

Change in ground reaction force parameters according to the frailty level of older women in the Timed Up and Go test

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ABSTRACT

As older people become frail, they tend to fall more easily. Moreover, women have a higher rate of falls than men. However, effective strategies to avoid elderly women falling are lacking. The Timed Up and Go test is a well-known indicator of falling tendency. This study clarifies the motor elements related to the Timed Up and Go test according to the degree of weakness in older outpatients to specify exercise intervention to improve weakness and prevent falls. Participants were 145 female outpatients who visited the Locomo-Frail outpatient clinic, classified into three groups (robust, prefrail, and frail, according to the definition of the Japanese Cardiovascular Health Study. Vertical ground reaction force parameters were measured for all participants when they stood up from a chair, walking speed, and the Timed Up and Go test. Results showed that walking speed is related to the Timed Up and Go test in the robust group; balance ability is related to the Timed Up and Go test in the prefrail group; and instantaneous force is related to the Timed Up and Go test in the frail group. These results suggest that weakness can be improved by performing exercise interventions of balance and instantaneous force elements in the prefrail and frail groups, respectively.

Keywords: Timed Up and Go test, ground reaction force parameters, frailty, elderly women

Abbreviations:

TUG: Timed Up and Go

vGRF: vertical ground reaction force

RFD: rate of force development

Vx: fluctuation value in left-right direction

Vw: load fluctuation value

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INTRODUCTION

As older people become frail, they tend to fall more easily. The annual fall rate among community-dwelling elderly aged 65 years and older is 20%, and that among the elderly in nursing homes is 40%.¹ Frail older adults sometimes fall even while changing clothes or sitting/standing.² Moreover, women have a higher fall rate than men. A. J. Brake et al reported that falls occur more frequently among elderly women compared with elderly men; the overall ratio being 2.7 : 1.³

The possibility of falling contributes to older people's sense of fear, which is strongly related to weakened muscle strength.⁴ Moreover, experiencing a hard fall reduces older adults' ability to perform their subsequent daily activities significantly.⁵ They avoid activities and lose their confidence due to the psychological trauma caused by falling.^{6,7} Accordingly, the range of activities of daily living that they can autonomously perform diminishes,⁸ and their health-related quality of life reduces.⁹

Predicting such falls can help prevent injuries and poor quality of life in older adults.

However, good strategies to avoid falling are lacking. The Timed Up and Go (TUG) test is a well-known indicator of falling tendency.¹⁰ The TUG test is one of several motor function tests that evaluate activities of daily living, especially those that cause falls.¹¹ Previous studies have clarified the relationship between the TUG test and functional ability to define fall risk¹² and fall experience.¹³ Falls have been demonstrated to be more common, especially in women than in men.¹⁴ Fried et al reported that the likelihood of frailty was also higher among women.¹⁵ In addition, Fernandez-Bolaños et al reported that prevalence of frailty was significantly higher in women (30.9%) than in men (9.3%) ($p < 0.001$),¹⁶ and Syddall et al reported that the prevalence of frailty was 8.5% among women and 4.1% among men ($p < 0.05$).¹⁷ These reports explain that women are more likely to become frail. Therefore, we focused on women by analyzing motor factors (balance, instantaneous force, and muscle strength) that are related to the TUG test time to reveal the risk of contributing factors to falls when motor functions decrease in elderly women.

Weakness of the lower limbs is one of the factors related to falls, and quantifying the muscle strength has led to the identification of people at risk of falls; a method to measure the ground reaction force was developed for that purpose.¹⁸ By quickly standing up or sitting on the force plate, vertical, anteroposterior, and lateral parameters can be obtained easily without invasion,¹⁸ where those parameters are calculated from some components of ground reaction force. The vertical ground reaction force (vGRF) parameters have been investigated as indicators of leg function in community-dwelling elderly.^{19,20} Tsuji et al¹⁹ found a correlation between TUG and muscle strength which is one of the vGRF parameters and represented by a peak force in a stand-up motion, whose coefficient was $r = -0.40$, and that between TUG and instantaneous force which is one of the vGRF parameters and represented by a time from start of stand-up to peak force, whose coefficient was $r = -0.52$. Abe et al found a correlation between TUG and the balance ability which is one of the vGRF parameters and represented by a medio-lateral variation from stand-up to stable standing position, whose coefficient was $r = 0.53 - 0.57$. Furthermore, Intra-class correlation coefficients was > 0.70 in both genders.²⁰

In the previous studies on TUG and vGRF,¹⁸⁻²⁰ the subjects were all community-dwelling elderly people, but they did not assess those whose condition was frail. Additionally, there are no reports that discuss the relationship between TUG and vGRF parameters depending on the classification of frailty.

This cross-sectional study aims to clarify the relationship between balance, instantaneous force, and muscle strength related to TUG time according to the degree of weakness using vGRF parameters to help improve the motor functions of lower limb muscle strength and balance by

specifying exercises according to the degree of weakness. We believe that the results of this study will contribute to improving physical weakness to reduce the risk of falling.

