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Relationship between Frail and Non-Frail Groups and Physical Function, Balance Function, and Walking Function Using Kihon Check List

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Abstract

Purpose: The objective was to clarify the relationship with physical function, balance function, and walking function in frail and non-frail groups. **Method:** Physical function was measured using height, weight, BMI, SMI, grip strength, knee extension strength, and balance function using a standing power measurement device (Tanita Corporation, ZARITZ, BM-220). Walking function was measured using walking speed, thoracolumbar vertical movement, and foot lift angle. **Results:** Ground reaction force (speed), Walking Function (walking speed, Rea Foot Lift Angle) were significantly lower in the KCL score ≥ 8 group (frail group) compared to the KCL score ≤ 7 group (non-frail group) ($p < 0.05$, $p < 0.01$). KCL total score and Ground reaction force (speed), Walking Function (walking speed, stride length Rea Foot Lift Angle) were each significantly correlated ($p < 0.05$, $p < 0.01$). **Conclusion:** Balance function and gait function tests were useful for assessing frailty.

Keywords

Kihon Check List, Balance Function, Walking Function

1. Introduction

Japan has entered a super-aged society where one in four people is elderly. While the proportion of individuals certified as requiring long-term care is 2.9% among those aged 65 to 69, it rises rapidly with age, reaching 26.2% among those aged 80 to 84 and 60.1% among those aged 85 and older [1]. Among the factors contributing to the need for long-term care, frailty due to aging ranks third after dementia and cerebrovascular disease. On the other hand, the Kihon Check List (KCL) was developed to identify frail individuals, who are considereVd priority targets for preventive care [2]. The KCL consists of 25 questions regarding motor function, oral function, nutritional status, cognitive function, etc., to which respondents answer "yes" or "no." Additionally, the Cardiovascular Health Study criteria (CHS criteria) exist as diagnostic standards for frailty [3]. The number of items meeting the CHS criteria was significantly correlated with the KCL total score [4]. Furthermore, the cutoff value for the KCL was determined to be between 7 and 8 points. That is, a KCL score of 8 or higher indicates frailty. Therefore, this study aimed to investigate the relationship between KCL scores and physical function, balance function, and walking function in community-dwelling older adults, dividing them into two groups: those scoring 8 points or higher (frail group) and those scoring 7 points or lower (non-frail group).

2. Subject and Methods

2.1. Participants

This study involved 41 participants aged 65 years or older (12 men, 29 women) who responded to a call for participation from the municipality of K Town, Nagasaki Prefecture (mean age 76.1 years). This study is intended for healthy older adults living in the community. Therefore, participants with neurological or orthopedic conditions, cognitive impairment, or those who use walking aids are excluded.

The inclusion criteria were defined as participants for whom all measurements of physical function, ground reaction forces, and walking function had been completed.

The recruitment method involved publishing a notice about the "survey" in the town bulletin, and residents who saw it participated. Participants were verbally informed of the survey's purpose, that participation was voluntary, that data collected would not be used for any purpose other than research, and that data would be anonymized before use. Informed consent was obtained from each participant.

2.2. Methods

2.2.1. General Information Participants

General information (age, gender) and KCL scores were used to calculate the number of frail and non-frail individuals (%) (**Table 1**).

2.2.2. Physical Function

BMI (Body Mass Index) was calculated as weight (kg) divided by height (m) squared.

Table 1. Subject characteristics (n = 41).

Evaluation items		
General information	Age (years)	76.1 ± 6.9
	Gender	Men 12 (29%)
		Women 29 (71%)
	Kihon check list (KCL)	Frail 17 (42%)
		Non-frail 24 (58%)
Physical function	Height (cm)	155.9 ± 8.8
	Weight (kg)	55.8 ± 11.2
	BMI (kg/m^2)	22.8 ± 3.2
	SMI (kg/m^2)	6.4 ± 0.9
	Grip strength (kg)	26.5 ± 7.9
	Knee extension strength (kg)	23.8 ± 10.2
	One-legged stance with eyes open (sec)	43.2 ± 43.2
Ground reaction force	Speed (RFD/W)	9.1 ± 1.8
	Power (F/W)	1.3 ± 0.1
	Ground reaction force duration (sec)	1.2 ± 0.3
Walking function	Walking speed (m/min)	76.7 ± 14.8
	Trunk vertical oscillation (cm)	4.0 ± 1.4
	Stride length (cm)	58.8 ± 10.1
	Front foot lift angle (cm)	29.5 ± 3.7
	Rear foot lift angle (cm)	22.8 ± 5.3

Average e ± standard deviation.

