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Evaluation of the Pediatric Clinical Test of Sensory Interaction for Balance in Children Aged 6-9 Years

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ABSTRACT

Objective: The Pediatric Clinical Test of Sensory Interaction for Balance (P-CTSIB) provides information on the utilization and integration of sensory inputs as well as postural sway during postural control tasks under various static conditions in children. The evaluation of the P-CTSIB performance in healthy children aged 6-9 years aims to obtain normative data.

Methods: A total of 81 children aged 6-9 years were included in the study. The participants were asked to maintain an upright posture in two different stance positions (feet together and heel-toe position) under six test conditions: eyes open or closed on a firm surface with a dome, and eyes open or closed on a foam pad with a dome. The amount of postural sway (anterior-posterior/medial-lateral), test duration, and test scores for each condition were recorded, and the data were compared across groups.

Results: In the study, descriptive statistics for the sway, test duration, and test scores obtained under all conditions in the feet together and heel-toe positions were determined. No significant difference was found between genders in terms of sway, duration, and scores under all test conditions. In the feet together position, a significant difference was found between groups in terms of sway in three test conditions and test scores in four test conditions. In the heel-toe position, a significant difference was found between groups in terms of sway measured in 4 test conditions and test scores in 2 test conditions ($p<0.05$).

Conclusion: The P-CTSIB is a cost-free test that can assess postural sway under different static test conditions without the need for any equipment. Measuring postural sway provides valuable information in the assessment of balance. It is expected that our findings will serve as a foundation for ensuring the availability of the test in our country. Age-specific normative data obtained from Turkish children will provide reference data for future studies involving children with balance-affecting pathologies.

Keywords: Child, postural control, balance, sway, normative

INTRODUCTION

Balance: it is a complex motor control task that requires the integration of sensory information, neural processing, and biomechanical factors (1). Effective balance control requires the combination of vestibular, proprioceptive, and visual system performance. Neurological factors responsible for balance provide sensory processing and motor output mechanisms, which form the neurophysiological basis, while musculoskeletal factors provide the mechanical structure for the response (2). Sensory inputs from the vestibular, visual, and somatosensory/proprioceptive systems are directed to the vestibular nuclei and cerebellum for processing and regulation. In response to these inputs, the vestibular nuclear complex forms connections with the muscles that control the eyes, neck, and spinal cord (3). These motor outputs result in three vestibular reflexes that maintain balance: the vestibulo-ocular (4), vestibulospinal (5), and vestibulocollic reflexes (citation needed). The examination of these reflexes is important in detecting vestibular dysfunction (6). The vestibular system provides postural control and visual stabilization through the vestibulo-ocular reflex and vestibulo-spinal reflex (7). The maintenance of postural control requires an active sensorimotor control system. Postural control involves sensory feedback, and the integration of visual and proprioceptive inputs is required for the center of pressure to move in phase with the center of mass. Postural control is a key component of physical movement, particularly in standing and walking (8,9).

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The development of vestibular function in children is associated with two important factors: postural control related to motor skills and the ability to stabilize vision during head movements (10). These aspects of vestibular function facilitate children's ability to adapt to environmental stimuli and movements. This highlights the importance of motor and sensorimotor control in the developmental process. It is known that between the ages of 6 and 10, children's ability to integrate visual and vestibular stimuli becomes more pronounced (11). The proprioceptive, visual, and vestibular systems develop more slowly than the automated motor processes that mature during early childhood (12). Balance assessment in children is considered an important component of their developmental evaluation (13). In adults, sensory systems involved in postural control are mature. Although these systems are anatomically developed, they are not functionally mature in children. The functional development of the afferent sensory pathways, which include the vestibular, proprioceptive, and visual systems, occurs gradually and hierarchically, beginning after the early maturation of low-level automatic motor processes (14).

It is recommended that a comprehensive clinical, otological, neurological, and vestibular examination be performed on children with complaints of dizziness and imbalance before resorting to expensive and unnecessary complementary test methods (15). In this context, there is a need for inexpensive, effective, and reliable methods for assessing balance in children.

Considering these challenges, the more accessible Clinical Test of Sensory Interaction for Balance (CTSIB) was developed (16). The CTSIB is a method suitable for static balance assessment that does not require a computerized force platform and is easy to use in clinical settings. The pediatric version of this test is called the Pediatric-CTSIB (P-CTSIB) (17). The P-CTSIB reflects the child's ability to integrate and use different sensory information to respond in various positions during static balance.