MATERIALS AND METHODS

Participants

In this study, we included patients who volunteered to participate in the Locomotor Frailty Sarcopenia Registry study at the time of their visit to the outpatient Locomo-Frail clinic.

Of the 300 patients who participated, we selected on 145 women (78.4 ± 5.7 years) who met the participation/exclusion criteria as shown in (Fig. 1)

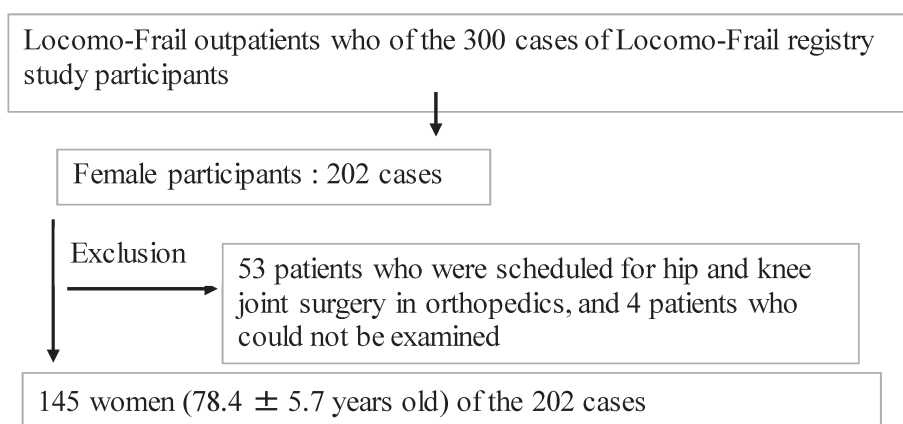


Fig. 1 Participant selection flow chart

The procedure for selecting study participants and the selection/exclusion criteria for study participation are presented.

Criteria for Participation in Locomo-Frail Registry Research:

- 1) A person who has received an explanation of the research content from a doctor in advance and signed a consent form.
- 2) People who can walk on their own (canes can be used).
- 3) People who can go to the hospital.

Exclusion Criteria:

- 1) Persons with visual or hearing impairments that interfere with daily life.
- 2) Those who have obvious paralysis at the time of registration.
- 3) Those who have been diagnosed with dementia (including those who are taking dementia medication).
- 4) Those with a neurological disorder that causes progressive limb dysfunction.
- 5) Those who are thought to be in the terminal stage.
- 6) Others who are judged inappropriate by a doctor.

Ethical Consideration

This study was conducted with the approval of the ethics committee of the National Center for Geriatrics and Gerontology (Locomo-Frail Sarcopenia Registry Study No.881) and written informed consent was obtained from each study participant. This study met the guidelines of the Declaration of Helsinki.

Procedure

For the state of frailty, the patients were classified into three groups: robust (R) group (23 cases, 75.3 ± 5.6 years old), prefrail (PF) group (75 cases, 77.4 ± 5.3 years old), and frail (F) group (47 cases, 81.4 ± 5.1 years old) using the criteria of the Japanese version of the Cardiovascular Health Study (J-CHS)²¹ (Table 1), modified Fried¹⁵ for Japanese people.

Table 1 Prevalence of frailty defined by the Japanese version of the Cardiovascular Health Study criteria

Components	Contents
1. Weight loss	Have you lost 2 kg or more in the past 6 months? “Yes”
2. Subjective fatigue feeling	In the past 2 weeks, have you felt tired without a reason? “Yes”
3. Exercise habits	Do you engage in moderate levels of physical exercise or sports aimed at health? Do you engage in low levels of physical exercise aimed at health? “No” to both questions
4. Decrease in walking speed	Gait speed < 1.0 m/s
5. Decrease of grip strength	Grip strength < 28 kg in men or 18 kg in women

Frailty, prefrailty, and robust are defined by having three - five, one - two, and zero components, respectively. Quoted from Satake et al (2017)²¹ with some modifications.

The vGRF (at the time of standing up from the chair) as well as two physical performance tests, TUG and walking speed, were examined. The vGRF parameters were measured using a motor function analyzer (zaRitz BM-220, produced by the Tanita Corporation, Tokyo, Japan) with a sampling frequency of 80 Hz.

First, participants were instructed to sit on a chair at a height of 41 centimeters and cross their arms in front of their chest with both feet on the detection plate (Fig. 2). They were preliminarily given audio and visual instructions; then, one practice round were performed.

