Examination of Balance Ability Evaluated by a Stipulated Tempo Step Test

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Abstract

This study is aimed at examining the correlation between age and gait time using a Single leg forward step (SFS) test. Two groups consisting of sixty healthy elderly women (age 71.4 ± 6.4 years) and twenty young women (age 20.2 ± 0.9 years) performed the step test. The test subjects put one leg forward and returned it to its original position while matching varying metronome tempos (40bpm, 60bpm, and 120bpm) for ten seconds. As an evaluation parameter, the time difference between the metronome sound and the time when the subject's foot hits the ground was used. A significant time difference was found only in the group of elderly women. The time differences were greater in the 40bpm and 120bpm step tests than in the 60bpm step test. The time variances showed significantly low correlations with gait time (r=0.33～0.42). Since the SFS test purposefully produces balance instability via shifts in one's center of gravity through forward and backward movements, the elderly with inferior balancing ability as well as a diminished ability to walk might have difficulty succeeding in this test. In conclusion, the SFS test is deemed effective in evaluating elderly subjects' balancing ability.

Keywords: Single leg forward step test, Dynamic balancing, The elderly

1. Introduction

Dynamic balancing is a person’s ability to maintain stability of posture during movement. It decreases with age and the hypofunction of the skeletal muscle and sensory organ systems. Dynamic balancing is an integral factor in the basic movements of daily life and its decrease in the elderly population is largely attributed to the falls they sustain (Isles et al., 2002). Instability of posture in a standing position and in other basic daily activities (e.g., rising from a sitting position, walking, walking up and down the stairs, turning around etc) increases the risk of falls in the elderly and largely influences their quality of life due to the accompanying restrictions on them (Legter, 2002; Cumming et al., 2000).

In order to predict an increased risk of falling, various dynamic balance tests have been devised in laboratories and clinical settings (Patla et al., 1990). Typical tests include the Berg Balance Scale (BBS) (Berg et al., 1995), the Tinetti Performance-Oriented Mobility Assessment (POMA) (Tinetti et al., 1986), and the Timed "Up & Go" Test (TUGT) (Podsiadlo and Richardson, 1991). These tests were primarily developed to evaluate the physical performance of the elderly in nursing home settings and screen the risk of falling in the active elderly. However, there are reports that reveal the failure of these tests in determining the risk of falling in the healthy elderly (O’Brien et al., 1998; Boulgarides LK et al., 2003; Shin and Demura, 2009). In addition, any test consisting of multiple movements requires more space and sufficient measuring time.

Shin and Demura (2007) proposed the dynamic balance test with increased simplicity and safety using the placed step. This test does not require any forward movement but a simultaneous shift in the physical center of gravity to both legs alternately while stepping. Shifting the center of gravity to either the right or the left leg requires supporting the body with one leg (Demura et al., 2008). In addition, although the step test conducted at normal walking speed is relatively easy due to the semi-automatic motion produced by the central pattern generator, the step test at either a very slow or quick tempo is very difficult even for the healthy elderly. Falls increase with the rise in the number of multiple risk factors. One frequently reported and consistently identified risk factor is impaired balance and mobility (Hill, 1997; Studenski et al., 1994; Anacker et al., 1992; Shumway-C et al., 1997).

As the elderly's stride length decreases with leg strength and the joints' range of motion (ROM), the ability to walk also decreases with age. In addition, the elderly are apt to trip while walking and risk falling due to a loss of balance. In the Single leg forward step test, subjects are required to move one leg forward and then return to the original position at a certain stride length while standing on the other leg. This movement requires a greater ability to balance than other step tests because subjects must return from an altered center of gravity to the original position without continuing in a constant forward direction. As stated above, the gait movement is closely related to a person's balancing ability. Hence it is important to examine the relationship of gait time and the SFS test in order to examine the SFS's usefulness. Also, a pilot study comparing the step tests with others at various stipulated tempos confirmed that the Single leg forward step test was more difficult to perform than other tests (Demura et al., 2007, 2008).

There have been no studies which probe the correlation between the SFS test and balancing abilities of different age groups. This study aims to examine the results of different age groups using the Single leg forward step test and the correlation of balancing ability in elderly and younger individuals.

2. Subjects and methods

2.1. Subjects

Sixty healthy elderly women (age 71.4 ± 6.4 year, height 148.7 ± 5.3 cm, weight 53.2 ± 7.1 kg) without leg disorders and who were able to walk independently and twenty young women (age 20.2 ± 0.9 year, height 161.3 ± 5.5 cm, weight 54.8 ± 6.4 kg) participated in the experiment. Prior to testing, the purpose and procedure of this study were explained to subjects in detail, and informed consent was obtained from them. Approval for this study was obtained from the Kanazawa University Department of Education Ethical Review Board.

