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ORIGINAL ARTICLE

Does time to maximum reach in floor test reflect physical function?

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Abstract

Objectives: This study aimed to determine the association between time to maximum reach in the floor test (henceforth referred to as floor reach test), standing balance, muscle strength, and joint range of motion.

Method: We enrolled 29 hospitalized patients who could stand. We measured the time required to perform a floor reach test (henceforth referred to as floor time) to the front, healthy side, and impaired side. Furthermore, we measured standing balance test, Berg balance scale as an overall balance index, muscle strength of the trunk, lower limbs and the joint range of motion. We used Spearman's rank correlation coefficient to select variables for the statistical analysis. Consequently, a canonical correlation analysis using floor time in three directions was used as the dependent variable to investigate trends among variables. Furthermore, we used multiple regression analysis to clarify factors influencing floor time in each direction.

Results: Floor time in three directions was related to standing balance, muscle strength, and joint range of motion. The Berg balance scale had a strong influence in all directions.

Conclusion: The measurement of floor time may lead to a comprehensive understanding of standing balance ability.

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Key words: maximum reach to the floor test; execution time; standing balance ability; muscle strength; joint range of motion.

Introduction

In clinical practice, we often evaluate the balance of patients in a standing position who have loss of function in one lower limb, such as in cerebral vascular disease or a lower limb fracture. One method of assessing balance in the standing position (henceforth referred to as standing balance) is the reach test. The Functional reach test (FRT), a reach test commonly used in clinical practice, indicates that a subject in the standing posture extends the upper limbs forward as horizontally as possible, and the longer the distance that can be extended, the better the standing balance[1)]. In addition to the FRT, which is a one-way reach test, there are also the multi-directional reach test (MDRT) and four-directional functional reach test (FFRT), which measure multi-directional reach in the standing position. These are related to many physical functions such as balance[2)], walking[3)], and social and physical activity skills[4)]. On the other hand, in older women, FRT correlated with age and height, but not with Timed up and go test (TUG), one leg stand, and 10m walking speed[5)], and MDRT did not correlate with TUG or other walking abilities[4)]. It is questionable whether currently available reach tests truly reflect physical function and movement ability. Therefore, as a new reach test, we developed a maximum reach test to the floor (henceforth referred to as floor reach test) based on vertical body movements, such as picking up an object from the floor in a standing position (henceforth

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referred to as floor reach movement). This test measures maximum forward reach and maximum lateral reach from the standing position to the floor. However, range of motion (ROM) of the joints is expected to be more related to the distance measured by the floor reach test than to standing balance. Therefore, we focused on the execution time of the floor reach test (henceforth referred to as floor time).

Tests that measure the time taken to perform motor tasks include the 10 m walk test, 360° rotation test, five times sit to stand test [6], and four square step test [7]. For example, the time taken to walk 10 m at maximum speed is related to muscle strength, balance ability, and ROM of the lower limbs [8, 9]. Additionally, the 360° rotation test is related to static balance ability and walking speed in older adults [10]. If the time to perform a specific movement is related to physical functions, including standing balance ability and muscle strength, floor time may also be related to physical functions. Thus, if the time required to perform a certain action is related to physical functions such as standing balance and muscle strength, we believe that floor time may also reflect physical functions such as standing balance and muscle strength to a large extent. Furthermore, if there is a strong relationship between floor time and standing balance, it may be possible to evaluate standing balance more easily and in less time than measuring floor length. Thus, if the time required to perform a certain action is related to physical functions such as standing balance and muscle strength, then floor time may have a strong relationship with physical functions such as standing balance and muscle strength. Furthermore, if there is a strong relationship between floor time and standing balance, it may be possible to assess standing balance more easily and in less time than measuring floor time. None of the previous studies on the reach test have measured the time to perform the reaching motion.

This study aimed to determine the relationship between floor time and physical functions such as standing balance, muscle strength, and ROM, and to determine whether physical functions affected by reaching direction differ.