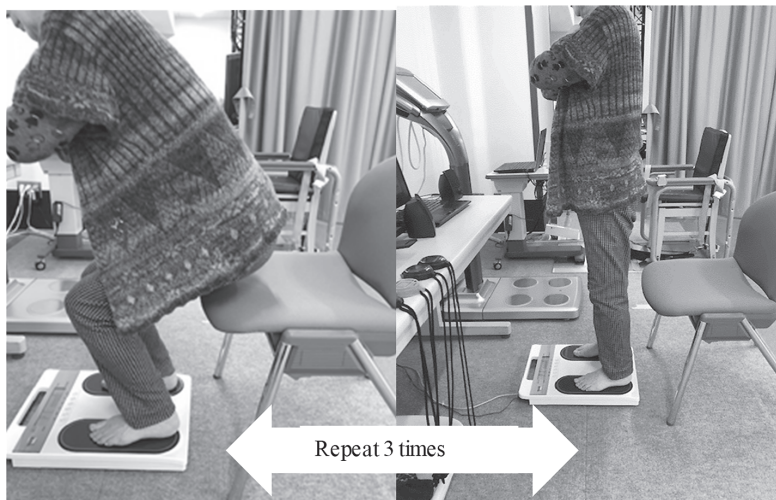


Fig. 2 GRF parameter measurement

Measurements of GRF parameters are shown. Participants crossed their arms in front of their chest and repeated the sitting and standing movements three times (consecutively), as indicated by the white arrows.

Participants stood up as soon as they received a voice instruction from the computer, ‘Stand up quickly!’ Simultaneously, an animation of the standing movement was projected on the connected computer screen. Similarly, the participants sat down on the chair after receiving another instruction along with the animation of the movement of sitting on a chair projected on the computer screen. These actions were repeated three times.

The vGRF parameters were recorded for each participant, and the trial showing the highest rising speed value among the three was selected. Of the following four vGRF parameters (a–d) based upon previous studies^{19,20} (Fig. 3), we used three (a, b, and d) in this study.

- a) Maximum reaction force peak value (F) / body weight (W): F/W , a value obtained by dividing the force applied in the vertical direction at the time of standing up by the weight of the participant. The result refers to peak reaction force.
- b) Rate of force development (RFD) / body weight (W): RFD/W (1/s), a value obtained by dividing the rate of force development by the participant’s body weight. The result refers to the rate of force development and instantaneous force.
- c) Stabilization time (St): St (s) is the time from when the vGRF has recorded the maximum value to the time when it stabilizes to the participant’s weight value. The shortest time taken by the load fluctuation to reach below 0.1 kg (the minimum indicated by zaRitz) is considered ‘stable’.
- d) V_x/V_w (mm/Kg): refers to the value obtained by dividing the fluctuation value in the left-right direction (V_x) by the load fluctuation value (V_w). Since V_x is calculated based on the load data; it will be large even if the load fluctuation is large, that is, even if the participant stands up strongly. Thus, to eliminate this effect and make the data more reliable, we divided V_x by V_w . Therefore, the V_x/V_w is a fluctuation in the left-right direction to the load fluctuation in a unit weight. We use this to indicate that the ability to maintain balance decreases as the value increases.²⁰

The explanation of V_x and V_w is as follows:

- V_x (mm/s): Mean value of the left-right variation of the center of gravity recorded every 0.0125 seconds between the time when the maximum ground reaction force is recorded and the time when the upright position is considered stable.
- V_w (Kg/s): Mean value of the ground reaction force variation recorded every 0.0125 seconds between the time when the maximum ground reaction force is recorded and the time when the upright position is considered stable.

TUG was manually measured twice with maximum effort via a stopwatch and the shorter one was recorded. Walking speed was measured on a 2.4 m sheet-type foot pressure contact measurement device (Walk Way), produced by Anima Corporation, Tokyo, Japan. A normal walking was performed twice using a 6.4 m walkway, which included acceleration and deceleration lanes.

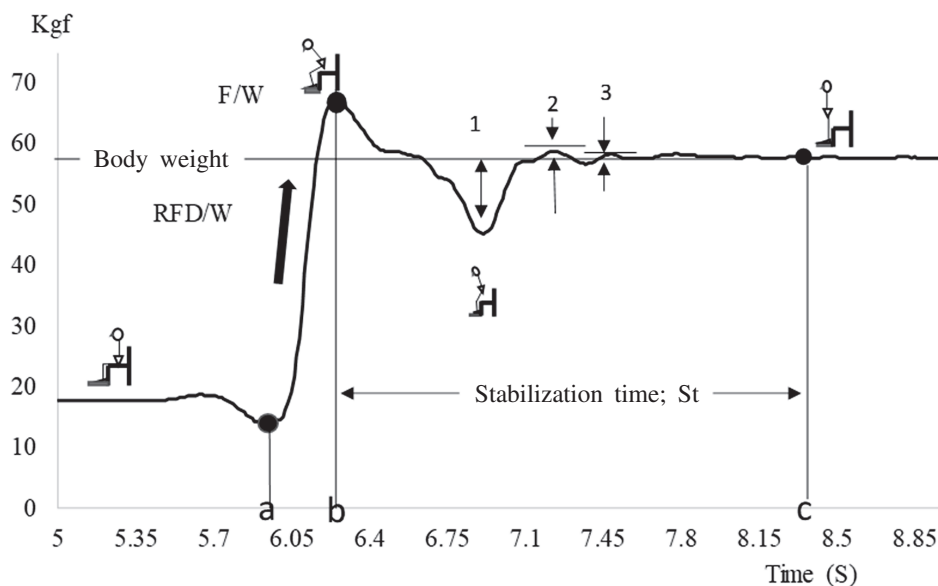


Fig. 3 Description of measured GRF curves and parameters

a: At the start of standing.

