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Performance Differences among Age-levels and Tempos in a step Test with Stipulated Tempo

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Abstract It is more difficult for the elderly to step while adjusting to a slow tempo than young people. However, the progression of this difficulty at different ages and how it affects the elderly over the 80 years has not yet been examined. This study aims to examine the performance differences among all age levels at different tempos of the step test with a stipulated tempo. The subjects were 158 healthy males aged between 10–80 years. Each subject performed the step test for 20 sec, stepping alternately to the beat of a metronome while adjusting to changes in metronome tempo (40, 60, and 120 bpm) twice. It was assumed that if the total number of time differences was small between the times of the metronome beats and stepping-foot contact with the ground, the person was able to step while easily adjusting to changing tempos. The results of a two-way ANOVA revealed a significant interaction between age, tempo, and performance. Results of multiple comparisons indicated that the total time difference was smaller for those aged under 60 years than for those aged 60 years and over for 40 bpm, and smaller for those aged under 20 years age than those aged 70 years and over for 60 bpm. The time difference at 40 bpm was higher than that at 120 bpm in the subjects aged under 60 years, and it was larger in the order of 40, 60, and 120 bpm for those aged between 60 and 80 years. It is difficult for the elderly to step while adjusting to a slow tempo, and differences in the tempos used largely affected performance. Even for those under 50 years of age, it was more difficult to step while adjusting to a slower than to a faster tempo.

Keywords: *aging, coordination, dynamic balance*

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1. Introduction

Dynamic balance is the ability to maintain stability of posture during physical movements such as walking and running. It decreases with the hypofunction of the skeletal muscle and sensory organ systems with age [1]. Dynamic balance in the elderly was studied because a decrease in dynamic balance is largely associated with falls in the elderly [1,2,3]. Ohnishi et al. [4] evaluated dynamic balance related to movements that change a support base by the Center of foot pressure (COP) sway during stepping (such as walking and going up and down stairs). Hill et al. [5] and Nakada et al. [6] devised a test using the spot step, which resembles walking, to evaluate dynamic balance ability in the elderly by measuring the number of steps taken within a fixed time frame. However, Shin and Demura [7] indicated that the demands of quick stepping with maximal effort made the test difficult to perform for the elderly with decreased leg strength, and could put them at risk of falling during the test.

Recently, Shin and Demura [1] evaluated dynamic balance in the elderly using the landing times of both feet during stepping with stipulated tempos (40, 60, and 120 bpm). This test was useful for evaluating dynamic balance ability without posing the risk of falls or requiring quick stepping, and was adopted in this study.

Age differences in the step test with stipulated tempo were examined and the step characteristics of the elderly are well documented [1,3,7]. Shin and Demura [1] reported that the time differences were significantly larger in the order of 40, 60, and 120 bpm in the elderly, but this tendency was not found in younger people. The elderly displayed greater time differences in tempos of 40 and 60 bpm than younger people. Concisely, the elderly displayed greater time differences at slower tempos that required longer balance times on a single leg. On the other hand, Aoki et al. [3] reported that differences in the center sway of foot pressure during stepping were insignificant among those aged under 60 years, but was larger in those in their 80s than in those who were 70 years of age and under. It may be very difficult for the super elderly to maintain a stable posture on a single leg due to markedly decreased leg strength. Hence, it is hypothesized that the super elderly will have larger time differences than those aged under 60 years in the step test at slow tempos.

2. Methods

2.1. Subjects

The subjects were 158 males aged between the ages of 10 and 80 years old who and belonged to sports clubs or exercise schools. They were all free of leg impediments, disequilibrium, and dysbasia; further, they were capable of independent living. They were all able to understand verbal instructions regarding the step test in this study. Sample sizes of each age-level group ranged from 18 to 20 people. Table 1 indicates means of age, height, and weight for each group. Before the experiment, the purpose, methods, and risks of this study were explained to each subject, and their consent was obtained. The present protocol was approved by the Ethics Committee on Human Experimentation of Faculty of Education, Kanazawa University.

