Sex and Age-Level Differences in Preschool Children in Walking Times on a Course and on a Balance Beam with Obstacles

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Received: June 29, 2014 Accepted: February 15, 2015 Online Published: June 10, 2015

doi:10.5430/wje.v5n3p115 URL: http://dx.doi.org/10.5430/wje.v5n3p115

Abstract

This study aimed to examine sex and age-level differences in preschool children with respect to walking times on a course and on a balance beam with obstacles. Subjects were 324 healthy preschool children: 4-year-old boys (51) and girls (51), 5-year-old boys (50) and girls (60), and 6-year-old boys (62) and girls (50). A 5- or 10-cm-high obstacle (depth, 11.5 cm; width, 23.5 cm) was set at the halfway point of a course (length, 200 cm; width, 10 cm) that was drawn on the floor and a balance beam (length, 200 cm; width, 10 cm; height 30 cm). The children walked to the end of the course and on a balance beam, and returned as quickly as possible under three conditions: no obstacle, low obstacle, and high obstacle. In all obstacle conditions, children aged 4–4.5 years walked on the course and the balance beam significantly slower than children aged 5 and 6 years, and children aged 4.5–5 years walked more slowly than children aged 5.5–6 years and children aged 6 years. Both walking was significantly slower in children aged 5–5.5 years than children aged 6 years (course: aged 6.5–7 years) in the high-obstacle condition, and was lower in the high-obstacle condition than in the no-obstacle condition in children aged 4 years. No significant sex difference was found in children in either walking time in all obstacle conditions. The walking time on the course showed a significant curvilinear regression with age in boys except for the no- and low-obstacle conditions. All balance beam walking times showed a significant curvilinear regression with age in both sexes in all obstacle conditions.

Finally, 4-year-old children walked more slowly than 5- and 6-year-old children on a course and on a balance beam regardless of the presence of the obstacles. Both walking abilities develop markedly in 4-year-old children, and children between 5.5 and 6 years walk at a similar speed. The two forms of walking, regardless of the presence of an obstacle, showed little difference based on sex in children aged 4–6 years. A 10-cm-high obstacle affects walking in 4-year-old children, but not in children older than 5 years.

Keywords: *dynamic balance; boys; girls; obstacle; walking*

1. Introduction

Nerve function and coordination develop remarkably in children between infancy and kindergarten age. Balance ability is an important component of coordination and is largely categorized into static balance and dynamic balance. During their development, it is possible for young children to achieve various locomotive movements, and dynamic balance contributes strongly to this achievement. Hence, it is important to adequately evaluate the balance ability. Walking on a balance beam and on a line have often been used to evaluate the dynamic balance of preschool children (Demura, Nagasawa, & Kasuga,1994 ; Aoki, Demura, Kasuga, Shin, & Kawabata, 2011 ; Bürgi, Meyer, Granacher, Schindler, Marques-Vidal, Kriemler, & Puder, 2011;Kasuga, Demura, Aoki, Shin, Sugiura, & Uchida, 2012a; Kasuga, Demura, Aoki, Sato, Shin, & Kawabata, 2012b). However, it is possible that a developmental evaluation of dynamic balance by age may differ according to the type and the degree of difficulty of the tests. For example, according to Kasuga et al. (2012a), the walking time on a course with obstacles showed a nonsignificant difference between 5- and 6-year-old children, but Aoki et al. (2011) reported that the walking time on the balance beam was significantly

longer in 5-year-old children than in 6- to 6.5-year-old children. In brief, the walking time for children older than 5 years may differ for walking on a course and on a balance beam.