Participants

This study included 29 patients (7 men, 22 women, average age 65.2 ±13.5 years) with asymmetrical lower limb function due to orthopedic disease or cerebral vascular disease or medical diseases who were admitted to the Hirosaki City Hospital general ward for physical therapy between September 2014 and March 2019. The inclusion criteria were those who could stand and walk independently without support or those who could walk with watching over. We excluded patients who had difficulty understanding the purpose of the research and verbal instructions, those who were expected to experience medical disadvantage due to the study's measurements, and those who could not bend down due to pain. Regarding the floor reach test movement, we did not confirm whether the test patient could complete the test.

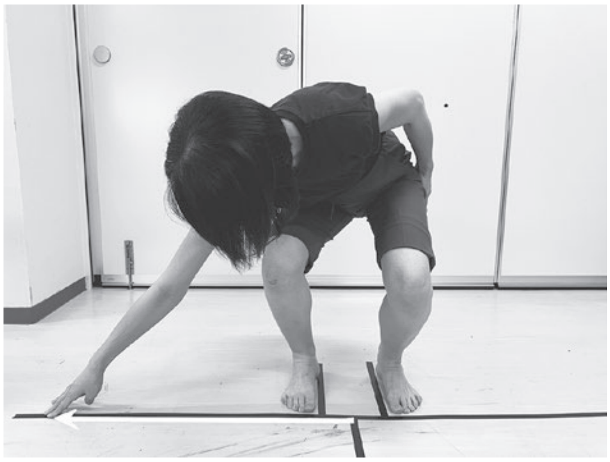
This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Review Board of Hirosaki City Hospital and Hirosaki University Graduate School of Medicine (reference number 2014-019). Participants provided written informed consent after being informed of the purpose of this study, the voluntary nature of their participation, the freedom to withdraw consent, and the protection of their privacy.

Methods

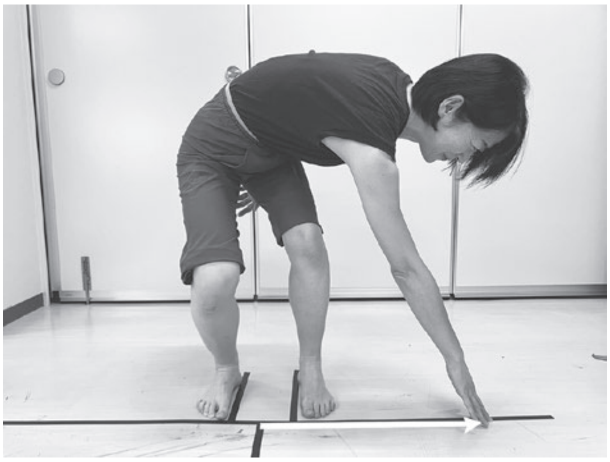
1. Measurement of floor length

We defined the "impaired side" as the side with lower limb dysfunction due to disease, or the side most recently treated if there is more than one disease, or the side with the greater

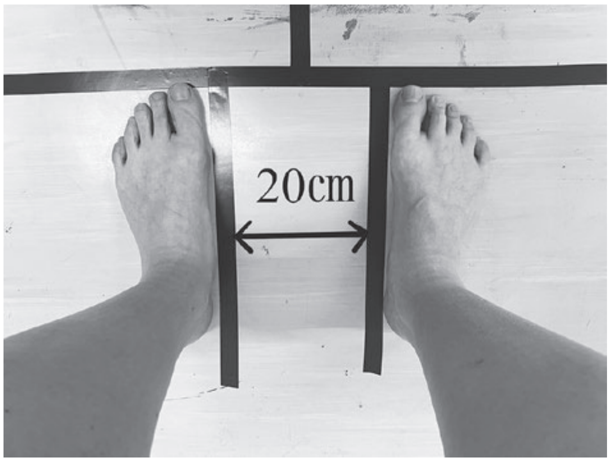
a. Front floor reach



b. Healthy side floor reach



c. Impaired side floor reach



d. Position of both feet

Figure 1 Methods for floor reach test

The figure shows the left side of the participant as the impaired side.
a-c: The solid line indicates floor length.
d: Position of both feet with legs opened 20 cm.
Floor reach test: The maximum reach in the floor test
Floor length: The length to maximum reach in floor test

degree of dysfunction if there is bilateral dysfunction.

