2016

Differences in functional fitness among older adults with and without risk of falling

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Research Article

Differences in Functional Fitness Among Older Adults With and Without Risk of Falling

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S U M M A R Y

Purpose: This study aimed to identify the differences in functional fitness between older adults who were at risk of falling and those who were not.
Methods: A total of 104 older adults aged 65—74 years were recruited from a local community senior center. They were independent older adults without a history of falls in the preceding 12 months. Falling risk status was assessed using the Fall Risk Test. Five dimensions of functional fitness with seven testing parameters (i.e., 30-second chair stand test, 30-second arm curl test, 2-minute step test, chair sit and reach test, back scratch test, 8-foot up and go test, and body mass index) were evaluated by the Senior Fitness Test.
Results: Only 78 participants completed all the tests, of which 48 participants were identified with risk of falling, and 30 participants were free from risk of falling. Results from multivariate analysis of variance found significant differences on the combined outcome variables, especially in the 8-foot up and go test, 2-minute step test, and 30-second arm curl test. Results from discriminant analysis found a significant discriminant function among all the seven testing parameters, where the 8-foot up and go test, and the 2-minute step test contributed most.
Conclusions: Older adults who are at the early stage of risk of falling tend to have lower functional fitness capacities, especially in agility and dynamic balance, aerobic endurance as well as in a combined relationship among all the testing parameters.

Introduction

With an increase in various problems emerging as a result of an ageing society, preventing or delaying the onset of physical frailty of people who are 65 years old and over is a primary concern in gerontology studies and practice [1]. People with advancing age and decreasing physical activity in daily life were reported to have a higher probability of falling [2]. According to the World Health Organization [3], falls are the second primary cause of accidental or unintentional injury deaths worldwide, and one out of three adults older than 65 years would fall every year [4]. Fall-associated injuries (e.g., fracture) can result in older adults losing their independence, requiring hospitalization and even death [5]. In addition, postfall syndromes, such as decreased self-efficacy and increased fear of falling, limit fallers' participation in physical activities, which

in turn make the adverse effects from falling become more severe [6].

Among the various ways to prevent falls, exercise-based fall prevention programs have been shown to be effective in preventing falls and fall-related injuries [7]. However, the effectiveness of exercise program varied depending on the falling risk status in various people [8,9]. Less effect from exercise programs were reported among older adults with no risk or very high falling risk [10]. Only those who are in the transition of frailty or in the process of losing their balance (low or moderate falling risks) can gain the most from balance training [11]. In addition, these people are more vulnerable to falls since they do not sufficiently realize the risks of falling, and, as a result, do not make sufficient preparation for falls prevention. Therefore, early identification for potential fallers plus the implementation of effective balance training in this population is essential to avoid falls [12].

There are various methods of early identification of potential fall candidates. Many studies have been conducted focusing on the comparison of physical or mental differences among older adults with or without a history of falling [13,14]. A battery of risk factors

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including history of falls, age, medical conditions, sedentary behavior, psychological status, nutritional deficiencies, impaired cognition, and visual impairments have been found to be correlated with falls and have been used to help identify potential fallers among older adults [15]. However, the logic behind these studies is questionable given the aim is to identify potential fallers (without falling experience) in the early stage. It is untenable to consider the possibility of identifying potential fallers from nonfallers using risk factors resulting from studies comparing fallers and nonfallers. Whereas, comparisons between nonfallers with risk of falling and nonfallers without risk of falling would be more appropriate for gathering comprehensive knowledge related to the deficiencies of potential fall candidates in the early stage of falls so as to avoid occurrence of falls.

Functional fitness, defined as having the physical capacity to perform normal daily activities safely and independently without undue fatigue [16], is essential for people to maintain quality of life in later life [17]. Functional fitness is an essential indicator of independence and life quality for older adults in the late years; it is also one of the most commonly reported indicators in fall-related studies. Among the various physical fitness parameters, muscle strength, endurance, and response time have contributed most to balance and postural stability [18]. In addition, one cross-sectional study revealed a close relationship between functional fitness and risk of falling, and physical functionality accounted for 24.0% of risk of falling [19]. A series of studies were conducted to explore the differences in functional fitness-related parameters between fallers and nonfallers among older adults, in which certain physical parameters were found, such as muscle strength and muscle power in the lower limbs [20], muscle endurance [21], response time for postural instability, flexibility [22], and agility and balance [12,18]. Several of these fitness-related parameters were applied to the prediction of falls, such as muscle strength of the lower limbs [23], agility and balance [24]. Differences in functional fitness between fallers and nonfallers have been well-documented [20], however little is known about these differences in nonfallers with or without risk of falling. Therefore, the purpose of this study was to identify the differences of the physical parameters associated with functional fitness among older adults with and without risk of falling.