Table 1. Basic statistics of subjects' age, height, and weight

Age-level	Sample size	Age (year)		Height (cm)		Weight (kg)	
		Mean	SD	Mean	SD	Mean	SD
10-19	20	16.8	1.7	171.0	5.2	62.7	5.9
20-29	20	21.5	1.6	172.9	3.1	66.2	5.4
30-39	20	34.6	3.4	172.3	5.0	72.2	10.0
40-49	20	42.9	2.7	172.6	6.3	73.1	10.7
50-59	20	55.4	2.5	169.0	6.4	64.3	10.4
60-69	20	66.3	2.3	164.2	5.9	63.2	7.6
70-79	20	73.8	2.6	166.0	8.0	66.9	9.7
80-89	18	82.5	3.4	163.3	10.2	58.4	11.0

2.2. Materials and Methods

A step test with stipulated tempos was performed as follows: subjects stood on the step sheet and stepped to match the tempo of a metronome. A 120-bpm tempo was reported to be the most efficient interval for walking [8]. Tempos of 60- and 40-bpm, which correspond to 1/2 and 1/3 intervals of 120 bpm, were selected as the slower tempos [1]. The 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 the footprint of foot pressure information. The sampling frequency was 100 Hz [1]. This device hads plate sensors that can measure foot pressure information such as touching time, when a subjects' right or left foot touches the step sheet and when it is taken off of it and records the information in a personal computer as on/off digital signals. The sampling frequency was 100 Hz [1]. The synchronization of a metronome and the gait analysis device was performed by beginning at the same time with an event switch.

2.3. Procedure and Parameters

The subjects had to remain balanced on a leg for longer periods when adjusting to a slow tempo, but stepped more quickly earlier in the test when using a tempo to which they had already adjusted. Thus, time differences occurred between the time of the tempo sound and the actual time of foot contact. It was assumed that subjects displaying smaller total of time differences had superior dynamic balance, so total time difference was selected as an evaluation parameter in this study. Because the number of steps within a stipulated time differed by tempo, time difference was calculated by dividing the total time differences by the total number of steps taken in 20 sec. The step test in each tempo was measured two trials. The mean of two trials was used as a representative value of parameter.

2.4. Statistical Analysis

A two-way ANOVA (one-factor repeated measures) was used to clarify the mean differences within different age levels and tempos. When a significant interaction or effect was found, a Tukey's Honestly Significant Difference (HSD) test was used for multiple comparisons. The linear or curve regression was calculated to identify the relationship between each parameter and age, and the significance of these coefficients was tested. The level of significance was determined to be 0.05.

3. Results

Table 2 displays the results of the two-way ANOVA (age level and tempo) used for these parameters. A significant interaction was found between age and performance. A multiple comparison test indicated that time differences in the 40 bpm step test were smaller for those aged under 60 years than for those aged 60 years and over, and smaller in the 60 bpm test for those aged under 20 years than for those aged 70 years and over. The time difference was significantly larger at 40 bpm than at 120 bpm for those aged under 60 years and in the order of 40, 60, and 120 bpm for those aged 60 years and over. According to Shin and Demura [1], a time difference in the step test with a stipulated tempo is significantly larger in the order of 40, 60, and 120 bpms among the elderly. The present results confirm this information.

Table 2. Mean differences of mean difference in each stipulated tempo by age-level and tempos

	40bpm(sec)		60bpm(sec)		120bpm(sec)		Two-way ANOVA			POST-HOC (Tukey hsd)
Age-level	Mean	SD	Mean	SD	Mean	SD	Effect	df	F-value	
10-19	0.05	0.01	0.04	0.01	0.02	0.00	Age	(7,150)	14.58*	Age
20-29	0.05	0.02	0.04	0.01	0.02	0.01	Tempo	(2,300)	252.23*	40bpm: 10,20,30,40,50s<60,70,80s
30-39	0.07	0.02	0.04	0.01	0.02	0.00	Interaction	(14,300)	4.24*	60bpm:10,20s<70,80s
40-49	0.06	0.02	0.04	0.01	0.02	0.01				Temp
50-59	0.07	0.04	0.04	0.01	0.02	0.01				10,20,30,40,50s:40bpm>120bpm
60-69	0.11	0.04	0.06	0.04	0.03	0.03				60,70,80s:40bpm>60bpm>120bpm
70-79	0.11	0.05	0.07	0.03	0.03	0.02				
80-89	0.12	0.07	0.07	0.03	0.03	0.01				

Figure 1 indicates the plots of means by age level at each tempo, as well as their regression coefficients. All tempos displayed significant linear regressions and intercepts. A multiple comparison test indicated that a significant difference

was found among the coefficients of all three tempos, but an intercept did not indicate this in all tempos.