Before measuring the floor length, we taped 2cm wide vinyl tape in a cross pattern on the floor. The participants placed the tips of their two feet on the horizontal line of the cross and stood with their legs 20 cm apart at the intersection of the cross. Next, using the upper limb on the same side as the lower limb on the healthy side without feet off the floor, the participants were asked to reach forward on the vertical line of the tape attached to the floor (henceforth referred to as front floor reach), and on the horizontal line towards the healthy side (henceforth referred to as healthy side floor reach) and towards the impaired side (henceforth referred to as impaired side floor reach). At this time, the participants were instructed to reach the floor as far as possible with their fingertips and then return to the standing position without touching the floor again. The examiner made a mark on the point touched by the fingertip and measured the distance from the intersection of the cross tapes to the mark (Figure 1). The participants were instructed to extend in each direction for the measurements, after practicing beforehand. Sufficient rest time was provided between attempts depending on the level of fatigue. Participants were asked to perform the floor reach test at a speed that they could perform stably and were instructed not to stop during each reach. The participants were asked to wear a waist belt during the measurement and the examiner held the belt gently to prevent them from falling, ensuring that it did not interfere with the participant's movements.

Participants failed the floor reach test if the participant was assisted by the examiner when the participant's body was unable to maintain standing balance, if any part of the body touched the floor other than the fingertips, when the fingertips touched the floor two or more times, or if the participant recoiled to stand by pushing the floor with the fingertips.

Before this study, we confirmed the intra-examiner reliability of the floor reach test in 14 hospitalized patients when measured three times in each of the three directions. The result shows confirmed that it showed high intra-examiner reliability in all three directions. The intraclass correlation coefficient ICC (1, 1) was ρ=0.75 to 0.95, and the number of repeated measurements required to exceed $\rho \geq 0.81$[11] was two or more in each direction.

2. Measurement of floor time

The floor reaching time was measured using a video of the subject performing the floor reaching test, recorded with a digital video camera (DVTR, Sony WX70, Japan). The DVTR attached to a tripod was placed horizontally. The DVTR was set to the maximum wide-angle setting, and the height of the lens was adjusted to the height of the participant's greater trochanter. The DVTR was installed at a distance where the whole body of the participant could be seen on the imaging screen during the floor reach test. The captured video file was imported to a computer and played back, and the floor time was measured. Floor time was defined as the time from when the examiner gave the command to start until the patient returned to the standing position after touching the floor and came to rest, and was measured in 1/100 s using a stopwatch.

3. Standing balance test

Standing balance was measured by one-leg standing time, FRT, and Timed up and go test (TUG). Taguchi et al.[12] summarized the test based on the balance ability classified by Hoshi[13]. We also measured the BBS[14] as a comprehensive assessment of standing balance ability.

1) One leg standing time

The test posture was one-legged standing with both hands on the waist and one leg raised approximately 5 cm from the floor, and the holding time was measured in 1/100s using a stopwatch. Measurements were performed thrice, with the longest measurement time being 120 s. During the measurement, the participant was asked to gaze at a viewpoint (mark) placed at eye level on a wall approximately 1.5 m away. Measurement ended when the raised foot touched the support leg or the floor, when the support leg shifted, or when both hands or one hand placed on the waist moved away from the waist.

2) Functional reach test

We aligned the tape measure with the height of the participant's acromion and fixed it on the wall in preparation for the test. Measurements were carried out in accordance with the method of Duncan et al.[1], with the participants standing naturally barefoot and facing 90° to the aforementioned wall.

As for the starting limb position, the shoulder joint of the limb to be measured was flexed at 90°, the elbow joint was extended, the forearm was pronated, and the participant's fingers were lightly grasped. Next, the participant was instructed to reach as far forward as possible along the tape measure fixed at shoulder height without changing the support base. The position of the end of the middle finger in the state of maximum reach (end limb position) was marked. The measured value was the distance from the starting limb position to the end limb position. FRT was repeated thrice after practicing twice.