Although previous research has well demonstrated the differences between fallers and nonfallers in a variety of physical parameters, the differences in functional fitness between nonfallers with and without risk of falling has not been sufficiently specified. Thus, the important degradation of functional fitness in the very early stage of falling would not have been recognized or examined. This study examined the functional fitness levels of older nonfallers with and without risk of falling, and showed the differences in the physical parameters related to functional fitness. The current results can contribute to an understanding of functional fitness of older adults at the early stage of falls, and also contribute to the early identification of potential fall candidates.

Methods

Study design

This was a descriptive study designed to identify the differences in functional fitness between older adults who were at risk of falling and those were not.

Setting and samples

A fall refers to the sudden, unintentional change of position causing individuals to land on the ground, floor or any other object [3]. According to the general definition [9], nonfallers in the present study refer to older adults with no history of falls in the preceding 12 months. A total of 104 nonfallers, aged from 65 to 74 years, were recruited from a senior center in Hong Kong. They were apparently healthy people living independently in the community. Exclusion criteria for participants included having cognitive impairment as tested by the Chinese version of Mini-Mental State Examination (with scores < 24) [25], uncontrolled hypertension (systolic blood pressure > 160 mmHg), joint replacement, incontinence, and dizziness. Finally, 78 participants were qualified to take part in this study.

Ethical consideration

This study was conducted after receiving approval from the Committee on the Use of Human and Animal Subjects in Teaching and Research of the Hong Kong Baptist University. In a briefing workshop, all participants were informed of the purpose, protocols, risks and benefits of this study. Participants were asked to sign a informed consent form prior to the start of this study. Additionally, participants were reminded to stop at any time if there was any physical discomfort during the testing process.

Measurements

Fall risk test

All participants were first assessed on their risks of falls with the Fall Risk Test (FRT) by the Biodex Balance System SD (Biodex Medical Systems, New York, USA). The Biodex Balance System consists of a movable balance platform that can provide up to 20 degrees of surface tilt in a 360-degree range of motion. The platform is interfaced with computer software (Biodex, Version 3.1) that enables the device to serve as an objective assessment of dynamic balance [26,27], The overall stability index (OSI), as the outcome of the FRT, represents the variance of platform displacement in degrees from level in both the anterior/posterior and medial/lateral directions. A larger OSI indicates poorer balance control on a moveable supporting platform. Previous evidence has indicated that the FRT is a reliable measurement for assessing balance abilities (intraclass correlation coefficient (ICC) = .80) [28]. Finn et al [29] in their study demonstrated that the FRT was an effective test in measuring and distinguishing the balance of people aged over 50 with various balance abilities. Meanwhile, a normative range for people without balance deficits were established accordingly (i.e., 54–71 yr: OSI = 1.79–3.35; 72–89 yr: OSI = 1.90–3.50) [26,29]. A participant is at risk of falling if performing outside of the age-dependent normal stability scores. In addition, the higher the OSI, the higher falling risk the participant would be at.

In accordance with the operation manual, the resistance levels of the platform in the present study were set from Level 12 to Level 8 [27]. Each participant completed three trials, with two practice trials in advance. Each trial lasted for 20 seconds, separated with 10 seconds of rest. At the beginning of the FRT, participants stood on a static platform with feet shoulder-width apart in their preferred foot position. The center point of the platform was within the vertical line of the center of the body. No foot movements were allowed after they settled on their preferred foot position. During the whole testing process, participants were asked to keep their eyes on the screen, and to adjust their body posture to hold the center of body within the smallest zone for as long as they were able. Participants were told to put their hands beside bodies and not to touch the handrail unless they felt so unstable that they might fall.