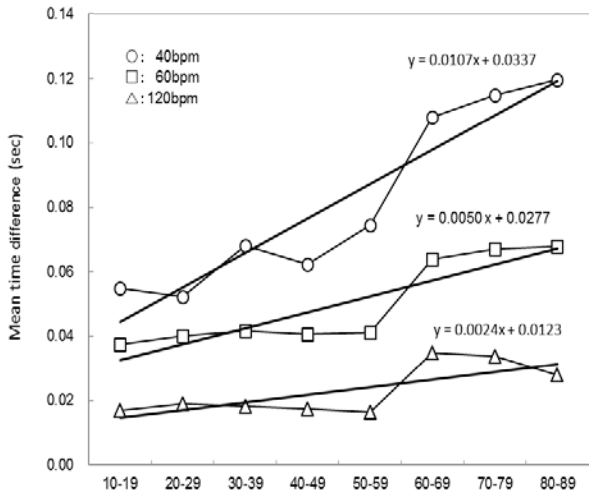

Figure 1. Plot of mean time difference and regression coefficient in each tempo

4. Discussion

4.1. Different Tempos

Significant time differences were found between those aged under 50 and over 60 years at 40 bpm, and between those aged under 20 years and those in their 70s at 60 bpm. In addition, time differences and regression coefficients among each age level at each tempo differed between 40 bpm and both 60 and 120 bpm. The step test in this study required that subjects step while matching a given tempo. Thus, they needed to stay balanced on one leg longer when using a slow tempo than when using a fast tempo, when they would step rhythmically and quickly. In any case, for subjects to perform the test, they must use dynamic balance [7]. From the present results, it can be inferred that stepping capacities are similar in 10–50 year olds, but those aged 60 years and over have greater difficulty stepping to the slow tempo, and their ability to adjust to slow tempos decreases with age. Shin and Demura [1] reported that young males displayed significantly smaller time differences at the 40- and 60-bpm tempos than older males. The present results supported Shin and Demura's report [1]. It has also been found that a decrease in muscle strength (for instance, anterior tibial muscle and peroneus muscle) related to plantar flexion and dorsiflexion exercise affects the stability of the body trunk and head [9], and ductor muscle groups contribute to the stability of flank movement during stepping [10]. Nakada et al. [6] reported that it is difficult for the elderly, who have markedly decreased nerve and leg muscle functions, to repeat step movements while keeping a stable posture when balanced on one leg. Thus, because of the large decrease of various physical functions including balance and leg strength, those aged over 60 years may have difficulties stepping at slow tempos.

4.2. Different Ages

It has been assumed that people aged over 60 years have more difficulty adjusting to different tempos. However, no significant difference among age levels from 60 years and upward was found, even at the slowest tempo. Aoki et al. [3] reported that center sway of foot pressure during stepping with stipulated tempo (while stepping with the eyes closed) is larger in 80-year-olds than in those aged under 70 years, but differences between the age groups were insignificant when they stepped with their eyes open. Although the elderly have greater dependence on visual information for posture control than their younger counterparts [11], visual information is little intercepted for eyes open. Hence, it superficially appears that there are no marked differences in performance among age groups over 60 years. However, the regression coefficient at 40 bpm was significant for those aged over 60 years, which suggests that balance ability may gradually decrease over the course of an entire lifespan. Furthermore, the degree of difficulty encountered by older people performing the step test differed considerably according to the tempos used. The step test with a slow tempo (40 bpm) may be useful for understanding age-related change. However, time differences were bigger at 40 bpm than at 120 bpm for those aged under 60 years, and in the order of 40, 60, and 120 bpm for those aged between 60 and 80 years. In short, adjusting to stepping at a slow tempo was difficult at all age levels. Bernstein [12] observed that the stepping motion resembles the everyday walking motion, and that adults have highly automated walking movements. The fastest tempo used in this study, 120 bpm, is close to that of the ordinary walking tempo and provides high stability, according to Toyama and Fujiwara [8]. Thus, in an exercise that resembles walking, such as the step test, individuals may be able to step with a stable posture while adjusting to the tempo. Hence, the error rate at the 120-bpm tempo is relatively small, even in the elderly. On the other hand, Shin and Demura [1] reported that the one-leg support time in the step test with stipulated tempo is longer at slower tempos for young people, but shorter for the elderly. Hence, it is inferred that time differences in the step test will increase at slower tempos in those aged over 60 years.

5. Conclusion

In conclusion, it is difficult for those aged over 60 years to step while adjusting to a slow tempo (40 bpm), and a difference in the tempo used in the step test largely affects their performance. Even for people aged under 50 years, it is more difficult to step accurately while adjusting to a slower tempo than when adjusting to a faster tempo.

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