Comparison of Balance Performance between Healthy Thai Aged 7-10 and 11-15 Years Measured by CTSIB

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Abstract

The ability to maintain balance and postural stability is the integral component for functional movements in all living activities. Balance and postural control requires complex interaction of musculoskeletal and neural systems, including sensory organization processes. As the development of sensory organization on postural control in children is not clear at this time, the purposes of this study were to compare the balance performance between children aged 7-10 and 11-15 years measured by Clinical Test of Sensory Interaction on Balance (CTSIB) and to determine the correlation between balance performance and characteristic of subjects (age, weight, height and BMI).

The results revealed significant decreases in balance performance during inaccurate visual or somatosensory conditions for the 7-10 yr. group compared with the 11-15 yr. group. Ankle and hip strategies were most commonly used for balance maintenance in both groups. However, the 7-10 yr. group had more stepping strategies, which represent postural instability for controlling balance in difficult and altered sensory conditions than the 11-15 yr. group. In addition, few significant correlations were presented between balance performance and the characteristic of subjects, especially age.

Keywords: Balance, Postural control, Sensory organization, Development, CTSIB

1. Introduction

An essential component of all daily activities such as quiet stance or complex athletic tasks is the ability to maintain balance and postural stability. Balance and postural control was defined as the ability to maintain equilibrium in a gravitational field by keeping or adjusting the COM (Centre of Mass) over the BOS (Base of Support) (1,2,3)

Balance and postural control requires complex interaction of musculoskeletal and neural systems. It is processed by receiving the multiple sensory information from the peripheral systems, which are integrated and organized by the CNS (Central Nervous System). The main sensory references required for maintenance of a vertical orientation of the body, include gravity by the vestibular system, the support surface by the somatosensory system, and the relationship of body to objects in environment by the visual system (1). These sensory inputs work together to maintain body balance via the process called sensory integration and organization. The sensory organization process is one of the necessary processes performing balance and postural control. Previous balance studies inferred that the test of sensory organization process is one of the sensitivity tests for impairment detection (4,5,6). CTSIB (Clinical Test of Sensory Interaction on Balance) is the examination developed from the concept of adaptation of human movement to altered environments (7). CTSIB has been use for neurology clinical assessment with acceptable reliability and sensitivity (8, 9). The study of balance performance including the sensory organization process are well documented in adults, elderly and in patients with neurological disorders. However, there is still controversy about the maturation of the balance and postural control. Forssberg, Nashner 1982 (10) revealed that sensory organization is developed at aged 7.5 years, corresponsing with the study by Shumway-Cook, Woollacott 1985 (11), concluded that the maturation of balance performance starts at aged 7-10 years. However, Peterka, Black 1990 (12) concluded that sensory purposes of this study were to compare the balance performance between children aged 7-10 and 11-15 years measured by the Clinical Test of Sensory Interaction on Balance (CTSIB) and to determine the correlation between the balance performance and characteristics of the subjects (age, weight, height and BMI).

2. Materials and Methods

2.1 Subjects

A total of 100 healthy children aged between 7-15 years were divided into 2 groups.
Group 1: children aged 7-10 years (n = 50)
Group 2: children aged 11-15 years (n = 50)

2.2 Instrumentation

2.2.1 The accessory equipment

- Data collection form
- A scale, stationery

2.2.2 The equipment for leg dominant test

- A ball
- An eraser

2.2.3 The equipment for CTSIB measurement

- A 45x45x12 cm^2 piece of medium-density foam
- A Visual conflict dome for producing inaccurate input was constructed similarly to the study of Shumway-Cook and Horak (3). The dome was attached to the headband for positioning on the head.
- A Blindfold for eliminating visual information
- A Stopwatch (CASIO quartz: HS-20)
- An "X" formed tape (0.5x8.0 cm) was placed on the wall at visual level and 2 m distance in front of the subject.

2.3 Experimental Procedure

Volunteers who met the inclusion criteria were invited to participate in this study. They were told about the testing procedure and they signed informed consent. Subjects in both groups were interviewed about their demographic data and general health status.

