Go）テストを含む体力検査および口腔内診査を実施し，更に，ミニメンタルステート検査（MMSE），老研式活動能力指標（TMIG-IC），転倒スコア（FRI-5）を用いて，認知機能，高次生活機能，転倒リスクをそれぞれ評価し，これらの結果を本研究のベースラインとした。2018 年に追跡調査を実施し，過去１年間の転倒の有無を確認した。参加者は残存歯数により（I）20 本以上，（II）１から 19 本，（III）無歯顎の３群に分けられた。従属変数を１年間の追跡期間中の転倒の有無，独立変数を残存歯数（I-III 群）としたロジスティック回帰分析を行った。
結果：182 名が１年間の縦断的研究に参加し，追跡期間中に転倒を報告した参加者は 182 名中 40 名であった。すべての共変量で調整した多重ロジスティック回帰分析の結果，II 群と III 群では転倒のリスクが有意に増加し，ベースライン以前に転倒歴のある参加者を除外したモデルでは，除外しないモデルより高いオッズ比を示した。
結論：以上の結果より，残存歯数の減少が転倒リスクを増加させること，高齢者の転倒予測因子としての残存歯数の有用性が示唆された。

Abstract
Introduction: This study aimed to assess the association between the number of remaining teeth and experience of falls in a 1-year prospective study within the community-dwelling older population who are over 75 years old in Japan.
Methods: Dental and physical fitness examinations, including hand grip strength, gait speed, and the timed up and go test, were performed in 2017 and set as the baseline for this study. The Mini-Mental State Examination, Tokyo Metropolitan Institute of Gerontology Index of Competence, and Fall Risk Index-5 were used to assess cognitive function, higher-level functional capacity, and fall risk, respectively. Follow-ups were carried out in 2018, and the experience of falls was ascertained by questionnaires. Participants were then categorized into 3 groups based on

the number of remaining teeth: (I) ≥ 20, (II) 1-19, (III) edentulous. The dependent variable was the experience of falls during the 1-year follow-up, while the independent variable was the dental condition (groups I-III) in multiple logistic regression.

Results: This study included 182 Japanese adults. Forty participants reported falling during the follow-up period. Multiple logistic regression analyses, adjusted for all covariates, showed that groups II and III had a significantly increased risk of falls, while the model excluding high-risk participants showed that groups II and III had a significantly increased risk of falls compared with group I.

Conclusion: These results suggest that a low number of teeth may increase the risk of falls, and that it may be possible to use the number of remaining teeth as a predictor of falls in older adults.

Introduction

Falls are a common geriatric syndrome that occur frequently in older adults[1]. Previous studies have reported that approximately 14-40% of community-dwelling older individuals experienced falls each year in developed countries[2-4], with rates increasing after the age of 75[5]. Six percent of falls cause fractures, and 24% cause other serious injuries[3]. In addition, over 90% of femoral neck fractures, the most serious form of osteoporotic fracture, are directly caused by falls[6]. Because older people often require long-term care due to falls or fractures[7], the increase burden of medical expenses is regarded as a problem. Furthermore, falls cause not only physical disabilities, but also immediate psychological consequences known as "post-fall syndrome," which lead to a complex association of disorders[8]. In patients with post-fall syndrome, the experience of a fall causes fear and significantly limits post-fall physical activity[9]. From both physical and psychological perspectives, falls significantly reduce the quality of life of older adults. According to previous studies, the etiology of falls among older adults was considered to be multifactorial, involving intrinsic (patient-related) and extrinsic (environmental) circumstances[10]. In addition, a wide variety of risk factors have been considered, such as age[10], history of falls[10-12], balance deficit[2, 11], muscle weakness[2, 13, 14], gait dysfunction[2, 15, 16], poor vision[2, 12], orthostatic anemia[16], cognitive impairment[10, 17, 18], living dysfunction[11], and medication status[10, 16]. Many fall risk factors are subclinical; hence, in many cases, they are evaluated only after visiting a medical institution following a fall or fracture. Previous review articles showed that fall risk evaluation might not be fully determined by a single test/measurement[19] and that the evaluation system did not have high accuracy[20, 21]. Therefore, it is necessary to frame strategies that properly evaluate the fall risk in older adults[22].