The 10m gait time of the present subjects (Mean 7.07s, SD 1.77s) was almost the same range as that in the reports (2006) of Health, Labour and Welfare Ministry which were carried out in a similar manner to this study.

2.2 Single leg forward step test ; SFS test

In the SFS test, subjects were instructed to stand with their bare feet on the step sheet and to direct their eyes to a forward line, holding arms at ease. They stepped the foot of their preference over a forward 25 cm line (Yoneda et al., 2007) and then returned the leg to its original position while matching the beeps of a metronome in place (See Figure 1). The subjects repeated these movements for 10 seconds. The test was conducted twice after three practice runs based on each stipulated tempo. In addition, if their heel did not cross over the line, subjects repeated the test.

The stipulated tempos were selected at 40bpm, 60bpm and 120bpm based on the report (Shin and Demura, 2007). A 120 bpm tempo was reported to be the most efficient interval during gait (Toyama and Fujiwara, 1990). Sixty bpm and 40 bpm tempos, which corresponded to 1/2 and 1/3 intervals of 120 bpm, were selected as slower speeds (Shin and Demura, 2007). A gait analysis meter (Walkway MG-1000, Anima and Japan) was used for the step test. This device can measure real time when the subject’s right or left foot touches the step sheet and takes off from a footprint based on the foot pressure applied. The sampling frequency was 100Hz.

The synchronization of a metronome and apparatus for gait analysis was performed by starting at the same time with a simple event switch.

*** Figure 1 near here ***

2.3 10m walk time

The 10m walk time was performed along a 10m line of 10cm width tape on flat ground. Each subject was requested to walk as fast as possible on the 10m line. A tester measured the time which subjects walked from the start line to the end of a 10m line twice with a stopwatch. The shorter time was used as the representative value.

2.4 Evaluation parameters

The time was calculated from when the subject's foot leaves the step sheet and then returns again to the step measuring apparatus. The beats are synchronized with the step measuring apparatus, and the time difference was calculated as the absolute difference between the metronome beat of each tempo and the plantar grounding time.

The mean time difference was calculated by dividing the total time difference for 10 sec by the total number of steps. And in this total time difference was excluded the value of first step. It was determined that a person with a lesser time difference can better match the tempos and has a better chance at dynamically balancing themselves. This means that regaining balance is easier after shifting the center of gravity.

2.5 Statistical Analysis

A two-way ANOVA was used to test mean differences according to age and tempos for the time difference. Multiple comparisons were examined by Tukey's HSD method. Pearson’s correlation was used to examine relationships between the time differences of each tempo step test as well as gait time. The probability level of 0.05 was indicative of a statistical significance.

3. Results

3.1. The differences in age-groups and tempo

Table 1 shows test results of the differences among age-groups and tempos. A significant interaction was not found. A significant difference in the tempo factor was found in each age group. A multiple comparison showed the difference between tempos only in the elderly, and the 40bpm and 120bpm tempos were larger values than the 60bpm tempo. A significant difference between age groups was found in all tempos and the elderly group’s tempo was greater.

*** Table1. near here ***

3.2. The relationships between each tempo step test and gait time

The gait time showed significant and low correlations with the step tests of 40bpm, 60bpm and 120bpm tempos (r=0.33～0.42). When taking the influence of age into consideration, the partial correlation coefficients were insignificant and low (r=0.14～0.23). It is inferred that aging strongly influences the time difference. In addition, it was confirmed that the result of our preliminary experiment which examined the relationship between gait time and SFS test in the young showed low correlations (40bpm r=0.21, p=p.55, 60bpm r=0.11, p=0.76, 120bpm r=0.14, p=0.69).

4. Discussion

The ability to maintain static and dynamic balance is a very important element of physical fitness in the elderly because of how it relates to their potential of falling. Hence, this ability must be properly measured and evaluated. When evaluating physical fitness of the elderly according to their deteriorating physical fitness, tests with high safety rates should be conducted. In addition, it is desirable that the test content relates closely to their regular activities in daily life and is available for rehabilitation and functional recovery (Demura et al., 2008).

To propose an effective test which evaluates the dynamic balancing ability in the elderly, this study examined the difference in age-groups of those who took the step tests. In this test, subjects put one leg forward and back again under differing metronome tempos (40bpm, 60bpm and 120bpm) while keeping the other leg stationary and by examining the correlation between the step test and gait time. These step tests may be effective for evaluating the dynamic balancing ability because of the related displacement of the center of gravity while changing steps in addition to the instability that occurs when the body is supported by only one leg.

The Single leg forward step test showed significant differences in time in each age group. However, the elderly had larger time differences than the young test group. In addition, the correlation between the rate of speed as well as the age group of the elderly were r=0.30(40bpm, r=0.42(60bpm), and r=0.42(120bpm). All value coefficients were significant and moderate or low. It is inferred that performances of the SFS tests decrease with increasing age of the test group regardless of the stipulated rate of speed.