b: At the time of recording the maximum ground reaction force.

c: Eventually near equal to the value of the body weight.

1, 2, and 3: Ground reaction force variation. Rebound a few times to get closer to the body weight value.

Maximum reaction force peak value (F)/body weight (W): F/W (Kgf/Kg), a value obtained by dividing the force applied in the vertical direction at the time of standing up by the weight of the participant. The result refers to peak reaction force.

Rate of Force Development: RFD (Kgf/s), a maximum slope per unit time of the graph between point (a) and (b). RFD/body weight (W): RFD/W (Kgf/s/Kg), a value obtained by dividing the rate of force development by the participant's body weight. The result refers to the rate of force development and instantaneous strength.

Stabilization time (St): St (s) is the time from when the vGRF has recorded the maximum value (b) to the time when it stabilizes to participants' weight value (c).

Vx (mm/s): Horizontal variation value (not shown in this Fig.). The movement of center of gravity to the left and right is recorded every 0.0125 seconds and is calculated as an absolute value. The average value from the time when the maximum ground reaction force is recorded until it stabilizes.

Vw (Kg/s): Load fluctuation value. The movement value of the ground reaction force variation is recorded every 0.0125 seconds and is calculated as an absolute value. The average value from the time when the maximum ground reaction force is recorded until it stabilizes.

Vx/Vw (mm/Kg): Magnitude of the lateral sway during action. The Vx normalized by Vw.

Statistical Analysis

One-way analysis of variance was used to compare the means of the measurement items among the three groups, and Tukey's test was used for multiple comparisons. Moreover, the chi-squared test was used to compare the proportions of fallers in the three groups of frail status over the past year and Pearson's product-rate correlation to correlate among the measurement items. Additionally, hierarchical multiple regression analysis was used to examine the contribution of the measurement items to the TUG time, with TUG as the dependent variable, age and walking speed as the two adjustment variables, and F/W, RFD/W, and Vx/Vw as the three independent variables. In all methods, $p < 0.05$ was set as the significance level.

RESULTS

The attributes of the participants are shown in Table 2. Over the past year, the number of fallers in the R, PF, and F groups were 6 (26.1%), 29 (38.7%), and 27 (57.4%), respectively, for a total of 62 patients. Fisher's exact test showed a significant association of fall experience in the R, PF, and F groups over the past year at $p < 0.05$. The difference in frequency due to the adjusted residual was also significantly higher in the F group at 2.5 compared to the other two groups, and the difference in fall frequency was not significant between the R and PF groups. Additionally, the number of associations indicating relevance was $\phi = 0.24$ and $p < 0.05$; the falls in the F group were significantly related.

Table 2 Participant attributes and comorbidities

Item	Unit	Total (n = 145)	Robust (n = 23)	Prefrail (n = 75)	Frail (n = 47)
Age (years)	years	78.4 ± 5.7	75.3 ± 5.6	77.4 ± 5.3	81.4 ± 5.1
BMI		22.7 ± 4.1	23.7 ± 3.4	22.6 ± 4.3	22.4 ± 4.2
Height	cm	148.2 ± 6.4	150.6 ± 5.0	148.8 ± 6.4	146.0 ± 6.6
Weight	Kg	50.0 ± 10.3	54.1 ± 10.2	50.1 ± 10.7	47.7 ± 9.3
History of fall	In the past year	62 (42.8%)	6 (26.1%)	29 (38.7%)	27 (57.4%) *
Comorbidities ¹⁾					
Heart disease ²⁾		33 (22.8%)	1 (4.3%)	18 (24.0%)	14 (29.8%)
Diabetes mellitus ²⁾		18 (12.4%)	1 (4.3%)	7 (9.3%)	10 (21.3%)
Hypertension ²⁾		65 (44.8%)	7 (30.4%)	33 (44.0%)	25 (53.2%)
Hyperlipidemia ²⁾		50 (34.5%)	6 (26.1%)	25 (33.3%)	19 (40.4%)
Respiratory disease ²⁾		15 (10.3%)	4 (17.4%)	7 (9.3%)	4 (8.5%)

¹⁾ Comorbidities also include cases where one person has multiple comorbidities.

²⁾ Numbers represent the amount of cases; the numbers in parentheses indicate the percentage within each group.