The role of teeth is to masticate food and help pronounce words. Additionally, associations with motor function, which is often used as a predictor of falls, have been reported. Yamaga et al. reported that occlusal conditions correlated with grip strength and lower limb motor function in 70- and 80-years older adults[23]. A survey of older adults showed that the number of teeth, occlusal force, and occlusal balance are involved in the motor function of the lower limbs[24]. A cross-sectional study of falls among community-dwelling older individuals showed a relationship between occlusal force and motor function, including grip strength[25].

Although the relationship between fall-related factors and oral condition has been reported[26, 27], few cohort studies have investigated the association between oral condition and falls in community-dwelling older individuals. To the best of our knowledge, there are no reports in the field of dentistry in which the hearing period of the experience of falls coincides with the investigation period. Therefore, we focused on the number of remaining teeth available for testing to describe oral function. This study aimed to assess the association between the number of remaining teeth and the occurrence of falls in the prospective one year among community-dwelling older individuals. In addition, we set the null hypothesis that "there is no association between the decrease in the number of remaining teeth and the experience of falls in the prospective one year in older"

Materials and methods

Study design

This is a longitudinal study.

Study participants

The participants in this study were community-dwelling older people living in Tosa Town, a rural area in the Kochi Prefecture, Japan.

In April 2017, all 1,002 individuals aged 75 years older currently residing in Tosa, except for 150 individuals living in hospitals or nursing homes, were sent written requests to participate in a community health survey. In total, 261 responded positively to participation in the survey. In August 2017, the study participants underwent dental and physical examinations at a community center, questionnaires on lifestyle and other topics, and medical interviews. In August 2018, a follow-up interview was conducted with 208 participants using a questionnaire. Twenty-six individuals did not provide complete data. The final sample size for this study was 182. Prior sample size calculations were not performed due to this study was an observational study of a population.

Measurement

Experience of falls

The experience of falls at least once during the 1-year follow-up period was determined, as an outcome of present study. This was ascertained by questionnaire in the Fall Risk Index (FRI)-5, which asked "Have you had any falls over the past year?" with possible answers of "Yes" or "No." Participants who did not provide a valid answer to the questionnaire were asked to confirm their response orally at the venue.

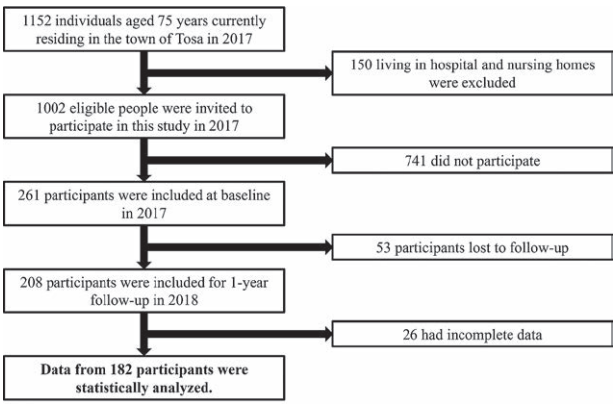

Figure 1 Flowchart of study participants selection.

Oral examination

Two trained dentists, under sufficient illumination using artificial light, determined the number of remaining teeth (range: 0–28, excluding the third molar) as a predictor. Implants, dummies, and residual root teeth were not counted as the remaining teeth. Participants were divided into three groups according to the number of remaining teeth: group I, with > 20 remaining teeth (healthy group); group II with 1-19 teeth (decreased number of teeth); and group III, with 0 teeth (edentulous group). Ansai et al. reported that those with 20 or more remaining teeth at age of 80 years had higher masticatory ability than those with less than 20 remaining teeth, and showed significantly higher motor function than edentulous older people[28, 29]. The criteria for the present study were based on this report. Participants were asked about their use of dentures with the question, "Do you usually use denture?" with possible answers of "I do not have it," "I have it and I usually use it," or "I have it but I don't usually use it."

Physical examination

For the anthropometric evaluation, we measured height and weight, and calculated the body mass index (BMI) was obtained by dividing the weight in kilograms by the square of the height in meters.