3) Timed up and go test

Measurements were performed according to the methods of Podsiadlo et al.[15] and Eekhof et al.[16]. A chair with no armrest with a height of 45 cm and a maker cone were placed 3 m apart. The participants were seated in chairs with the back of their trunk in contact with the backrest. At the signal, the participants rose from the chairs, walked at maximum speed to the cone, went around the cone, returned to their chairs, and sat down again. A stopwatch was used for measurement in units of 1/100 s. Time measurements was repeated thrice and a rest period of at least 30 s was provided between each measurement. Those who used a cane when walking were allowed to use it.

4) Berg balance scale

The BBS by Berg et al.[14] includes the following 14 items: sitting to standing position, maintaining standing position, sitting position with feet on the floor, standing to sitting position, transfer, maintaining standing position with eyes open, maintaining standing position with eye closed, forward reach, picking up things from the floor, looking behind over the left and right shoulders, 360° turn, putting feet on the table, tandem standing position, and one-leg standing position. Each item was scored on a five-point scale from 0–4 points. The total score (maximum of 56 points) of all 14 items was evaluated. The higher the score, the better the overall standing balance.

4. Muscle strength test

1) Knee joint extension muscle strength

Isometric maximum muscle strength was measured according to the method of Kato[17]. The limb positions for measurement were as follows: Participants sat on the edge of a seat with their heels apart, their trunks were kept vertical, and their hands were placed on the seat on either side of their trunks. A manual muscle strength meter (Nippon Medix, Micro FET) was applied to the front of their lower legs at the level of the upper edge of the medial malleolus and was fixed to the leg of a chair with a belt. The participants were instructed to extend their knees and apply maximum force gradually and were asked to perform a maximum contraction for 3 s. After sufficient practice, measurements were taken thrice on the left and right sides. A rest period of at least 30 s was provided between measurements. The knee extension torque was determined by multiplying the length of lower leg and the measurement value with the trunks. A manual muscle strength meter.

2) Trunk extension muscle strength

Isometric maximum muscle strength was measured according to the wall compression method of Endo et al.[18]. The participants were seated with their backs facing a wall, and a manual muscle strength meter was fixed between the participant's 7th thoracic vertebrae and the wall. The participants were instructed to stretch their trunks and gradually increase their strength, as if pushing against a wall with their backs, and were asked to perform a maximum contraction for 3 s. During the measurement, care was taken to ensure their buttocks were not lifted. After sufficient practice using this method, measurements were taken thrice. A rest period of at least 30 s was provided after each measurement.

5. Range of motion test

The ROM of forward bending of the trunk, rotation of the thoracolumbar region, flexion of hips, flexion of knee joints, and dorsiflexion of ankle joints was measured using a goniometer and tape measure. All measurements were performed by two physical therapists, including the first author. The measurement method was based on the "Range of Motion Display and Measurement Method"[19] by the Japanese Orthopedic Association. One person passively moved the participants' joints through their final range of motion, and the other person measured them with a goniometer or tape measure. Forward bending of the trunk was measured using the following method to measure the mobility of the thoracolumbar spine.

First, the participants' backs were exposed, and they took off their shoes and stood upright with their feet shoulder-width apart. Next, the examiner marked the participants' left and right posterior superior iliac spines (PSIS) and the left and right PSIS midpoint. The distance from the spinous process of the 7th cervical vertebra to the marked midpoint of the PSIS was measured using a tape measure while standing upright and in maximum forward bending[20]. Both hands were hung forward during maximum forward bending, and the knee joint was extended. Measurements were repeated thrice, and the difference between standing upright and maximally bending forward was used as the measured value.

Statistical analysis

1. Analysis for variable selection

The relationship between variables was confirmed using Peason's correlation coefficient or Spearman's rank correlation coefficient to avoid multicollinearity before statistical analysis. If the absolute value was $\geq$0.7, the variable considered important for the floor reach test was retained. Regarding ROM and knee joint extension strength, we selected the measurement results of the healthy side because the function of the healthy side is more important for the floor reach test than that of the impaired side.

2. Confirming the independence of each floor time

Canonical Correlation Analysis (CCA) was performed to explore the factors that affect all floor times. CCA is a multidimensional, multiple regression-like technique that finds multiple independent variables influencing multiple dependent variables. Three canonical variates (1 to 3) are output, and if the canonical loadings for each floor time are all about the same size, they represent almost the same thing. If the magnitude of the canonical loading on each floor time differs for each canonical variable, the factors that affect each floor time will differ.