Many previous studies have also reported on the sex difference in the dynamic balance of preschool children (Demura, 1993; Demura et al., 1994; Demura, 1995; Aoki et al., 2011). Aoki et al. (2011) observed that no sex difference was found in the walking time on a balance beam in 5 and 6 year olds. Also, Kasuga et al. (2012a) reported that no sex difference was found in 4–6 year olds in the walking time on the course. Demura et al. (1994) examined the sex difference in 3–6 year olds in the walking time on a balance beam and line, and in the times for a series of one-legged hopping and hopping from stone to stone, and reported that a significant sex difference was found only in the time for the series one-legged hopping. According to Harcherik, CArbonari, & Cohen, (1982) considering forward, backward, toe, and heel walking times on a balance beam in 4- to 14-year-old children, a significant sex difference was found only in backward walking times. From the above, a sex difference in achievement time may be found in difficult tasks, but not in easy tasks. In addition, Kasuga et al. (2012a) reported that 4-year-old children are slower than 5- and 6-year-old children in walking on a course; however, Demura et al. (1994) reported that there was no difference between 4- and 5-year-old boys in walking on a balance beam, and that 4-year-old girls were slower than 5-year-old girls. In short, it is assumed that the shortness of walking time differs between boys and girls by age.

This study aimed to examine sex and age-level differences in preschool children with respect to walking time on a course and on a balance beam with obstacles.

2. Method

2.1 Subjects

Subjects were 324 healthy preschool children from 4 to 6 years. Table 1 shows the details of the subjects. The experimental purpose and methods were explained to all the children and their parents, and their consent was obtained. This study protocol was approved by the Ethics Committee on Human Experimentation of Faculty of Education, Kanazawa University.

Table 1. The Basic Statistics of Age, Height and Weight

		Age(years)		Height(cm)		Weight(kg)	
		Mean	SD	Mean	SD	Mean	SD
Boys	aged 4 to 4.5 years	4.2	0.1	100.9	3.5	16.5	1.2
	aged 4.5 to 5 years	4.7	0.1	102.6	4.6	16.7	1.7
	aged 5 to 5.5 years	5.2	0.1	107.2	4.0	18.0	1.5
	aged 5.5 to 6 years	5.7	0.1	107.4	4.4	17.7	1.8
	aged 6 to 6.5 years	6.2	0.1	112.8	5.0	20.1	2.3
	aged 6.5 to 7 years	6.7	0.1	115.9	3.7	20.8	1.5
Girls	aged 4 to 4.5 years	4.2	0.2	99.3	4.6	16.0	2.0
	aged 4.5 to 5 years	4.8	0.2	102.6	3.8	16.6	1.9
	aged 5 to 5.5 years	5.2	0.1	105.4	3.6	17.7	1.7
	aged 5.5 to 6 years	5.7	0.2	108.2	5.6	18.4	2.9
	aged 6 to 6.5 years	6.2	0.2	112.3	3.2	19.7	2.0
	aged 6.5 to 7 years	6.7	0.1	116.2	3.5	21.0	1.7

2.2 Methods of Tests

Walking on a course test: obstacles (depth, 11.5 cm; width, 23.5 cm) with different heights (5 cm and 10 cm) were set at the halfway point of a course (width, 10 cm; length, 200 cm). The children walked on the course under three conditions: no obstacle, low obstacle, and high obstacle.

Walking on a balance beam test: the same obstacles as in the walking on a course test were set at the halfway point of the balance beam (width, 10 cm; height, 30 cm; length, 200 cm). The children walked on the beam under three conditions: no obstacle, low obstacle, and high obstacle.

In both tests, the time was measured from when the children crossed the starting line (line tape length, 10cm; width, 10cm), reached a turn line, and then returned to the starting line. The children were instructed to walk as fast as possible, to change direction quickly after reaching the turn line, and to return to the original position. We measured

the time again if they fell or their foot touched the obstacle while walking. The children carried out three trials for each test. In addition, if a child fell, or if his or her foot touched the obstacle three times in succession, we judged it impossible to measure the time.

2.3 Statistical Analysis

The intraclass correlation coefficient (ICC) for each test was calculated to examine the reliability. A three-way ANOVA was used to examine the mean differences in sex, age, and obstacle conditions for each walking time. When a significant interaction or main effect was found, a Tukey's Honestly Significant Difference (HSD) test was used for a multiple comparison. The linear or curve regression was calculated to examine the relationship between each walking time and the child's age, and the significance of the above coefficients was tested. The level of significance was determined to be 0.05.