We examined hand grip strength as a measure of upper limb muscle function using a Smedley-type hand dynamometer in both the dominant and non-dominant hands while standing. We used the larger value. In addition, we calculated the gait speed by recording the time required to move straight for 4 m to evaluate the motor function of the lower limbs. According to the frailty definition from 2017 when our measurements were taken, a hand grip strength of less than 28 kg for men and less than 18 kg for women was defined as "weakness," and gait speed of less than 1 m/s was defined as "slowing"[30].

We used the timed up-and-go (TUG) test, to assess fall risk[31].This test measured the time taken to stand up from a standard chair, walk 3 m at a natural pace, turn around, and sit back down in the chair[31]. A time of 13.5 seconds more was defined as "high risk"[32].

Cognitive function examination

The Mini-Mental State Examination (MMSE)[33] was used to assess the cognitive function of participants, which was one of the factors associated with falls[34]. A group with a score of less than 24 points was considered "cognitive impairment group"[35].

Higher-level functioning, health status, and lifestyle factors were assessed using the Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC)[36, 37] rating scale of 0-13. The TMIG-IC scale includes instrumental self-maintenance scores corresponding to instrumental activities of daily living (0-5), intellectual activities (0-4), and social roles (0-4), with higher scores indicating higher competence.

Fall Risk Index-5

FRI-5 is a questionnaire designed to evaluate the risk of falls using 5 items[38]. The five items are as follows: "Have you had any falls over the past year?", "Do you feel your walking speed has declined recently?", "Do you use a cane when you walk?", "Is your back bent?", and "Do you take more than five kinds of prescribed medicines?" with possible answers of "Yes" or "No" to all. The history of falls received a score of 0 or 5, all other items were scored 0 or 2, the sum of all items ranged from 0 to 13, and the sensitivity and specificity at a cutoff value of 5/6 were 68% and 70%, respectively[38].

Interview

The participant's past medical history (including heart disease and cerebrovascular disease as well as their current medication status for the treatment of insomnia were recorded.

Statistical analyses

To describe the sample characteristics, frequency distributions were determined for the qualitative variables, and the mean and standard deviation were calculated for each quantitative variable: age, BMI, and TMIG-IC and FRI-5 scores. The chi-square test was used for categorical variables, and the t-test and Mann–Whitney U test were used for continuous variables between those who experienced falls within the follow-up period and those who did not. Multiple logistic regression analysis was performed to investigate the association between number of remaining teeth and falls. The dependent variable was the experience of falls at the 1-year follow-up, while the independent variable was the dental status (groups I-III). The potential confounders were age, sex, gait speed, handgrip strength, MMSE, TMIG-IC, and FRI-5. Two logistic regression models were used. Model-1 was an analysis of enrolled 182 participants. To prospectively assess the risk of falls, model-2 was set up, in which those who had experienced a fall in the year prior to baseline or those who had dentures but did not use them were excluded as having a high risk of falls[39, 40]. That is, those who answered "yes" for "Have you had any falls over the past year?" or "I have it but I do not usually use it" for "Do you usually use denture? in the baseline questionnaire.

Statistical significance was set at p-value < 0.05. Statistical analyses were performed using the SPSS software (version 24.0 for Windows; SPSS, Chicago, IL, USA).

Results

Table 1 shows the characteristics of the participants. A total of 182 participants were enrolled, 117 (64.3%) of whom were women. The average age was 81.9 ± 4.80 years. Forty (22.0%) participants had experienced a fall in the past year. The number of participants with remaining teeth in groups I, II, and III was 70 (38.4%), 68 (37.4%), and 44 (24.2%), respectively.

Table 2 shows the associations of measured variables with the experience of falls during a 1-year follow-up. Among the three groups divided by the number of remaining teeth, there was a significant difference in the experience of falls. The grip strength weakness and the FRI-5 high-risk group were also significantly associated with falls in the past year.