The dependent variable was the floor time in three directions. The independent variables were front floor length selected above, healthy side hip flexion ROM, healthy side knee joint flexion ROM, healthy side ankle dorsiflexion ROM, trunk forward bending ROM, healthy side knee joint extension strength, BBS, and age.

3. Factors affecting each floor time

As an additional analysis, multiple regression analysis was performed for each floor time to confirm the factors influencing each floor time. To confirm the factors that influence standing balance, muscle strength, and ROM, we performed a multiple regression analysis through the Stepwise method using each floor time as dependent variable and the healthy side hip flexion ROM, healthy side knee joint flexion ROM, healthy side ankle dorsiflexion ROM, trunk forward flexion ROM, healthy side knee joint

Table 1. Baseline data

Characteristics	Total (n=29)
Age (year)	65.2 ± 13.5*
Height (cm)	154.3 ± 10.1*
Weight (kg)	55.1 ± 15.9*
Gender (the number of people)	
Man	7
Woman	22
Diagnosis (the number of people)	
Trochanteric fracture	5
Femoral neck fracture	1
Patella fracture	1
Pelvic fracture	2
Knee osteoarthritis	1
Vertebral osteomyelitis (cervical vertebra)	1
Cervical spondylotic myelopathy	2
Cervical spine injury	1
Cerebral infarction	2
Cerebral hemorrhage	1
Diabetes	2
Femoral diaphyseal fracture	4
Proximal tibial fracture	5
Ankle fracture	3

* : mean ± SD
Among the 3 cases of ankle fractures, 2 individuals presented concomitant femur fractures, resulting in an overlapping count.

extension strength, BBS, and age as independent variables. The above analyses were performed using R4.1.2 (CRAN, freeware).

Results

Table 1 shows the demographics of the participants. The average age of the participants was 65.2 ± 13.5 years, of which 76% were women. Participants' diseases included 24 participants with musculoskeletal disorder, 3 with cerebral vascular diseases, and 2 with diabetes. Table 2 shows the results of all measurement items. The mean floor reach time was 6.0 ± 1.7 seconds for front floor reach time, 5.8 ± 1.8 seconds for healthy side floor time, and 6.1 ± 1.8 seconds for impaired side floor time. Table 3 shows the results of the correlation analysis between the selected variables The maximum and minimum correlation coefficients among the selected variables were 0.651 and 0.196, respectively.

1. Result of independence of each floor time

Table 4 shows the results of the canonical correlation analysis. The numbers in the table are canonical loadings, and the variables with larger absolute values of canonical loadings are more closely related. This time, we adopted an absolute value of the canonical load of ≥0.20. In the first canonical variate, for all floor times in three directions, the influence was highest in the following order: Front floor length, BBS, age, healthy side hip flexion ROM, healthy side ankle dorsiflexion ROM, trunk forward flexion ROM, healthy side knee joint extension strength, and healthy side knee joint flexion ROM. In the second canonical variate, the influence was highest in the following order: BBS, Front floor length, healthy side ankle dorsiflexion ROM, healthy side hip flexion ROM, trunk forward

Table 2. Measurement results

Measurement parameters		Total (n=29)
Floor time (seconds)		
Front		6.0 ± 1.7
Healthy side		5.8 ± 1.8
Impaired side		6.1 ± 1.8
Floor length (cm)		
Front		60.3 ± 11.0
Healthy side		73.0 ± 12.1
Impaired side		50.0 ± 11.6
Range of motion test (°)		
SLR	Healthy side	70.3 ± 16.5
	Impaired side	72.1 ± 17.2
Hip flexion	Healthy side	108.6 ± 10.8
	Impaired side	106.7 ± 12.5
Knee flexion	Healthy side	139.8 ± 20.3
	Impaired side	128.1 ± 21.2
Ankle dorsiflexion	Healthy side	14.8 ± 5.1
	Impaired side	12.4 ± 4.9
Rotation of the thoracolumbar region		
	Healthy side	43.6 ± 10.3
	Impaired side	44.7 ± 11.1
Forward bending of the trunk (cm)		5.6 ± 2.3
Standing balance test		
One-leg standing time (seconds)		
	Healthy side	26.5 ± 36.3
	Impaired side	9.2 ± 22.5
FRT (cm)		23.1 ± 5.9
TUG (seconds)		14.6 ± 5.9
BBS (points)		47.8 ± 7.0
Muscle strength test		
Knee joint extension muscle strength (Nm)		
	Healthy side	64.9 ± 33.6
	Impaired side	42.4 ± 21.1
Trunk extension muscle strength (kgf)		13.0 ± 4.6