Figure 2.1 The materials for CTSIB (Foam and dome test) and equipment for leg dominant test

Clinical Test of Sensory Interaction on Balance (CTSIB)

In this study, the CTSIB was performed in tandem position. Tandem stance is with the toe of the preferred foot
touching the heel of the opposite foot. The balance performance was evaluated under various sensory conditions. All subjects were tested for three trials on each of the following six conditions (3) and instructed to stand as still as possible, looking straight ahead, with hands beside the body until the trial was over.

Condition 1: standing quietly on the floor, eyes open
Condition 2: standing quietly on the floor, eyes closed
Condition 3: standing quietly on the floor, conflict dome
Condition 4: standing quietly on the foam, eyes open
Condition 5: standing quietly on the foam, eyes closed
Condition 6: standing quietly on the foam, conflict dome

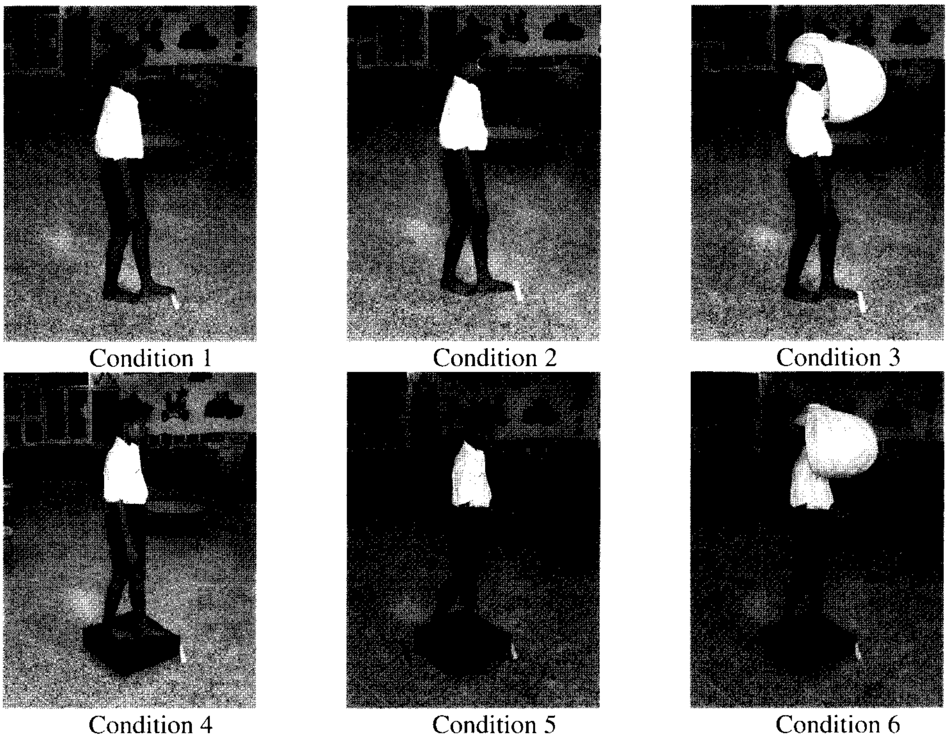

Figure 2.2 Six conditions test in CTSIB (Foam and dome test)

The CTSIB procedure was the following:

1. Prior to starting the test, the subject was explained that the duration of each trial was 30 seconds and to keep on standing with each foot in position until the examiner said "stop"
2. The movement strategies were observed and scored during standing.
3. For the time record, if the subject could stand over 30 seconds on the first trial in each condition, the total time score of 90 (30x30) was assigned and the next condition was tested. In the case that the subject could stand for longer than 30 seconds on the second trial, the level of 60 (30x2) plus the number of seconds that he stood in the first trial was recorded as the total time. A trial was terminated when the subject changed foot positions or opened eyes for closed eyes conditions.
4. Examiner recorded the CTSIB variables, which consisted of:

- Duration
  First time: standing time at 1st test trial
  Total time: total time from all 3 trials
- Movement strategy for controlling balance during each condition

1. Ankle strategy: distal (ankle) to proximal (hip or trunk) response.
2. Hip strategy: movement response from proximal to distal parts.
3. Suspensory strategy: knee flexion response.
4. Stepping strategy: stepping by foot or hand.