SMI (Skeletal Muscle Mass Index) was calculated by dividing the limb skeletal muscle mass values obtained from the body composition analyzer (InBody430, InBody Japan) by height squared.

Grip strength was measured using a Smedley-type dynamometer (SPR_651, Matsumiya Medical Instruments) once on each side, with the higher value recorded (kg).

The one-legged stance test with eyes open measured posture maintenance time using a digital stopwatch. The measurement position was standing. The test ended when the opposite foot touched the floor. Measurements were taken once on each side, with the higher value recorded (seconds).

Knee extension force was measured using a handheld dynamometer (Isometric Muscle Strength Measuring Device, Anima Co.). Measurements were taken once on each side with the knee joint flexed at 90 degrees in a seated position, with the higher value recorded (kg).

2.2.3. Balance Function

Balance function was measured using a standing power measurement device (zaRitz BM-220 motion function analyzer, manufactured by Tanita Corporation). With a sampling cycle of 12.5 milliseconds, the vertical ground reaction force (kgf) during the chair stand-up movement was recorded by a computer. Measurements were performed according to the method of Shen *et al.* [5]. Subjects sat on a 40 cm high chair with both feet placed on the device's platform. They rested both hands naturally on the front edge of the seat and maintained a posture with knees bent approximately 90˚. From this seated position, upon the examiner's signal, subjects stood up quickly with maximum effort and maintained an upright posture for 2 seconds. This study utilized three types of ground reaction force variables (**Figure 1**). The number of times a person stands up from a chair is counted only during the first test.

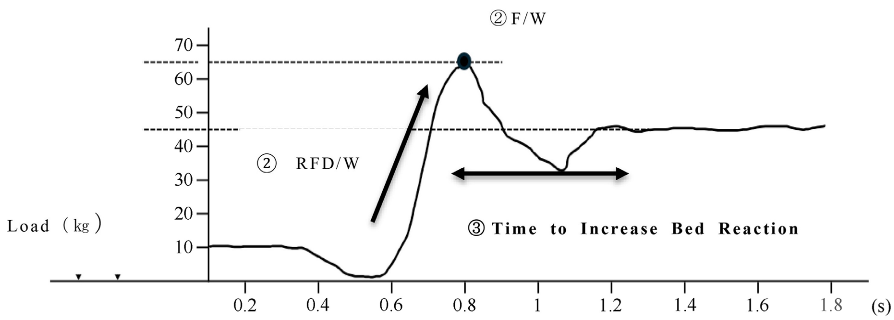

Figure 1. Displaying each parameter using ground reaction forces.

Parameter:

① Speed (Rate of force development/weight, hereafter RFD/W): Represents the "speed" when standing up. A higher value indicates a faster rise. Calculated as maximum load divided by body weight. ② Power (peak reaction force per body/weight, hereafter F/W): Represents the "strength" when standing up. A higher value indicates a more powerful rise. ③ Time to peak ground reaction force: An indicator combining the magnitude of movement during the standing-up action and the time until sway subsides.

2.2.4. Walking Function

Walking function was evaluated using a gait posture measurement system (manufactured by NEC Solution Innovators) (**Figure 2**). While this system outputs numerous metrics, the following were selected as indicators of walking function for this study: walking speed (m/min), thoracolumbar vertical movement (cm), step length (cm), foot lift angle_front (cm), and foot lift angle_back (cm). The analysis interval was defined as one walking cycle (equivalent to three steps) from the point where the Kinect v2 sensor began recognizing the subject's physical characteristics beyond the 4.5 m distance threshold, up to 1.25 m. Subjects were guided to the starting point and instructed to walk naturally toward the Kinect v2 sensor.