Functional fitness test

The functional fitness of older adults was measured using the Senior Fitness Test (SFT) battery [16]. The SFT is a widely used

measurement for functional fitness of older adults in the ageing and physical activity field [30]. It was first developed and validated by Rikli and Jones [1] with the purpose of early identification of older individuals at risk of losing functionality. There are seven testing items assessing the five dimensions of functional fitness, including body mass index (BMI), 30-second chair stand for lower limbs' muscle strength, 30-second arm curl for upper limbs' muscle strength, 2-minute step test for aerobic endurance, chair sit-and-reach test for lower body flexibility, back scratch test for upper body flexibility, and 8-foot up and go test for agility and dynamic balance [1]. The rationales behind the SFT along with the validity and reliability of these testing items have been well described in the Senior Fitness Test Manual [16]. The present study has followed the testing procedures suggested by this manual.

Data collection

Data collection was conducted in a local community senior center from January to March 2014 by a group of well-trained testers with qualified senior fitness specialty certification. All the participants were informed the pretest instructions (e.g., wear clothing and shoes appropriate; avoid excess alcohol use for 24 hours before testing through telephone). The FRT was conducted before the SFT with at least a 15-minute rest interval. A total of 60 minutes was arranged to finish all the tests.

Data analysis

Descriptive statistics of all the variables were reported with means and standard deviations. An independent t test was carried out to determine if there were any significant differences in the demographic and clinical parameters between participants in the two groups (i.e., age, height, percent of body fat, and blood pressure). Seven dependent variables were used, including BMI, repeat numbers for chair stand test and arm curl test, distance for back scratch test and chair sit and reach test, time for the 8-foot up and go test, and steps for the 2-minute step test. The independent variable was group (G1, with risk of falling, and G2, without risk of falling). A one-way, between-groups, multivariate analysis of variance (MANOVA) was conducted to determine the differences between G1 and G2 on the overall performance of functional fitness (combined tests). Any significant group differences were further examined with separate univariate ANOVAs on each of the seven testing items. In addition, discriminant analysis following significant MANOVA results was performed to reveal discriminant functions between G1 and G2. For all variables analyzed, the level of significance was set at .05. All data were analyzed using SPSS version 22.0 (IBM Corp; Armonk, NY, USA).

Results

Among the 104 participants, 78 participants completed both the FRT and the SFT, among which 48 participants (69.70 ± 3.64 yr) were identified with risk of falling (G1), and 30 participants (70.10 ± 3.75 yr) were free from risk of falling (G2). Table 1 shows the demographic and clinical variables of participants in each group. No significant difference was found between groups in age, height, percent of body fat, and blood pressure (all $p > .050$).

Results from the preliminary assumption tests revealed no serious violations of normality, linearity, outliers, homogeneity of variance and covariance matrices, and multicollinearity. Using Wilks's statistic, there were significant group differences on the combined functional fitness testing items [$\Lambda = .71$, $F(7, 70) = 4.06$,

Table 1 *Demographic and Clinical Variables of Participants.*

Variables	G1[a] ($n = 48$)		G2[b] ($n = 30$)	
	M	SD	M	SD
Age (yr)	69.70	3.64	70.10	3.75
Height (cm)	155.70	8.24	154.10	5.66
Body fat (%)	27.30	7.80	26.10	6.50
Blood pressure				
SBP (mmHg)	133.70	24.10	133.70	16.00
DBP (mmHg)	70.20	15.10	70.90	9.18

Note. DBP = diastolic blood pressure; SBP = systolic blood pressure.
[a] G1 = participants with risk of falling.
[b] G2 = participants without risk of falling.

$p = .001$, partial $\eta^2 = .289$]. This indicates a significant difference in the overall functional fitness between participants with and without risk of falling. Separate univariate analysis in each of the seven testing items revealed that the significant group differences were only evident in the 8-feet up and go test [$F(1, 76) = 13.35$, $p < .0005$, partial $\eta^2 = .149$], the 2-minute step test [$F(1, 76) = 7.75$, $p = .007$, partial $\eta^2 = .093$], and the 30-second arm curl test [$F(1, 76) = 4.41$, $p = .039$, partial $\eta^2 = .055$]. This indicates that participants with risk of falling had significantly lower capacities in the 8-feet up and go test (G1 = 6.75 ± 1.12, G2 = 5.85 ± 0.95), 2-minute step test (G1 = 82.70 ± 16.50, G2 = 92.33 ± 11.93), and 30-second arm curl test (G1 = 14.80 ± 4.00, G2 = 16.80 ± 4.00), compared with the age-matched participants without risk of falling. No statistical difference was found in BMI, 30-second chair stand test, back scratch test, and chair sit and reach test. Detailed values for each of the parameters in each group are presented in Table 2.