Humans have an endemic walk pattern that advances semiautomatically within a constant cycle. This gait cycle is largely divided into stance, swing, and double stance phases. Furthermore the swing phase consists of an acceleration, mid swing and deceleration rythm (Saito, 2005). In the SFS test, subjects repeated putting one leg forward and returning it to the original position without putting both legs together. In short, because there is no deceleration phase produced when putting together both legs after stepping forward, the brake force increases when the stepped-forward leg is returned to its original position (by making the directional change). Therefore, elderly individuals with a smaller range of mobility in their leg joints and an inferior balancing ability and leg strength, may have difficulty performing the Single leg forward step test.

In the pilot study, the SFS test was conducted based on the leg length considering ROM of the elderly (30%, 40% and 50% of maximal stride length). As a result, it was confirmed that there is an increased correlation between all of the tests regardless of relative length of the forward movement. In short, it is inferred that the elderly had more difficulty in moving one step forward and returning the leg to the original position after stepping out.

Shin and Demura (2007) conducted the place step tests with elderly and young adults using an adjusted stipulated rate of speed (40bpm, 60bpm and 120bpm). They reported that because the 120bpm did not show any difference between the age-level, it may not be as effective as the dynamic balance test. However, in the SFS test, the 120bpm tempo showed insignificant differences as well as the 40bpm tempo of slow tempo, though both tempo step tests showed a significant difference in age groups. Because the 40bpm step test due to a slower rate of speed than the 60bpm requires the slow extension of joints in the hip, knee and ankle, the instability aspect and the myofunctional exertion for the supporting leg are increased. On the other hand, in the 120bpm step test which is faster than the 60bpm step test, it may have been difficult for the elderly to adjust the tempo due to the high frequency of strength exertion of the supporting and stepping legs. In short, although the Single leg forward step test of 40bpm and 120bpm tempos differs in physical fitness factors related to both tempo tests, both tests have a high degree of difficulty and are considered to be effective in evaluating dynamic balance in the elderly. The 60bpm tempo step test may be able to match a speed easy for the elderly.

The time differences in the Single leg forward step test significantly related to the gait time in all tempos. However the correlation coefficient was low.

Although bipedal walking is related to various physical functions, the ability to balance contributes to it greatly. In short, because both legs alternately become an initial starting point, the center of gravity position changes to up and down or right and left, and the phenomenon which balances is mechanically lost and replaced again as the motion is regularly repeated (Benda et al., 1994).

The SFS movement has very similar aspects to walking due to requiring flexion of the hip and a forward stretching of the toes. However, the SFS movement may require greater balance ability exertion than walking because of these points: the movement cannot be conducted by its own stable timing because it should be followed the stipulated metronome’s sound. In addition, the SFS test must make the center of gravity change back and forth while keeping one leg stationary as a supporting leg.

5. Conclusion

The elderly performed less well than younger test group in the Single leg forward step test. It is hypothesized that the slow or fast tempo tests require greater dynamic balancing. In addition, the Single leg forward step tests of all tempos are related significantly to gait time. Hence, the Single leg forward step test is useful to evaluate dynamic balancing in the elderly.

Conflict of interest statement

None.

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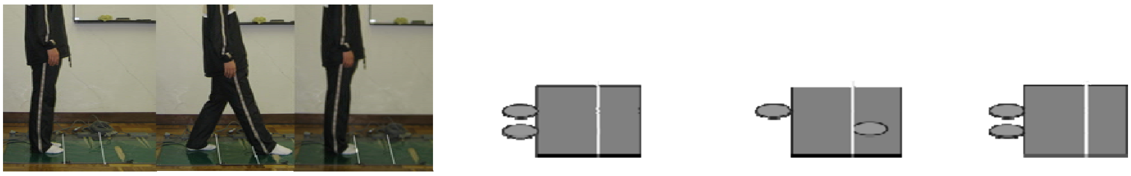
Table1. The results of the Two-way ANOVA (Age×Tempo) in the time difference (sec.)

	40bpm		60bpm		120bpm		Two-way ANOVA		Post-hoc HSD	
	Mean	SD	Mean	SD	Mean	SD		F-value	Tempo	Group
The elderly	0.160	0.06	0.115	0.07	0.148	0.11	Age	21.9 *	The youth n.s	40, 60, 120 The elderly> The youth
The youth	0.085	0.03	0.053	0.02	0.041	0.02	Tempo	5.2 *	The elderly 40,120 > 60	
							Interaction	1.7		

注. *: $p<.05$, 40: 40bpm, 60: 60bpm, 120: 120bpm



Subjects stepped forward with the preferred leg and the returned the original position to the tempo of the metronome.

The length of step is 20cm.

Figure 1.　Single leg forward step Test