* $p < 0.05$

As shown in Table 3, in the R-PF groups, there were no significant differences in TUG, F/W, RFD/W, and Vx/Vw, but walking speed was significantly ($p < 0.01$) lower in the PF group than in the R group.

Between the R-F groups, TUG ($p < 0.001$), walking speed ($p < 0.001$), F/W ($p < 0.01$), and RFD/W ($p < 0.01$) were significantly lower in the F group than in the R group. However, Vx/Vw showed a significantly higher value ($p < 0.001$) in the F group than in the R group. In the PF-F groups, TUG ($p < 0.001$), walking speed ($p < 0.001$), F/W ($p < 0.05$), and RFD/W ($p < 0.01$) were significantly lower in the F group than in the PF group. Meanwhile, Vx/Vw was significantly higher in the F group than in the PF group ($p < 0.001$).

Table 3 Comparison of GRF parameters and PPT among the robust, prefrail and frail groups

		TUG	WS	F/W	RFD/W	Vx/Vw	Age
Group	Robust	8.67 ± 1.78	1.30 ± 0.21	1.25 ± 0.07	8.73 ± 1.58	1.30 ± 0.71	75.3 ± 5.6
	Prefrail	10.36 ± 3.46	1.11 ± 0.26	1.22 ± 0.08	8.04 ± 1.67	1.68 ± 0.82	77.4 ± 5.3
	Frail	13.94 ± 5.94	0.83 ± 0.22	1.18 ± 0.08	7.00 ± 1.94	2.28 ± 1.06	81.4 ± 5.1
Significance	R-PF	NS	**	NS	NS	NS	NS
	R-F	***	***	**	**	***	***
	PF-F	***	***	*	**	**	***

TUG: Timed Up and Go

WS: walking speed

GRF: ground reaction force

PPT: physical performance test (TUG and WS)

R: robust

PF: prefrail

F: frail

* p < 0.05, ** p < 0.01, *** p < 0.001

There were significant correlations between TUG and walking speed in the R, PF, and F groups ($r = -0.80$, $p < 0.001$; $r = -0.81$, $p < 0.001$; and $r = 0.76$, $p < 0.001$, respectively). There were significant correlations between TUG and F/W in the R, PF, and F group ($r = -0.49$, $p < 0.01$; $r = -0.39$, $p < 0.001$; $r = -0.58$, $p < 0.001$, respectively). There were significant correlations between TUG and RFD/W in the R, PF, and F group ($r = -0.50$: $p < 0.01$, $r = -0.51$: $p < 0.001$, $r = -0.54$: $p < 0.001$, respectively), and the correlations between TUG and Vx/Vw in the R, PF, and F group ($r = 0.42$: $p < 0.05$, $r = 0.65$: $p < 0.001$, $r = 0.39$: $p < 0.01$, respectively) (Table 4).

The overall scatter plots of TUG and evaluation items are shown in (Fig. 4).

Table 4 Correlation among age, TUG, walking speed, and vertical GRF parameters

		TUG	Age	WS	F/W	RFD/W	Vx/Vw
Robust	TUG	1.00	0.37 *	-0.80 ***	-0.49 **	-0.50 **	0.42 *
	Age		1.00	-0.53 **	0.06 NS	0.04 NS	0.21 NS
	WS			1.00	0.31 NS	0.34 NS	-0.23 NS
	F/W				1.00	0.80 ***	-0.56 **
	RFD/W					1.00	-0.76 ***
	Vx/Vw						1.00
	Prefrail	TUG	1.00	0.42 ***	-0.81 ***	-0.39 ***	-0.51 ***
Age			1.00	-0.33 **	-0.23 *	-0.31 **	0.38 ***
WS				1.00	0.51 ***	0.59 ***	-0.59 ***
F/W					1.00	0.80 ***	-0.38 ***
RFD/W						1.00	-0.52 ***
Vx/Vw							1.00

	TUG	1.00	0.31 *	-0.76 ***	-0.58 ***	-0.54 ***	0.39 **
	Age		1.00	-0.33 *	-0.13 NS	-0.04 NS	0.27 *
Frail	WS			1.00	0.39 **	0.32 *	-0.17 NS
	F/W				1.00	0.80 ***	-0.48 **
	RFD/W					1.00	-0.50 ***
	Vx/Vw						1.00