Each measurement related to walking was taken only during the first administration.

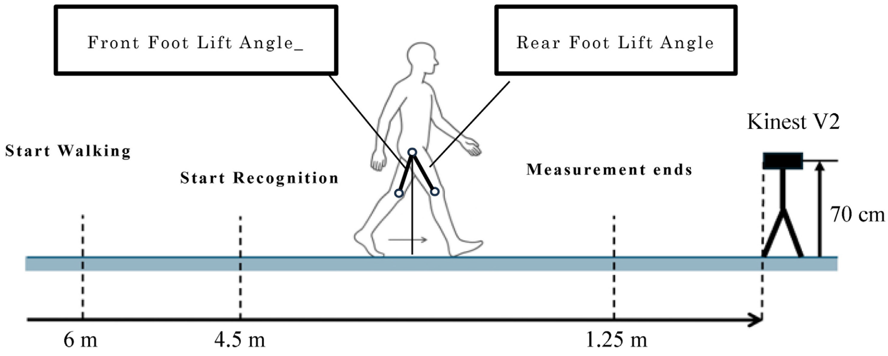

Figure 2. Protocol for using a gait analyzer.

2.2.5. Statistical Analysis

Participants were divided into two groups based on KCL scores: those with 8 points or higher and those with 7 points or lower. An independent t-test was performed to compare each functional indicator between these groups.

Pearson's correlation coefficients were calculated to assess the relationship between the total KCL score and each functional indicator. Statistical analysis was performed using the Windows version of SPSS 26.0, with a statistical significance level set at 5%.

3. Results

A comparison of physical function between frail and non-frail older adults revealed no significant differences in age, body composition, muscle strength, or One-Legged Stance with Eyes Open (**Table 1**).

Ground reaction force (speed), Walking Function (walking speed, Rea Foot Lift Angle) were significantly lower in the KCL score ≥ 8 group (frail group) compared to the KCL score ≤ 7 group (non-frail group) ($p < 0.05$, $p < 0.01$) (**Table 2**).

Table 2. Comparison between frail group, non-frail group and each functional variables (n = 41).

		Frail group (n = 17)	Non-frail group (n = 24)
General information	**Age (years)**	**74.1 ± 9.8**	**76.4 ± 6.9**
Physical function	**Height (cm)**	**155.7 ± 12.0**	**155.9 ± 9.2**
	Weight (kg)	**59.9 ± 18.7**	**55.0 ± 9.2**
	BMI (kg/m²)	**24.2 ± 4.9**	**22.5 ± 2.7**
	SMI (kg/m²)	**6.4 ± 0.9**	**6.4 ± 1.3**
	Grip strength (kg)	**23.2 ± 6.3**	**21.5 ± 5.7**
	Knee extension strength (kg)	**18.6 ± 6.2**	**15.2 ± 6.3**
	One-legged stance with eyes open (sec)	**32.3 ± 38.6**	**45.5 ± 44.3**

Continued

Ground reaction force	Speed (RFD/W)	7.2 ± 2.3	9.4 ± 1.5**
	Power (F/W)	1.2 ± 0.1	1.3 ± 0.1
	Ground reaction force duration (sec)	1.2 ± 0.1	1.2 ± 0.3
Walking function	Walking speed (m/min)	63.5 ± 17.4	73.5 ± 12.7**
	Trunk vertical oscillation (cm)	3.3 ± 1.7	4.1 ± 1.4
	Stride length (cm)	52.3 ± 13.2	60.3 ± 8.9*
	Front foot lift angle (cm)	28.1 ± 2.8	29.8 ± 3.8
	Rear foot lift angle (cm)	18.7 ± 5.4	23.7 ± 4.9*

Notes: *p < 0.05, **p < 0.01 by unpaired comparisons.