3. Results

The ICCs of the walking time in each condition were 0.64–0.71 in 4-year-old boys, 0.71–0.81 in 4-year-old girls, 0.64–0.83 in 5-year-old boys, 0.68–0.82 in 5-year-old girls, 0.66–0.78 in 6-year-old boys, and 0.60–0.72 in 6-year-old girls.

Table 2 shows the basic statistics of the walking time on the course according to sex, age, and obstacle, and the results of the three-way ANOVA (age × sex × obstacle). Nonsignificant interaction was found in all conditions, and a significant main effect was found in age and obstacle factors. For walking on a course, a multiple comparison test showed the following: the walking times in the no-, low-, and high-obstacle conditions were longer in 4- to 4.5-year-old children than in 5- and 6-year-old children, and longer in 4.5- to 5-year-old children than in 5.5- to 6-year-old children and 6-year-old children. In addition, the walking time in the low-obstacle condition was longer in 5- to 5.5-year-old boys than in 6.5- to 7-year-old boys, and in the high-obstacle condition it was longer in 5- to 5.5-year-old boys and girls than in 6.5- to 7-year-old boys and girls. Moreover, a significant difference among conditions was found only in 4 year olds, and the no-obstacle condition showed a shorter time than the high-obstacle condition.

Table 2. The Basic Statistics of Course Walking Times and Results of the Three-way ANOVA

		Mean	SD	Mean	SD	Mean	SD	F-value				post-hoc
Boys	aged 4 to 4.5 years	6.0	2.0	6.5	2.4	7.5	4.1	F1: 0.65		No obstacle:	Male and Female	aged 4–4.5 years > 5-year-old, 6-year-old
	aged 4.5 to 5 years	5.5	1.3	5.9	1.3	6.7	1.9	F2: 27.93 *			Male and Female	aged 4.5–5 years > aged 5.5–6 years, 6-year-old
	aged 5 to 5.5 years	4.7	1.5	5.3	2.0	5.3	0.9	F3: 59.58 *		Low obstacle:	Male and Female	aged 4–4.5 years > 5-year-old, 6-year-old
	aged 5.5 to 6 years	4.2	0.9	4.6	1.3	4.9	1.1	F4: 0.17			Male and Female	aged 4.5–5 years > aged 5.5–6 years, 6-year-old
	aged 6 to 6.5 years	4.3	0.8	4.5	1.0	4.8	1.1	F5: 0.26			Male	aged 5–5.5 years > aged 6.5–7 years
	aged 6.5 to 7 years	3.7	0.6	3.9	0.9	4.2	1.1	F6: 2.72 *		High obstacle:	Male and Female	aged 4–4.5 years > 5-year-old, 6-year-old
Girls	aged 4 to 4.5 years	5.9	2.1	6.8	2.7	7.2	2.4	F7: 0.44			Male and Female	aged 4.5–5 years > aged 5.5–6 years, 6-year-old
	aged 4.5 to 5 years	5.8	1.5	6.1	1.7	6.9	2.5				Male and Female	aged 5–5.5 years > aged 6.5–7 years
	aged 5 to 5.5 years	4.9	1.4	5.3	1.4	5.5	1.3			4-year-old :	Male and Female	No obstacle < High obstacle
	aged 5.5 to 6 years	4.3	0.8	4.8	1.0	4.9	1.0					
	aged 6 to 6.5 years	4.3	1.1	4.4	0.8	4.8	0.9					
	aged 6.5 to 7 years	4.2	1.2	4.3	1.0	4.4	1.0					

*p<0.05, unit:sec, F1:sex, F2:age, F3:obstacle, F4:sex × age, F5:sex × obstacle, F6: age × obstacle, F7:sex × age × obstacle

Figure 1 shows regression coefficients of each within-course walking time. The walking time on a course showed a linear regression in the no- and low-obstacle conditions and a curvilinear regression in the high-obstacle condition in boys, but showed a curvilinear regression in all conditions in girls.