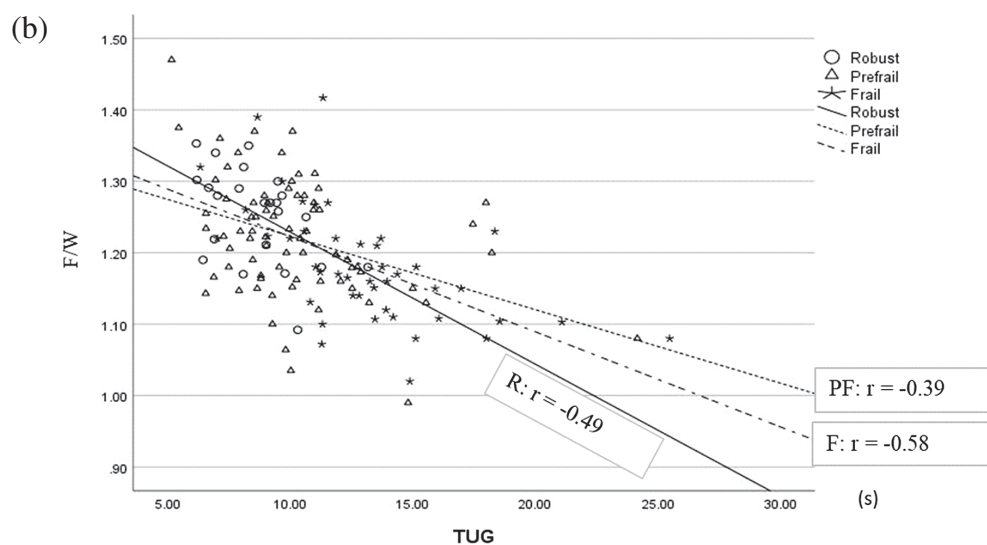
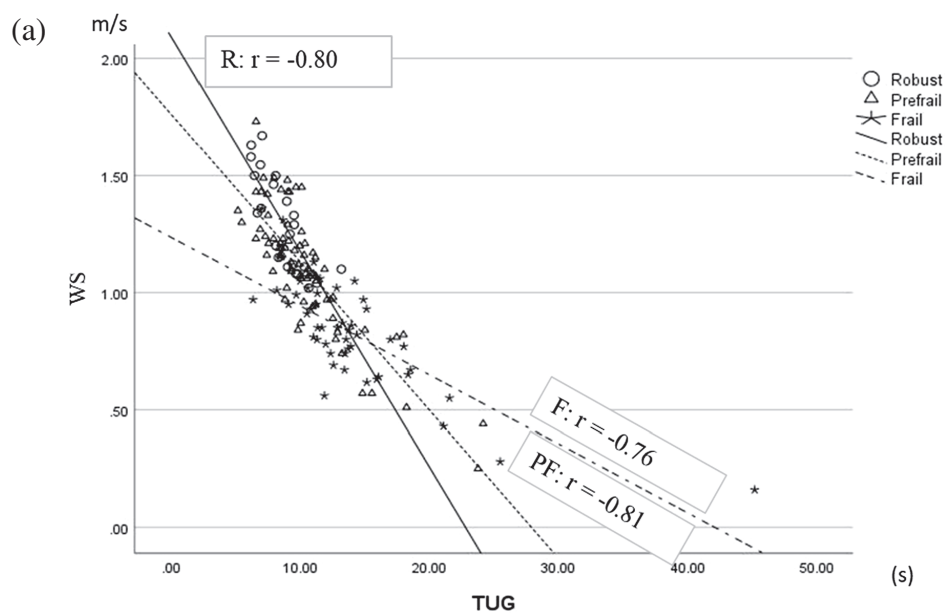
NS: no significance

WS: walking speed

TUG: Timed Up and Go

GRF: ground reaction force

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.