Mean ± SD
Floor time: The time to maximum reach in floor test
Floor length: The length to maximum reach in floor test
SLR: Straight leg raising; FRT: Functional reach test
TUG: Timed up and go test; BBS: Berg balance scale

flexion ROM, and age. In the third canonical variable, the degree of influence on floor time on the impaired side was highest in the following order: healthy side knee extension strength, healthy side ankle joint ROM, and healthy side hip joint ROM.

2. Factors affecting each floor time

Tables 5-7 show the results of multiple regression analysis. BBS was selected as the factor that affects the floor time in all three directions. All the analyses of variance were significant, and the coefficient of determination was 0.19 for the front floor time, 0.44 for the healthy side bedtime, and 0.40 for the impaired side bedtime. Specifically, the degree of fit could not be considered high for the front floor time.

Discussion

This study demonstrated that floor time in three directions reflected physical functions such

Table 3. Association between selected measurement variables

	Front floor length	Healthy side hip flexion ROM	Healthy side knee flexion ROM	Healthy side ankle dorsiflexion ROM	Forward bending of the trunk ROM	Healthy side knee muscle strength	BBS	Age
Front floor length	1							
Healthy side hip flexion ROM	−0.651**	1						
Healthy side knee flexion ROM	−0.041**	−0.406**	1					
Healthy side ankle dorsiflexion ROM	−0.488**	−0.432**	−0.365**	1				
Forward bending of the trunk ROM	−0.041**	−0.204**	−0.331**	−0.389**	1			
Healthy side knee muscle strength	−0.411**	−0.021*	−0.091*	−0.320**	−0.296**	1		
BBS	−0.571**	−0.458**	−0.196**	−0.415**	−0.587**	−0.491*	1	
Age	−0.538**	−0.463**	−0.365**	−0.399**	−0.608**	−0.356	−0.355**	1

Values are shown as Spearman rank correlation coefficient. **$p<0.01$, *$p<0.05$.
Floor length: The length to maximum reach in floor test; ROM: Range of motion test; BBS: Berg balance scale
Health side knee muscle strength: Healthy side knee joint extension muscle strength

Table 4. Relationship between floor time and physical function

Independent variables	First canonical variable	Second canonical variable	Third canonical variable
Front floor length	−0.82	−0.43	−0.06
BBS	−0.84	−0.39	−0.01
Age	−0.64	−0.26	−0.10
Healthy side hip flexion ROM	−0.55	−0.27	−0.43
Healthy side ankle dorsiflexion ROM	−0.52	−0.35	−0.33
Forward bending of the trunk ROM	−0.40	−0.26	−0.05
Healthy side knee muscle strength	−0.47	−0.16	−0.69
Healthy side knee flexion ROM	−0.25	−0.16	−0.13
Dependent variables			
Front floor time	−0.35	−0.91	−0.19
Healthy side floor time	−0.83	−0.51	−0.20
Impaired side floor time	−0.76	−0.60	−0.25
Canonical correlation coefficients	0.78	0.59	0.47

Healthy side knee muscle strength: Healthy side knee joint extension muscle strength
Floor time: The time to maximum reach in floor test
Floor length: The length to maximum reach in floor test

as standing balance ability, muscle strength, and ROM. The most relevant of which is standing balance ability. Therefore, the ability to move weight forward, sideways, upward, and downward, as well as the ability to balance to maintain this movement, is necessary to perform the floor reach test movement quickly.