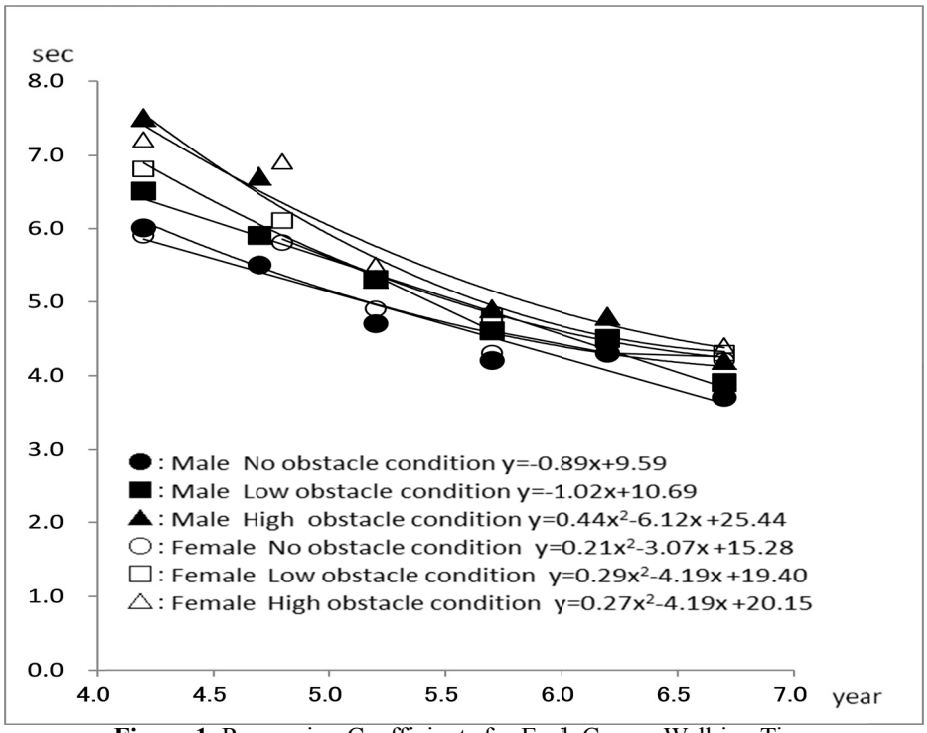

Figure 1. Regression Coefficients for Each Course Walking Time

Table 3 shows the basic statistics of walking times on a balance beam according to sex, age, and obstacle, and the results of the three-way ANOVA (age × sex × obstacle). Nonsignificant interaction was found in all conditions, and a significant main effect was found in age and obstacle factors. For balance beam walking, the results of a multiple comparison showed the following: the walking time of the no-, low-, and high-obstacle conditions was longer in 4- to 4.5-year-old children than in 5- to 6-year-old children, and longer in 4.5- to 5-year-old children than in 5.5- to 6-year-old children and 6-year-old children, and in 4- to 4.5-year-old children than in 4.5- to 5-year-old girls. The walking time in the low-obstacle condition was longer in 5-year-old children than in 6.5- to 7-year-old boys and in 6-year-old girls, and in the high-obstacle condition was longer in 5- to 5.5-year-old children than in 6-year-old children, and in 4- to 4.5-year-old children than in 4.5- to 5-year-old children and in 5.5- to 6-year-old children than in 6-year-old boys. Moreover, a significant difference among conditions was found only in 4-year-old children, and the walking time for the no-obstacle condition was shorter than that for the high-obstacle condition.