The relationship between the experience of falls and groups based on the number of remaining teeth is shown in Table 3. Logistic regression analysis of model 1 showed that the number of remaining teeth was significantly associated with falls; and adjusted odds ratios (95% confidence intervals) for risk of falls were 2.95 (1.06-8.20) and 3.04 (1.05-8.82) in the groups II and III, respectively. Similarly, the association between grip strength weakness and falls was shown: 3.26 (1.41-7.51). Model 2, which excluded high-risk participants,

Table 1 Characteristics of participants (n = 182)

Variable	mean ± S.D. or N (%)
Age	81.9 ± 4.80
Sex: Female	117 (64.3)
Experience of falls at 1-year follow-up	40 (22.0)
Number of remaining teeth	13.3 ± 10.4
Group I (≥ 20)	70 (38.4)
Group II (1-19)	68 (37.4)
Group III (0)	44 (24.2)
Do you usually use denture?	
= I do not have it	44 (24.2)
= I have it and I usually use	134 (73.6)
= I have it but I don't usually use	4 (2.2)
Grip strength weakness (male: < 26 kg, female: < 18 kg)	56 (30.8)
Gait speed slowing (< 1 m/s)	62 (34.1)
TUG high risk (≥ 13.5 s)	16 (8.8)
BMI	23.3 ± 3.24
< 18.5	7 (3.8)
18.5 ≤ ≤ 25.0	123 (67.6)
25.0 <	52 (28.6)
TMIG-IC score	11.5 ± 2.16
MMSE decline (≤ 23)	15 (8.2)
FRI-5 high risk (≥ 6)	73 (40.1)
Have you had any falls over the past year? = yes	32 (17.6)
Do you feel your walking speed declined recently? = yes	128 (70.3)
Do you use cane when you walk? = yes	57 (31.3)
Is your back bended? = yes	90 (49.5)
Do you take more than 5 kinds of prescribed medicines? = yes	50 (27.5)
Cerebrovascular disease	13 (7.1)
Heart disease	20 (11.0)
Usage of sleeping pills	44 (24.2)

indicated the significant association between the number of remaining teeth and falls: 5.48 (1.37-21.8) and 5.36 (1.21-23.9) in the groups II and III, respectively. In addition, adjusted odds ratios in both groups were greater than those in model 1.

Discussion

This study revealed an association between the number of remaining teeth and falls within a prospective year among community-dwelling older individuals.

Our results showed that falls significantly increased in participants with a low number of remaining teeth, similar to those with weak grip strength. A history of falls in the past year is a major risk factor for falls[9, 41, 42], and there have also been reports that people with poor dental occlusion without dentures have an increased risk of falls[39, 40]. After excluding these high-risk participants, the impact of a reduced number of remaining teeth on falls increased. These findings suggest that the number of remaining teeth and history of falls were isolated as risk factors. Our results highlighted the potential contribution of oral health to falls in community-dwelling older individuals. Honeywell et al. also reported that older adults who is malnutrition had fewer teeth than those with normal nutritional status[43]. Furthermore, Ishida et al. reported that in the acute phase, low nutrition at the time of admission increased the risk of falls by approximately 2.8 times[44]. Thus, it was suggested that a decrease in the number of remaining teeth may lead to malnutrition, which in turn may increase the risk of falls. Although there was a significant difference in age for the experience of falls during the one year follow-up, the average difference in the age was about 2 years. The participants in this study were older than 80, and the social significance of a 2-year difference in mean age are not considered to be strong.

As of 2019, Japan has a population of 126.17 million, of which 35.89 million are aged 65 years or older, and the population ratio is 28.4%, making it a "super-aging

Table 2 Associations of measured variables with experience of falls at a 1-year follow-up