The first canonical correlation analysis showed that the better the subject's standing balance ability, the better the subject is able to maintain balance even with large and fast body movements, resulting in shorter floor time. Additionally, since

Table 5. Factors influencing front floor time

Independent variables	Partial regression coefficient	Standardized partial regression coefficient	p
Intercept	11.16		<0.01
BBS	−0.11	−0.44	<0.05
AONOVA p<0.05	R^2=0.20		

Floor time: The time to maximum reach in floor test
ANOVA: analysis of variance; BBS: Berg balance scale

Table 6. Factors influencing healthy side floor time

Independent variables	Partial regression coefficient	Standardized partial regression coefficient	p
Intercept	−11.39		<0.01
BBS	−0.17	−0.67	<0.01
ANOVA p<0.01	R^2=0.44		

Floor time: The time to maximum reach in floor test
ANOVA: analysis of variance; BBS: Berg balance scale

Table 7. Factors influencing impaired side floor time

Independent variables	Partial regression coefficient	Standardized partial regression coefficient	p
Intercept	−13.70		<0.01
BBS	−0.16	−0.63	<0.01
ANOVA p<0.01	R^2=0.40		

Floor time: The time to maximum reach in floor test
ANOVA: analysis of variance; BBS: Berg balance scale

the floor reach test involves bending the body downward, it is easy to imagine that the ROM of the hip joints and ankle joints will have a great affect. We believe that being able to move these joints greatly impaired floor time. Furthermore, we expected that longer floor lengths would result in longer floor times. However, the results showed that the longer we expected the floor time, the shorter would be the floor length. Focusing on these relationships, we believe that if we can measure floor time, we can predict physical function.

The second canonical correlation analysis showed that BBS, front floor length, healthy side ankle dorsiflexion ROM, healthy side hip flexion ROM, forward bending of the trunk ROM, and age were related to floor time in the three directions, especially front floor time, while knee joint extension strength and ROM had little effect. This result indicates that reaching while leaning forward is more efficient than reaching while crouching down.

The third canonical correlation analysis showed a correlation between impaired side floor time and healthy side knee joint extension muscle strength, healthy side hip flexion ROM, healthy side ankle dorsiflexion ROM. The result indicates that characteristics of people who rely on large ROM and strong muscular strength to reach by suppressing the movement of the hips and pelvis, where the body's center of gravity is located.

The results of multiple regression analysis showed that BBS was a common factor that impaired floor time in all directions: front, healthy side, and impaired side. This shows that floor time in any direction reflects comprehensive standing balance ability. Since BBS requires an average of 13.9 minutes to measure in older people[21], floor reach time has the advantage of measuring comprehensive standing balance ability in a much shorter time than BBS. However, the results of multiple regression analysis show that the fit of the regression model for front floor time is low. Therefore, factors that were not measured may affect front floor time. For example, hip extension muscle strength may greatly affect the forward floor reaching motion in which the body is bent forward. Additionally, the forward floor reach movement is also seen to be performed while crouching down, and these differences in movement style may affect the execution time.

This study had some limitations. The participants were hospitalized and in limited physical conditions and environments; hence, it is unclear how they differ from healthy participants of the same age. Furthermore, since this study was a cross-sectional study, it is impossible to establish the causal relationship between floor time and physical function. The association with falls and other clinically problematic events is also unknown. Future longitudinal studies should determine the association between floor time and physical function and the relationship between floor time and the ability to perform activities of daily living and fall.

Conclusion

To determine whether the execution time of the floor reach test that we developed reflects physical function and whether the physical function reflected differs depending on the direction of reaching, we investigated the relationship between floor time in three directions: standing balance ability, muscle strength, and ROM. In this study, floor time was associated with standing balance, muscle strength, and ROM, and BBS strongly influenced in all reach directions. Therefore, it became evident that floor time can be used to determine comprehensive standing balance ability.

Disclosure statement

The authors declare no conflicts of interest.

Acknowledgments

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References

1) Duncan PW, Weiner DK, J Chandler, Studenski S. Functional reach. A new clinical measure of balance. J Geronol. 1990;145:192-7.