The MANOVA was followed up with discriminant analysis, which revealed one discriminant function, canonical $R^2 = .29$. Additionally, this discriminant function can significantly differentiate groups [$\Lambda = .71$, $x^2(7) = 24.71$, $p = .001$]. The correlations between outcomes and the discriminant function showed that the 8-foot up and go test ($r = .66$) and the 2-minute step test ($r = -.50$) contributed most to this discriminant function. Moreover, this discriminant function was found to be positively correlated with 8-foot up and go test and BMI ($r = .33$), whilst negatively correlated with the 2-minute step test, 30-second arm curl test ($r = -.38$), back scratch test ($r = -.25$), 30-second chair stand test ($r = -.09$), and chair sit and reach test ($r = -.05$).

Table 2 *Comparisons of Functional Fitness Between Participants With and Without Risk of Falling.*

Testing parameters	G1[a] ($n = 48$)		G2[b] ($n = 30$)		F	p	Partial η^2
	M	SD	M	SD			
MANOVA							
Combined	—	—	—	—	4.06	.001	.289
Univariate							
BMI (kg/m^2)	23.48	3.07	22.24	2.58	3.36	.071	.042
Arm curl (reps)	14.80	4.00	16.80	4.00	4.41	.039*	.055
Chair stand (no.)	13.80	4.00	14.30	3.70	0.26	.610	.003
Back scratch (cm)	−2.59	7.89	−0.39	4.80	1.89	.174	.024
Chair sit and reach (cm)	3.20	8.80	3.70	8.60	0.06	.805	.001
8-feet up & go (s)	6.75	1.12	5.85	0.95	13.35	<.001*	.149
2-minute step (no.)	82.70	16.50	92.33	11.93	7.75	.007*	.093

Note. BMI = Body Mass Index; MANOVA = multivariate analysis of variance; reps = repetitions.
*$p < .050$.
[a] G1 = participants with risk of falling.
[b] G2 = participants without risk of falling.

Discussion

The present study compared seven physical parameters associated with functional fitness among older adults with and without risk of falling. Results reveal that older adults with risk of falling have a lower performance in overall functional fitness, as well as in agility and dynamic balance, aerobic endurance, and muscle strength of upper limbs in comparison with those without risk of falling.

Results from the discriminant analysis reveal a discriminant function that significantly differentiates the two groups. The correlation coefficients between each of the seven testing items and the discriminant function show that the 8-foot up and go test and the 2-minute step test contributed most to this discriminant function. In addition, this discriminant function has a positive correlation with agility and balance, but has a negative relation with aerobic endurance and upper limb muscle strength. Although the underlying dimensions of this discriminant function cannot be confirmed in the present study, it has been possible to identify that reduced functional fitness was not only found in agility, dynamic balance, aerobic endurance, and muscle strength of the upper limbs separately, but also in a combined relationship among all the tested items.

The 8-foot up and go test is a modified version of the timed "up and go" test [30], in which the distance has been reduced from 10 feet to 8 feet. The shorter distance is more feasible for use in a home setting [31], and has been used to discriminate between physically independent and dependent older female adults [32], as well as between fallers and nonfallers [31]. In addition, this test is an effective assessment tool for dynamic balance and agility [16,33]. A previous study evaluating the psychometric properties of the timed "up and go" test indicated that the rationales of this test correlated with dynamic balance and agility [33]. The timed "up and go" test is quite a complex test despite its apparent simplicity. It contains multiple components associated with capacities of living independence, such as standing up from a seated position, walking, turning, stopping and sitting down [34]. Successful completion of each component involves balance abilities [30]. For instance, movement from sit-to-stand, from the kinematic perspective, is defined as a transitional movement to the upright posture requiring movement of the center of mass from a stable position to a less stable position over extended lower limbs [35]. It involves at least three stages including forward movement, acceleration, and the stabilization of the center of mass. In addition, the two turns during this test have been found to be challenging for older adults' balance abilities [36]. In light of the similar properties of the 8-foot up and go test and the FRT (all for measuring dynamic balance), it is reasonable for use with the group with risk of falling who demonstrated lower performance in the 8-foot up and go test in this study. Future studies may use different screening tools for risk of falling to assess the efficacy of the 8-foot up and go test.