Variable	Experience of falls at a 1-year follow-up		
	No n = 142 (78.0%)	Yes n = 40 (22.0%)	p-value
Number of remaining teeth[a]	14.6 ± 10.01	8.7 ± 10.06	0.001[c]
Group I (≥ 20)[b]	62 (43.7)	8 (20.0)	
Group II (1-19)[b]	51 (35.9)	17 (42.5)	0.013[d]
Group III (0)[b]	29 (20.4)	15 (37.5)	
Usage of dentures[b]			
= I do not have it	35 (24.6)	9 (22.5)	
= I have it and I usually use	103 (72.5)	31 (77.5)	0.524[d]
= I have it but I don't usually use	4 (2.8)	0 (0)	
Age[a]	81.5 ± 4.68	83.2 ± 5.06	0.043[c]
Sex: Female[b]	92 (64.8)	25 (62.5)	0.790[d]
Grip strength weakness (male: < 26 kg, female: < 18 kg)[b]	36 (25.4)	20 (50.0)	0.003[d]
Gait speed slowing (< 1 m/s)[b]	47 (33.1)	15 (37.5)	0.604[d]
TUG high risk (≥ 13.5 s)	14 (9.9)	2 (5.0)	0.529[d]
BMI			
< 18.5	6 (4.2)	1 (2.5)	
18.5 ≤ ≤ 25.0	97 (68.3)	26 (65.0)	0.752[d]
25.0 <	39 (27.5)	13 (32.5)	
TMIG-IC[a]	11.4 ± 2.25	11.7 ± 1.79	0.447[c]
MMSE decline (≤ 23)[b]	13 (9.2)	2 (5.0)	0.399[d]
FRI-5 (≥ 6)	51 (35.9)	22 (55.0)	0.030[d]
Have you had any falls over the past year? = yes	15 (10.6)	17 (42.5)	0.000[d]
Do you feel your walking speed declined recently? = yes	95 (66.9)	33 (82.5)	0.056[d]
Do you use cane when you walk? = yes	40 (28.2)	17 (42.5)	0.084[d]
Is your back bended? = yes	69 (48.6)	21 (52.5)	0.662[d]
Do you take more than 5 kinds of prescribed medicines? = yes	38 (26.8)	12 (30.0)	0.685[d]
Cerebrovascular disease	8 (5.6)	5 (12.5)	0.136[d]
Heart disease	14 (9.9)	6 (15.0)	0.358[d]
Usage of sleeping pills	36 (25.4)	8 (20.0)	0.485[d]

a: Mean ± Standard Deviation, b: Number of participants (%), c: student's t-test, d: Chi-square test

Table 3 Odds ratios from the multiple logistic regression analysis with the number of remaining teeth as independent variables

Independent variables	Dependent variable: Experience of falls at a 1-year follow-up							
	Model 1[$]				Model 2[#]			
	ORc	95% C.I.	ORa	95% C.I.	ORc	95% C.I.	ORa	95% C.I.
Group *(ref: Group I)*								
Group II	2.58	1.03 - 6.47	2.95	1.06 - 8.20*	5.00	1.33 - 18.8	5.49	1.37 - 21.8*
Group III	4.01	1.53 - 10.5	3.04	1.05 - 8.82*	5.87	1.43 - 24.0	5.36	1.21 - 23.9*
Age	1.08	1.00 - 1.15	1.02	0.94 - 1.11	1.26	0.94 - 1.13	0.98	0.88 - 1.09
Sex female *(ref: Male)*	0.91	0.44 - 1.87	0.61	0.27 - 1.40	1.26	0.48 - 3.29	0.96	0.33 - 2.82
Grip strength weakness *(ref: Normal)*	2.94	1.43 - 6.09	3.26	1.41 - 7.51*	2.31	0.92 - 5.79	2.27	0.76 - 6.80
Gait speed slowing *(ref: Normal)*	1.21	0.59 - 2.52	0.90	0.39 - 2.12	1.81	0.73 - 4.49	1.60	0.53 - 4.87
MMSE decline *(ref: Normal)*	0.52	0.11 - 2.42	0.34	0.05 - 2.15	1.09	0.22 - 5.31	0.44	0.06 - 3.17
TMIG-IC score	1.07	0.84 - 1.29	1.07	0.86 - 1.34	1.00	0.81 - 1.23	1.02	0.78 - 1.33
FRI-5 high risk *(ref: Normal)*	2.18	1.07 - 4.44	2.06	0.92 - 4.60	0.71	0.24 - 2.05	0.59	0.17 - 2.06
Nagelkerke R^2				0.187				0.150

*: $p < 0.05$
$: Model 1 n = 182
#: Model 2 n = 147 (excluded subjects with history of fall at baseline from model 1)
ORc: Crude odds ratio, ORa: Adjusted odds ratio
C.I.: Confidence interval
ref: reference groups

society"[45]. This number is the highest among developed countries and is expected to remain high in the future[45]. In particular, the population aged 75 years or older, called the late older, is 18.49 million (14.7%), which exceeds the population aged 65 to 74 years, and the proportion is expected to increase. Tosa Town, Kochi Prefecture, where this survey was conducted, is a "super-aged town" with an aging rate of 44.8%; therefore, it is an area that can be positioned as a model for developed countries that are expected to face the problem of aging in the future[46, 47]. Furthermore, the average age of the participants in this study was 81.6 years, and the male-to-female ratio was 67:118 (approximately 4:7). In the 80-84 years old group of the Japanese population, the male-to-female ratio is approximately 4:6[48]. Forty participants reported falls within one year during the follow-up period, accounting for 21.6% of the total. The prevalence of falls per year was often less than 20% in a previous survey of community-dwelling older individuals in Japan[4]. The ratio of the three groups divided by the number of remaining teeth showed almost the same distribution as that reported in a previous study[49].