2) Holbein-Jenny MA, Billek-Sawhney B, Beckman E, Smith T. Balance in personal care home residents: a comparison of the Berg Balance Scale, the Multi-Directional Reach Test, and the Activities-Specific Balance Confidence Scale. J Geriatr Phys Ther. 2005;28:48-53.

3) Arao M, Kinoda N, Shiomi T. Reliability and Validity of a Multi-Directional Reach Test for Patients with Stroke. Physical Therapy Japan. 2007;34:279-85.

4) Newton RA. Validity of the multi-directional reach test: a practical measure for limits of stability in older adults. J Gerontol A Biol Sci Med Sci. 2001;56:M248-52.

5) Nakamura I, Okuda M, Kage H, Kunitsugu I, Sugiyama S, Hobara, T, Asami I. The relationship between a functional reach test and other balance tests. J Phys the Sci. 2006;21:335-9.

6) Dite W, Temple VA. A clinical test of stepping and change of direction to identify multiple falling older adults. Arch Phys Med Rehabil. 2002;83:

1566-71.

7) Bohannon RW, Smith J, Hull D, Palmeri D, Barnhard R. Deficits in lower extremity muscle and gait performance among renal transplant candidates. Arch Phys Med Rehabil. 1995;76:547-51.

8) Bohannon RW. Comfortable and maximum walking speed of adults aged 20-79 years: reference values and determinants. Age Ageing. 1997;26:15-9.

9) Steffen TM, Hacker TA Molinger L. Age- and gender-related test performance in community-dwelling elderly people: Six-Minute Walk Test, Berg Balance Scale, Timed Up & Go Test, and gait speeds. Phys Ther. 2002;82:128-37.

10) Shubert TE, Schrodt LA, Mercer VS, Busby-Whitehesd J, Giuliani CA. Are scores on balance screening tests associated with mobility in older adults?. J Geriatr Phys Ther. 2006;29:35-9.

11) Tsushima E, Ishida M. Collecting and summarizing medical data. Tokyo: Tokyo Tosho Co., Ltd.; 2013. p.56-71.

12) Taguchi N, Uchida R, Kikuchi H. *Baransu no sokuteihō ebidensu ni tsunageru tame no rinshō bamen de midjika ni tsukaeru sokuteihō* [Balance measurement method: A measurement method that can be used easily in clinical situations to connect to evidence]. Journal of Physical Therapy. 2013;30:1035-45.

13) Hoshi F. Thrapeutic Exercise for Dysfunctions with Ataxia. Journal of Physical Therapy. 1998;5: 109-17.

14) Berg K, Wood-Dauphine S, Williams JI, Gayton D. Measuring balance in the elderly: preliminary development of an instrument. Physiotherapy Canada. 1989;41:304-11.

15) Podsiadlo D, Richardson S. The Timed "Up & Go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc. 1991;39:142-48.

16) Eekhof JA, De Bock GH, Schaapveld K, Springer MP. Short report: functional mobility assessment at home. Timed Up and Go Test using three different chairs. Can Fam Physician. 2001;47:1205-7.

17) Katoh H. *Kinryoku no sokuteihō* [Measuring method of muscle strength]. Journal of physical therapy. 2013;30:1351-56.

18) Endo T, Tsushima E, Omata J, Iwabuchi M, Shirato O, Ito S. The Reliability of Trunk Extensor Strength Meaurements, Utilizing Hand held Dynamometer, of Geriatric Patients Presenting Kyphos. Annual Report of The Tohoku Section of Japanese Physical Therapy Association. 2014;26: 172-6.

19) Yonemoto K, Ishigami S, Kondo T. *Kansetsu kadōiki hyōji narabini sokuteihō* [Joint range of motion indication and measurement method] The Japanese Journal of Rehabilitation Medicine. 1995; 32:207-17.

20) Hideaki Senju. Physical therapy evaluation. 3rd edition. Kiyohachi Nakajima (ed.). Fukuoka: Kyushu Jinryo Bunko; 2014. p.55-70.

21) Matsushima Y, Tsushima H. Clinical usefulness of a Berg Balance Scale as an assessment tool for balance in standing position. Physical Therapy Research. 2006;23:43-9.