2.5 Data Analysis

The SPSS/PC (11.0) program was used to analyze data. The normal distributions of data were tested by Kolmogoro Siminov Goodness of Fit test. If the data showed a normal distribution, an Independent Samples T-test was used to compare data between the two aged groups. If the data was not normally distributed, the Mann Whitney U-test was used to determine the comparison between the two groups. The correlation between duration variables and characteristics of subjects was computed by Pearson's r when the data were normally distributed. If the distribution was not normally distributed or ordinal data were determined, the Spearman's rho was used instead.

3. Results

3.1 Characteristics of subjects

Two groups of subjects, consisting of 50 healthy children aged 7-10 years (group I) and 11-15 years (group II) participated in the study. Age, height, weight, and body mass index (BMI) of both groups are shown in Table 3.1

3.2 Comparison of balance variables obtained from CTSIB between 2 groups (7-10 yrs and 11-15 yrs)

3.2.1 Duration variables (1^{st} time and total time)

Descriptive data for the 1^{st} time and total time for CTSIB are presented in Table 3.2.1. For male results, there were decreases for the 1^{st} time in the 7-10 years (group I) for condition 2 (p= 0.001), condition 3 (p= 0.006) and condition 6 (p= 0.011) compared with the 11-15 years (group II). In addition, significant decreases of total time in group I compared with group II were present in conditions 2 (p= 0.001), 3 (p= 0.004), 5 (p= 0.034) and 6 (p= 0.003).

For female results, both 1^{st} time and total time variables were significant. There were decreases for group I compared with group II in conditions 2, 3, 5, and 6.

Table 3.1 Characteristics of subjects

Group	Sex	Weight (kg)	Height (cm)	BMI (kg/m^2)
Gr. I (7-10 yrs)	Male (24)	30.10±8.46	131.33±9.14	17.25±3.30
	Female (26)	30.37±9.78	133.19±11.18	16.71±3.08
Gr. II (11-15 yrs)	Male (25)	49.6±15.54	156.84±10.04	19.90±4.93
	Female (25)	47.17±9.38	153.86±7.69	19.90±3.67

Table 3.2.1 Comparison of the first time (mean ± SD) and total time (mean ± SD) of CTSIB between 2 groups (7-10 yrs and 11-15 yrs)

Variables	Male		p-value	Female		p-value
	7 – 10 yrs	11 – 15 yrs		7 – 10 yrs	11 – 15 yrs	
Condition 1						
First time	30±0	30±0	1.000	30±0	30±0	1.000
Total time	90±0	90±0	1.000	90±0	90±0	1.000
Condition 2						
First time	25.22±6.45	29.60±1.99	0.001**	24.63±7.69	29.25±3.73	0.004**
Total time	83.38±10.33	88.41±7.97	0.001**	83.48±9.20	89.25±3.73	0.004**
Condition 3						
First time	23.14±9.01	29.01±3.72	0.006**	23.94±9.21	29.34±3.32	0.003**
Total time	78.76±16.68	89.01±3.72	0.004**	78.33±19.19	89.34±3.32	0.003**
Condition 4						
First time	29.75±1.25	29.96±0.22	0.953	30±0	29.75±1.23	0.308
Total time	89.75±1.25	89.96±0.22	0.953	90±0	89.75±1.23	0.308
Condition 5						
First time	20.27±9.35	23.89±8.02	0.133	21.46±10.41	28.34±5.03	0.002**
Total time	68.51±22.29	81.75±12.67	0.034*	68.78±23.72	88.34±5.03	0.001**
Condition 6						
First time	21.04±9.47	27.18±7.04	0.011*	20.70±10.43	26.97±8.43	0.013*
Total time	67.93±25.75	86.12±10.69	0.003**	71.55±23.79	87.37±7.72	0.003**

* significant at $p \leq 0.05$, ** significant at $p \leq 0.01$

3.2.2 Movement strategies (ankle / hip / suspensory / stepping)

The frequency of movement strategy occurrences are illustrated in Table 3.2.2. From both groups, the ankle strategy is the most commonly used for controlling balance in all 6 conditions. For conditions 2, 3, 4, 5, and 6, there were combined movement strategies, especially ankle and hip strategies for balance control in both groups. However there were differences between the 2 groups for the occurrence of the stepping strategy. Group I (7-10 years) used the stepping strategy for balance control more than group II (11-15 years) in conditions 2, 3, 5, and 6.