Besides the 8-foot up and go test, the significant difference in the 2-minute step test indicates reduced aerobic endurance of the group with risk of falling compared to the group without risk of falling. The 2-minute step test, as suggested by Rikli and Jones [16] can replace the 6-minute walk test to measure aerobic endurance. Aerobic endurance has been taken as a key indicator for differentiating fallers from nonfallers [21] and has a negative relationship with falling risks [18]. Different from the 6-minute walk test, the 2-minute step test requires participants to lift their knees to a height equaling the midlevel between the patella and iliac crest [16]. The intensity and duration of single-leg support are comparatively larger than the standard step; in other words, the performance of 2-minute step test needs additional balance abilities. It could be expected that participants who have lower balance control will encounter more difficulty than those without risk of falling in performing the 2-minute step test.

Upper body muscle strength is another physical fitness parameter found in the current study to be different between groups. Most of the previous studies have focused on the muscle properties of lower limbs rather than of upper limbs. Although some studies have demonstrated significant correlations between the 30-second arm curl test and the risk of falling [18], no study had explored the effect of upper limb muscle strength on dynamic balance or risk of falling. Therefore, further studies into this cause-effect relationship are recommended.

Among the statistically nonsignificant physical parameters, the 30-second chair stand test is a widely used field test that measures muscle strength of the lower limbs among older adults [37]. The nonsignificant differences found on the 30-second chair stand test in this study was not expected as muscle strength of lower limbs has been considered as one of the main determinants for falls in older adults [18]. This result may be explained by the growing dispute regarding the relationship between muscle strength and dynamic balance [38]. Although muscle strength and muscle power are connected to each other, their roles may be different in keeping body balance. It was demonstrated that the muscle strength of the lower limbs was more associated with static balance, while muscle power was more important for dynamic balance [39]. Future studies with a cause-effect design are crucial to developing more understanding of this effect.

This study has several limitations. Firstly, although decreased dynamic balance ability is a key risk factor, the risk of falling is a complicated concept and can be influenced by other factors. The FRT, as indicated by this study, is more related to the dynamic balance during stance. Application of the current results, therefore, could be compromised, since the selection and divide of people with and without the risk of falling were only based on the performance on the FRT. Secondly, a further differentiation of participants at low, moderate, and high risk of falling was not performed. Finally, all the participants were within the age of 65 and 74 years; the interpretation of results to people over 74 years old could be limited.

Conclusions

Older adults who are at the early stage of risk of falling have an overall reduced functional fitness capacity, especially in agility and balance, aerobic endurance, and upper limb muscle strength, as well as a combined relationship among all the testing items. Given the large group differences in the 8-foot up and go test, older adults with deteriorating agility and dynamic balance would indicate a higher probability of falling. In turn, among the various physical fitness parameters, agility and dynamic balance capacity are the parameters most likely to deteriorate earlier. In addition, the three significantly reduced physical capacities, as found in this study, emphasize the importance of implementing of effective interventions aimed to improve agility and dynamic balance, aerobic endurance and muscle strength among older adults in the early stage of risk of falling. Furthermore, the 8-foot up and go test plus the 2-minute step test and the 30-second arm curl test, could be used in combination to identify potential fall candidates.

Based on the current findings, community nurses are recommended to recognize the falling risk factors for older nonfallers at an early stage of falling. Moreover, community nurses should apply proper fitness examination and conduct customized exercise interventions to prevent degradation of functional fitness, especially the degradation of agility, dynamic balance, aerobic endurance, and muscle strength of upper limbs. Last, as many health professionals have agreed, there is no clear identification of the risk for stability

loss [40], and it is hard to find specific parameters that can be generalized to all older adults. Therefore, population-based "cut-off" values of these tests, as well as the generalization of results warrant further study.

Conflicts of interest

Acknowledgments

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