KCL total score and Ground reaction force (speed), Walking Function (walking speed, stride length Rea Foot Lift Angle) were each significantly correlated ($p < 0.05$, $p < 0.01$) (Table 3).

Table 3. Correlation coefficient KCL total score and each functional variables (n = 41).

	KCL	
General information	Age (years)	−0.10
Physical function	Height (cm)	−0.04
	Weight (kg)	0.11
	BMI (kg/m^2)	−0.19
	SMI (kg/m^2)	−0.27
	Grip strength (kg)	−0.24
	Knee extension strength (kg)	−0.34
	One-legged stance with eyes open (sec)	−0.35
Ground reaction force	Speed (RFD/W)	−0.61**
	Power (F/W)	−0.29
	Ground reaction force duration (sec)	−0.29
Walking function	Walking speed (m/min)	−0.49**
	Trunk vertical oscillation (cm)	−0.29
	Stride length (cm)	−0.36*
	Front foot lift angle (cm)	−0.22
	Rear foot lift angle (cm)	−0.3*

Notes: *p < 0.05, **p < 0.01 by correlation coefficient.

4. Discussion

This study aimed to divide community-dwelling older adults into frail and non-frail groups based on their KCL total scores and compare them regarding physical function, ground reaction forces, and gait function indicators. Results showed significant differences between the frail group and the non-frail group in Ground reaction force (Speed), Walking Function (walking speed, Rea Foot Lift Angle). This clearly demonstrated that the frail group exhibited poorer Ground reaction force and Walking Function. In this study, the total KCL score correlated with Rea Foot Lift Angle (Speed), Walking Function (walking speed, stride length, and Rea Foot Lift Angle) during the swing phase. Mizuno *et al.* [6] reported that the fall group exhibited a shorter swing phase compared to the non-fall group, attributing this to insufficient leg lift due to weakened hip muscles and reduced stride length caused by fear of falling. This study also revealed a negative correlation between Ground reaction force indicators and Walking Function or balance function in the frail group. Miyahara *et al.* [7] compared ground reaction force indicators during chair rise with other balance function assessments (CS-30, TUG, and one-leg stance with eyes open) to verify their validity. They reported that Ground reaction force indicators are valid as balance function assessment tools for the elderly. These findings suggest that Ground reaction force metrics may serve as a simple indicator reflecting balance function in frail populations.

Ground reaction force indices F/W and RFD/W used in this study are both measures for evaluating the chair rise movement, indicating Power (F/W) and its rate of force development Speed (RFD/W). In older adults, difficulty with the rise movement leads to limitations in mobility [8] [9], and results in reduced activity levels and increased fall risk [10]. The present results showed significant differences between the two groups for these indicators as well, with RFD/W exhibiting a strong correlation with the KCL total score. Furthermore, Speed (RFD/W) reflects not only muscle strength but also the speed of its exertion—that is, "power"—making it potentially capable of sensitively detecting age-related declines in motor function that cannot be fully captured by muscle mass alone. Additionally, these measurements can be performed simply and non-invasively, enhancing their potential for clinical application. They are expected to be utilized as functional assessment tools in a wide range of settings, including home care, residential facilities, and outpatient rehabilitation.

The results of this study indicate that indicators for evaluating Walking Function and Ground reaction force are useful tools for reflecting frailty. By utilizing these indicators in combination, it is considered possible to assess the current physical function status of older adults, predict functional decline, and develop appropriate rehabilitation interventions. Furthermore, it can be said that these indicators hold the potential to serve as an important foundation for designing comprehensive care prevention programs utilizing gait and balance function metrics.

Future research should expand the applicability of Walking Function and Ground reaction force indicators and verify their usefulness through studies involving a more diverse range of subjects. Subgroup analyses based on more detailed care level classifications are needed to clarify the characteristics of gait and balance function decline associated with progression in care level.

The sample size in this study was small. In the future, we will increase the sample size and conduct further research and analysis.

Statement

This study was conducted with the approval of the Nagasaki International University Research Ethics Review Committee (Approval Number: R7-F58).

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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