Several methods have been proposed for recording fall history[50]. In previous studies, this was obtained by the final questionnaire asking about falls in the past 1 year after 3 years from baseline[39] or for the past 6 months after 3 years or more from baseline[51]. This study covered the entire 1-year follow-up period and, to our knowledge, is the first of its kind in dentistry. The experience of falls was self-reported, and there was a possibility that confounding factors such as the cognitive function of the participants existed; however, in several studies[52, 53], fall data were obtained by recalling falls over 1 year, and the validity was reported[54, 55].

In this study, common risk factors for falls were adopted as covariates, but no significant differences were found in other items except grip strength. Recent investigations demonstrated that the effects of external factors were potentially larger than those of internal factors in a survey of community-dwelling older individuals[56].

Although there have been reports of TUG as a significant predictor of fall risk[32], a recent systematic review concluded that performance-based tests, such as TUG, had poor to moderate accuracy for predicting future falls, especially in high-functioning older adults (no cognitive impairment, no use of walking aids, good physical performance)[57]. All participants in this study were able to come to the survey center on their own; thus, there might be a bias in being a relatively healthy population. Hence, no significant difference was found between TUG and falls in this study.

When the number of remaining teeth is classified into three groups as in this study, a decrease of it might be included as an internal risk factor of falls. While some studies have suggested a relationship between falls[39] and the number of remaining teeth, it is not common to a fall prevention perspective. Incorporating more evaluation items related to internal factors into the evaluation of fall risk might be useful for fall prevention because internal factors often have different contribution rates depending on the participant[58]. According to a previous review, the detection and improvement of risk factors can significantly reduce the rate of future falls[2]. Our results suggest that focusing on the number of remaining teeth may help in detecting people with a high risk of falls. Moreover, when the standard procedures (gait speed and TUG) is used, there is a risk that the subjects may fall during the test. On the other hand, in the evaluation of fall risk based on the number of remaining teeth, as in this study, only an intraoral examination is required, so there is almost no risk of the subjects falling during the examination. Therefore, the method in this study could asse a safer way to assess fall risk than the standard procedures.

Our study has some limitations. First, falls have multi-risk factor syndromes owing to many internal and external factors[59]. Internal factors included weakness, gait disturbance, cognitive decline, and decreased living independence; thus, we adopted grip strength, gait speed, MMSE, and TMIG-IC as covariates in this study. However, we did not use an index of balance that is considered the most important risk factor for falls, along with weakness and gait disturbance[2]. Moreover, the external factors were not considered. Second, since the post-hoc power test showed that the power was above 95%, the situation was prone to type 1 errors. Third, many epidemiological studies in the dental field include other statuses: chewing ability[60], severity of periodontal disease[49], and occlusal condition[61]. The number of remaining teeth was selected as the indicator of oral

health in the current study, since it is often used as an indicator of oral health[62, 63]. However, there is a possibility of an incomplete description of the oral health status. Fourth, although a full report of the circumstances and symptoms was required when we assessed the fall subjects[64], we did not obtain the number or situation of falls. Our outcomes possibly included sudden falls that differed from the effects of fall risk factors. Additionally, the current study did not identify high-risk fallers who repeatedly fell during the follow-up period.

Conclusion

This study suggests that a decrease in the number of teeth may be a useful predictor of falls in community-dwelling older adults. Community-based fall risk screening can benefit older adults. This predictor is easy to implement, safe for participants, and is a non-invasive procedure that by many health care providers can perform.

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Statement of Ethics

This study was approved by the Osaka University Research Ethics Committee (OUKS1703).

The participants provided written informed consent to participate in the study.

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Authors' contributions

MW, YK, MI, HO, and HM: study concept and design, data analysis and interpretation, and manuscript preparation.

RS: leader of the setting and management of health examinations.

All authors: survey and interpretation of data, manuscript revisions, and approval of the manuscript.

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