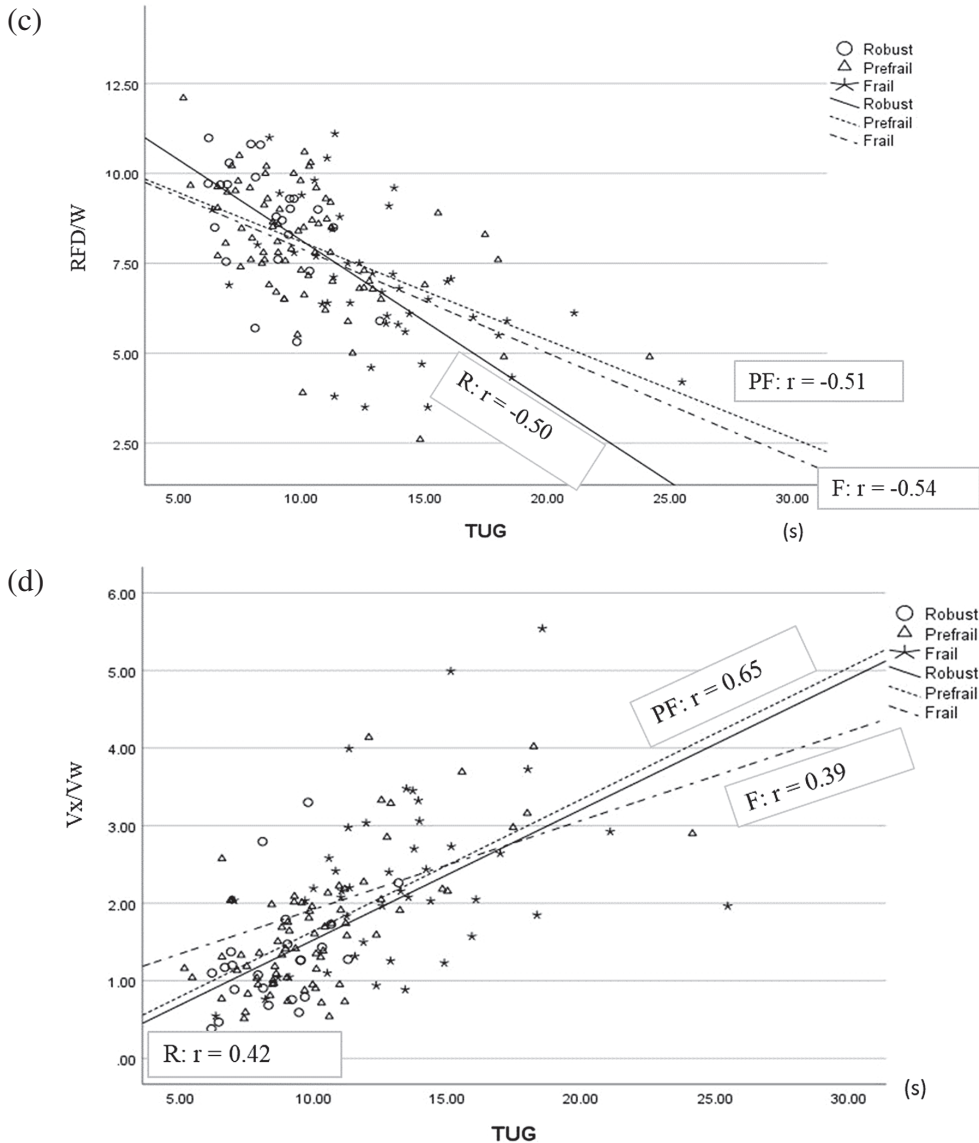


Fig. 4 Scatter plots of Timed Up and Go (TUG) and walking speed, ground reaction force (GRF) parameters

Fig. 4a: The correlation between TUG and walking speed is shown as scatter plots for the robust, prefrail, and frail groups, respectively.

Fig. 4b: The correlation between TUG and F/W is shown as scatter plots for the robust, prefrail, and frail groups, respectively.

Fig. 4c: The correlation between TUG and RFD/W is shown as scatter plots for the robust, prefrail, and frail groups, respectively.

Fig. 4d: The correlation between TUG and Vx/Vw is shown as scatter plots for the robust, prefrail, and frail groups, respectively.

WS: walking speed

R: robust

PF: prefrail

F: frail

The results of multiple regression analysis showed that the vGRF parameter items related to TUG time were not significant in the R group. On the other hand, in the PF group, the contribution of V_x/V_w (standardized β coefficient: 0.23, $p < 0.01$, adjusted R^2 value: 0.70) was identified in addition to the adjusted variable walking speed. Finally, in the F group, the contribution of RFD/W (standardized β coefficient: -0.34 , $p < 0.01$, adjusted R^2 value: 0.66) was identified in addition to walking speed (Table 5).

Table 5 Multiple regression analysis showing the relationship between TUG and vertical GRF parameters by frailty

		Non- standardization factor	Standardization coefficient	Significant probability	CI (95%) for B		Collinearity statistics	
		B	β		Lower limit	Upper limit	Allowance	VIF
Robust	Age	-0.023	-0.074	0.645	-0.128	0.081	0.720	1.389
	WS ***	-7.243	-0.836	0.000	-10.105	-4.382	0.720	1.389
Prefrail	Age	0.077	0.132	0.065	-0.005	0.159	0.840	1.191
	WS ***	-8.156	-0.632	0.000	-10.220	-6.092	0.643	1.555
	V_x/V_w **	0.872	0.228	0.007	0.248	1.496	0.617	1.621
Frail	Age	0.066	0.091	0.341	-0.073	0.205	0.884	1.131
	WS ***	-11.031	-0.625	0.000	-14.572	-7.490	0.797	1.255
	RFD/W **	-0.623	-0.336	0.001	-0.974	-0.271	0.895	1.117

WS: walking speed

TUG: Timed Up and Go

GRF: ground reaction force

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

DISCUSSION

In this study, we used the vGRF parameters obtained when standing up from the chair to investigate how muscle strength and balance related to TUG contribute to the degree of frailty. Age and walking speed adjusted hierarchical multiple regression analysis showed no significant contribution of vGRF parameters in the R group. However, in the PF group, the contribution of V_x/V_w to TUG (standardized β : 0.23) was shown, and the positive correlation with TUG was significant. Since the V_x/V_w value is an index of balance, the balance ability decreases as the value increases,²⁰ indicating that the TUG becomes longer as the V_x/V_w value increases. Additionally, in the F group, the contribution of RFD/W to TUG (standardized β : -0.34) was seen; there was a significant negative correlation with TUG, indicating that the TUG becomes shorter as the instantaneous force increases.