Table 3.2.2 Frequency of occurrences at each movement strategy of CTSIB for 2 groups (7-10 yrs and 11-15 yrs)

Movement strategy	Male		Female	
	7 – 10 yrs (24)	11 – 15 yrs (25)	7 – 10 yrs (26)	11 – 15 yrs (25)
Condition 1				
Ankle	24	25	26	25
Hip	8	6	11	9
Suspensory	1	-	-	1
Stepping	-	-	-	-
Condition 2				
Ankle	24	25	26	25
Hip	20	15	24	18
Suspensory	4	1	6	3
Stepping	11	1	10	1
Condition 3				
Ankle	24	25	26	25
Hip	20	20	25	20
Suspensory	9	2	7	7
Stepping	10	2	10	1
Condition 4				
Ankle	24	25	26	25
Hip	21	17	24	18
Suspensory	7	4	6	9
Stepping	-	1	-	1
Condition 5				
Ankle	24	25	26	25
Hip	20	24	25	23
Suspensory	14	11	14	11
Stepping	14	8	13	3
Condition 6				
Ankle	24	25	26	25
Hip	22	23	26	24
Suspensory	15	14	19	17
Stepping	13	5	10	2

Table 3.3 Correlation between duration variables obtained from CTSIB and the characteristics of subjects (n = 100)

Variables	Age	Sex	Weight	Height	BMI
Condition 1					
First time	-	-	-	-	-
Total time	-	-	-	-	-
Condition 2					
First time	0.391^{**}	0.007	0.285^{**}	0.291^{**}	0.223^{*}
Total time	0.393^{**}	0.022	0.271^{**}	0.288^{**}	0.206^{*}
Condition 3					
First time	0.437^{**}	0.030	0.259^{**}	0.298^{**}	0.123
Total time	0.446^{**}	0.027	0.273^{**}	0.310^{**}	0.140
Condition 4					
First time	-0.012	0.060	0.075	-0.002	0.122
Total time	-0.012	0.060	0.075	-0.002	0.122
Condition 5					
First time	0.298^{**}	0.157	0.159	0.216^{*}	0.037
Total time	0.380^{**}	0.128	0.222^{*}	0.283^{**}	0.086
Condition 6					
First time	0.345^{**}	0.004	0.392^{**}	0.303^{**}	0.384^{**}
Total time	0.406^{**}	0.042	0.441^{**}	0.358^{**}	0.423^{**}

\- can not calculate

* $p \leq 0.05$

** $p \leq 0.01$

3.3 Correlation between duration variables obtained from CTSIB and characteristics of subjects

The correlation between balance durations from CTSIB and characteristics of subjects are given in Table 3.3. Due to a lack of data variation, the correlation coefficient values between duration variables tested in condition 1 and the characteristics of subjects could not be calculated. The analysis revealed moderately significant correlation ($p \leq 0.05$) between subject characteristics and time variables in conditions 2, 3, 5, and 6, especially the with age-variable.

4. Discussion and Conclusion

The study revealed significant decreases in 1st time and total time during the inaccurate visual or somatosensory conditions (condition 2, 3, 5 and 6) for the 7-10 yr. group compared with the 11-15 yr. group. In addition, the 7-10 yr. group had more stepping strategies, which represent postural instability for controlling balance in the difficult and altered sensory conditions (conditions 5 and 6) than the 11-15 yr. group. According to the balance sensory systems (1), the conditions 2, 3, 5 and 6 are the conditions that visual or somatosensory information are eliminated or inaccurate and the vestibular system is important for controlling balance. Similar to Peterka and Black 1990, (12), subjects younger than 15 years showed poor balance control in altered somatosensory conditions (conditions 4, 5, and 6). Additionally, Cherng et al, 2001 (13) revealed that the sensory organization process and vestibular efficiency of balance control in children are poorer than in young adults. In addition, the ultimate development of the vestibular system for postural control is present at around 15-16 years old (14) However, the present study is different than Lebiedowska and Syczewska, 2000 (15). They showed that the balance performance was not different in ages 7-18 years. For the correlation with subject characteristics, there were few significant correlations between balance performance and the characteristic of subjects, especially age in this study.

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