Table 3. The Basic Statistics of Balance Beam Walking Times and Results of the Three-Way ANOVA

		Mean	SD	Mean	SD	Mean	SD	F-value			post-hoc	
Boys	aged 4 to 4.5 years	17.4	7.4	16.7	7.4	21.5	8.8	F1: 2.49	No obstacle:	Male and Female	aged 4–4.5 years > 5-year-old, 6-year-old	
	aged 4.5 to 5 years	11.9	5.7	13.8	5.5	15.4	7.1	F2: 55.74 *		Female	aged 4–4.5 years > aged 4.5–5 years	
	aged 5 to 5.5 years	8.3	2.7	9.2	2.5	9.8	2.1	F3: 56.56 *		Male and Female	aged 4.5–5 years > aged 5.5–6 years, 6-year-old	
	aged 5.5 to 6 years	7.9	3.9	9.3	4.9	10.0	4.5	F4: 0.56	Low obstacle:	Male and Female	aged 4–4.5 years > 5-year-old, 6-year-old	
	aged 6 to 6.5 years	5.6	1.7	6.9	2.9	7.2	3.1	F5: 0.15		Female	aged 4–4.5 years > aged 4.5–5 years	5-year-old > 6-year-old
	aged 6.5 to 7 years	5.8	1.7	5.7	1.5	6.4	2.8	F6: 3.21 *		Male and Female	aged 4.5–5 years > aged 5.5–6 years, 6-year-old	
Girls	aged 4 to 4.5 years	15.9	7.8	17.8	7.4	19.9	8.3	F7: 1.09		Male	5-year-old > aged 6.5–7 years	
	aged 4.5 to 5 years	14.2	6.8	15.2	6.3	17.8	5.5		High obstacle:	Male and Female	aged 4–4.5 years > 5-year-old, 6-year-old	
	aged 5 to 5.5 years	9.1	4.2	10.1	4.7	11.8	7.5			Female	aged 4–4.5 years > aged 4.5–5 years	
	aged 5.5 to 6 years	8.5	4.5	9.7	3.9	10.1	3.0			Male and Female	aged 4.5–5 years > aged 5.5–6 years, 6-year-old	aged 5–5.5 years > 6-year-old
	aged 6 to 6.5 years	6.4	2.4	6.8	2.4	7.7	2.6			Male	aged 4– 4.5 years > aged 4.5– 5 years	aged 5.5–6 years > 6-year-old
	aged 6.5 to 7 years	6.5	1.9	7.2	2.2	7.9	2.9		4-year-old	Male and Female	No obstacle < High obstacle	

*p<0.05, unit:sec, F1:sex, F2:age, F3:obstacle, F4:sex × age, F5:sex × obstacle, F6: age × obstacle, F7:sex × age × obstacle

Figure 2 shows regression coefficients for each balance beam walking time. All balance beam walking times showed a significant curvilinear regression in all obstacle conditions in both sexes.