The decline in balance ability was reported in the National Institute for Longevity Sciences Longitudinal Study of Aging (NILS-LSA).²² In the NILS-LSA Monograph 5th, women in their 60s (92.8 ± 66.4 s.), 70s (49.3 ± 55.5 s.), and 80s (19.4 ± 23.7 s.) showed significantly shorter unilateral standing time with increasing age. These results corroborate with the results of this study, namely, a decrease in balance ability related to TUG in the PF group, which has a higher mean age than the R group.

TUG is one of several motor function tests that assess activities in daily life, especially those that cause falls,¹¹ and is also known as an indicator of walking speed, strength, and balance.^{10,23-25} Furthermore, TUG has elements of standing up from a chair, walking, turning, and sitting down; it also has an element of instantaneous force because instantaneous force is required in the first step of standing up.²⁶ Additionally, when a person turns during the TUG test, the advancing vector suddenly changes, so centrifugal force is generated in the direction perpendicular to the tangent line of the arc created by the turning radius. Therefore, muscular strength and balance against centrifugal force are required.

Balance control is also a factor that influences the time factor of TUG, which has a great impact on the rising time and the turning time; the muscle strength of the hip and the knee joints especially affects the rising time from the chair.²⁷ On the other hand, instantaneous force, although an attribute that is related to strength, is different from strength. It is the ability to exert muscle strength per unit time (competence/time) and is related to physical ability rather than muscle strength.²⁸⁻³⁰ This means that instantaneous force is related to quick movements in activities of daily living. Furthermore, instantaneous force is related to gait variability in frail elderly people, and gait pattern variability is associated with falls.³¹ Additionally, quick muscle contraction decreases with aging due to an increase in Type I muscle fibers and a decrease in Type II muscle fibers.³² Therefore, if the balance factor is improved in the PF group and the instantaneous force is improved in the F group, the TUG time can be shortened, which would reduce weakness and the risk of falls.

As shown in Table 3, there was a statistically significant difference between the R and PF groups in terms of walking speed. Moreover, the PF group tended to show lower values than the R group in terms of parameters other than walking speed, although there was no statistically significant difference. Since there were significant differences in all parameters, including TUG, between the PF and F groups, it is presumed that there is a difference in motor ability among the R, PF, and F groups. Furthermore, the results of this study showed that the frequency of falls in the F group was significantly higher than in the other two groups. If athletic ability declines, activity decreases and the degree of weakness further increases suggesting that there will be a negative spiral of increased risk of falls.

The term 'frail' is defined as a state of increased vulnerability to health problems due to various functional changes and decreased reserve capacity associated with aging,³³ 'prefrail' is a state that is intermediate between robust and frail and can be restored to a normal state by appropriate measures.

However, moderate frailty shows functional improvement with intervention, but severe frailty does not.³⁴ Therefore, intervention at the prefrail stage is more effective, and the 12-months intervention was effective on daily activity and short physical performance battery walking.³⁵ Moderate-intensity group exercise was effective for physical fitness and falls in the prefrail group, but not for the frail group.³⁶ These previous studies show that early intervention in frailty is more effective.

Interventions aimed at strengthening muscle strength and improving balance ability should be performed for prefrail elderly with one or two out of the five diagnostic items of J-CHS. Furthermore, those for instantaneous force should be given to frail elderly who have three or more. Thus, we think that adding exercise interventions would improve the physical weakness of PF or F stage patients.

The limitations of this study were as follows. Firstly, the number of participants was rather small, and since we focused on women, it prevented us to discuss men. Additionally, the causal relationship between the balance factor, instantaneous force factor, and TUG time is not clear because the study employed a cross-sectional design. Furthermore, there is no information on

each phase of TUG. In the future, it will be necessary to increase the number of cases, add male subjects, clarify the causal relationship in longitudinal studies, and verify the effect of intervention on elderly people who tend to be frail. Additionally, in order to confirm the results of this study, a combined evaluation of spatiotemporal parameters and electromyography showing lower limb muscle activity during the rise, walk, and turn phases of TUG might be desirable. Those studies would clarify the action of lower limb muscles and body movements in each phase of TUG.

CONCLUSIONS

This study included female participants classified by J-CHS frail phenotype. Then, using the vGRF parameters obtained when standing up from the chair, the muscle strength, instantaneous force, and balance that affect the TUG time were investigated. It was clarified that the decrease in balance ability in the prefrail group and the decrease in instantaneous force in the frail group contribute to TUG. This suggests that in addition to muscle strengthening, which is a common exercise intervention for the community-dwelling elderly, exercise instructions, and interventions aimed at strengthening balance and instantaneous force may be desirable to reduce physical frailty and the risk of falls in the prefrail elderly.

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