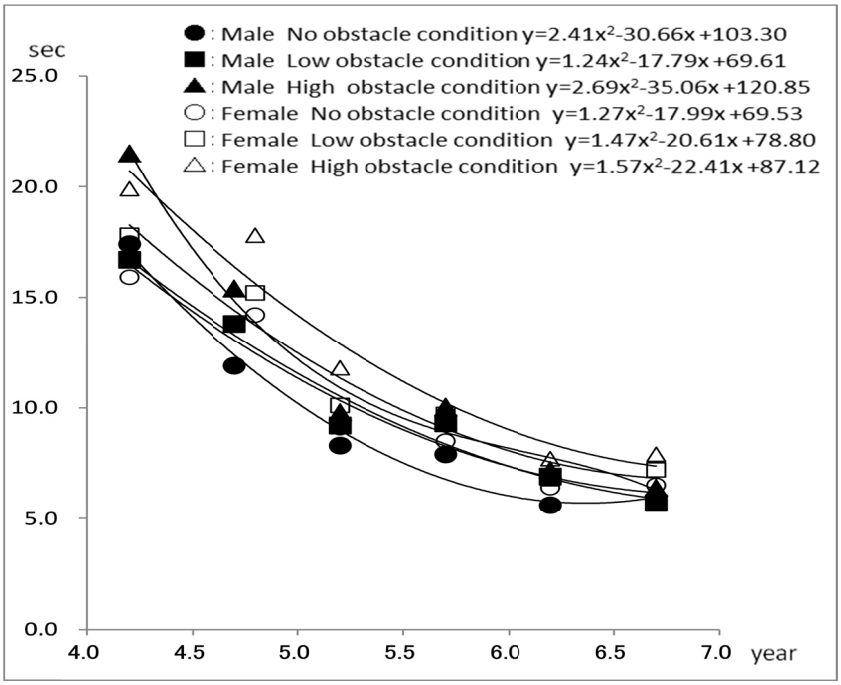

Figure 2. Regression Coefficients for Each Balance Beam Walking Time

4. Discussion

Regardless of the presence of the obstacle in the course or the balance beam, walking on a course and on a balance beam became faster with age in both sexes. Niederer, Kriemler, & Gut, J., et al. (2011) reported that a number of steps on a balance beam increases for nine months in 5-year-old children. According to Harcherik et al. (1982), a child's walking speed on a balance beam increases with age up to 11 years. Children who experience early growth and development can walk at about 1 year (Clearfield, 2011), engage in compound movement by 6 years (Takagi, 2009), and step over an obstacle smoothly at 6 years (Aoki et al., 2011). It is recognized that 6 year olds can walk faster than 5 year olds, and that 5 year olds can walk faster than 4 year olds both on a course and on a balance beam regardless of the presence of an obstacle. This is because they have an increased ability to engage in compound movements in addition to having developed dynamic balance and walking ability with age.

In the present study, the walking time between the no- and high-obstacle conditions differed only in 4-year-old boys and girls in both walking on a course and on a balance beam. When stepping over an obstacle, children must lift their foot higher than the obstacle. They are required to exert dynamic balance to maintain a stable posture with the supporting leg when lifting the other foot (Aoki et al., 2011). It is difficult for 4-year-old children to maintain a stable posture with one leg while lifting the other foot high due to the short length of their legs (Kasuga et al., 2012a). It is recognized that 4-year-old children become slower in walking when they step over an obstacle that is even 10 cm in height.

In the study, the walking time on a course and on a balance beam in all conditions showed a nonsignificant sex difference at all age levels. According to Demura et al. (1994), no sex difference was found in 3- to 6-year-old children for walking on a balance beam. Aoki et al. (2011) also reported that no sex difference was found in 5- and 6-year-old children for walking on a balance beam. When obstacles are placed on both a course and on a balance beam, the child's difficulty during walking increases. Hence, it was assumed that a sex difference would be found in the walking time. However, the above hypothesis was rejected. Walking is the most fundamental movement of daily life. From the present results, it appears that even if a task such as stepping over an obstacle is added, it is possible for 4– 6 year olds of both sexes to achieve similar rates.

For boys, the walking time in tasks with low difficulty (walking on a course with no and low obstacles) shortened proportionally with age (linear regression), but in tasks with high difficulty (both walking on a course with a high obstacle and walking on a balance beam) the length of the walking time was only minimally short after age 5

(curvilinear regression). It is recognized that walking on a balance beam or stepping over a high obstacle even when walking on a floor has a significant effect on the walking of 4-year-old children, but has little effect on children over 5 years. On the other hand, for girls, after age 5, even the walking time in tasks with low difficulty (with or without a low obstacle) was minimally short (curvilinear regression). Demura et al. (1994) reported that walking in a line is significantly faster in 6-year-old boys than in 5-year-old boys, but the same is not true for girls. From the above report, it is considered that girls, as compared with boys, have a brief walking time based on their age when they experience walking with low difficulty, such as walking on a line. In short, they can walk at almost the same speed after they are 5 years old. It is recognized that children after age 5.5 can walk on a course within a certain amount of time even if the difficulty is high, which means the course contains a high obstacle, because they have developed sufficient walking and dynamic balance abilities.

5. Conclusion

In conclusion, walking on a course and on a balance beam, regardless of the presence of obstacles, is slower in 4-year-old children than in 5- and 6-year-old children. Both walking abilities develop markedly with age after 4 years, but children after age 5.5 can walk with almost the same speed. A sex difference in 4- to 6-year-old children is not found in either form of walking described above. Even a 10-cm-high obstacle affects walking in 4-year-old children, but has little effect in children over 5 years.

Acknowledgments

This work was supported by JSPS KAKENHI Grant Number 24500680.

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