In this study, the evaluation of P-CTSIB performance in healthy children aged 6-9 years is planned, thus providing normative data for an inexpensive, easy-to-apply, and reliable test method for this population. The aim is for these data to be used as a reference for children at risk of balance disorders.

METHODS

Participants

A total of 81 healthy children were included in the study. The children included in the study were divided into four age groups. The first group included 19 children (9 female, 10 male) aged 6 years to 6 years 11 months. The second group included 18 children (11 female, 7 male) aged 7 years to 7 years 11 months. The third group included 23 children aged 8 years to 8 years 11 months. The fourth group included 21 children (14 female, 9 male) aged 9 years to 9 years 11 months.

Children were included in the study based on the following criteria:

•No reported neurological disorders (according to parental information),

•No uncorrected visual impairments,

•No history of developmental motor disorders or musculoskeletal system conditions,

•No engagement in regular physical exercise programs,

•No use of sedative or performance-enhancing medications that could affect the nervous or balance systems.

Children who did not meet one or more of the above criteria were excluded from the study.

Ethics Committee Information

This study was approved by the Ethics Committee of the Ankara Yıldırım Beyazıt University Health Sciences Ethics Committee (decision no: 835, date: 06.01.2022). The children included in the study were those attending primary school. With permission obtained from the Ministry of National Education, children from primary schools were included in the study. The purpose and procedure of the study were explained to the parents, and they were asked to sign a written informed consent form.

Pediatric Clinical Test of Sensory Interaction for Balance

The P-CTSIB evaluates the child's ability to use visual, somatosensory, and vestibular inputs to maintain standing balance (17). All children included in the study were asked to maintain an upright standing position in six test conditions, including positions where one or more of the visual or proprioceptive inputs were impaired. At the beginning, the children were informed about the test and the importance of cooperation. The test procedure was reviewed before each stage. The duration of static balance, the amount of anterior-posterior body sway, and the medio-lateral body sway were evaluated under six different sensory conditions and two different standing positions (6 evaluations in the feet together position and 6 in the heel-to position, totaling 12 evaluations). The combination of three conditions for the visual variable (eyes open, eyes closed, and with dome) and two conditions for the support surface variable (on a firm surface and on a foam pad) formed the six sensory condition levels of the test. These six conditions were as follows:

1. Eyes open, on a firm surface;
2. Eyes closed, on a firm surface;
3. Eyes open with dome, on a firm surface;
4. Eyes open, on a foam pad;
5. Eyes closed, on a foam pad;
6. Eyes open with dome, on a foam pad (Table 1).

The relationship between the P-CTSIB conditions and sensory systems is shown in Table 2.

Table 1. Images of the example participant in different postural positions

Conditions	Feet together position	Heel toe position
Condition 1 Firm surface Eyes open		
Condition 2 Firm surface Eyes closed		
Condition 3 Firm surface Visual conflict dome		
Condition 4 Foam pad Eyes open		
Condition 5 Foam pad Eyes closed		

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Table 1. continued

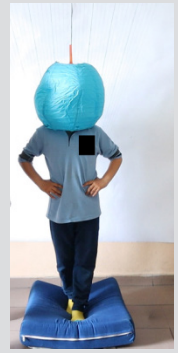
Conditions	Feet together position	Heel toe position
Condition 6 Foam pad Visual conflict dome		

Table 2. Conditions of the Pediatric Clinical Test of Sensory Interaction for Balance (P-CTSIB) and the relationship between sensory systems

Conditions	Available sensory input	Absent/inaccurate sensory input
Condition 1 **Firm surface** **Eyes open**	Vestibular Proprioceptive Vision	-
Condition 2 **Firm surface** **Eyes closed**	Vestibular Proprioceptive	Absent vision input
Condition 3 **Firm surface** **Visual conflict dome**	Vestibular Proprioceptive	Inaccurate vison input
Condition 4 **Foam pad** **Eyes open**	Vestibular Vision	Inaccurate proprioceptive input
Condition 5 **Foam pad** **Eyes closed**	Vestibular	Absent vision input inaccurate proprioceptive input
Condition 6 **Foam pad** **Visual conflict dome**	Vestibular	Inaccurate proprioceptive input inaccurate vison input

Sway Analysis

The participants were asked to maintain an upright standing position in each of the 6 test conditions: (eyes open/closed on a firm surface with a dome, eyes open/closed on a foam pad with a dome, for two different standing positions (feet together and heel-to-toe). The best trial score for each condition was recorded (either the trial with the longest duration or the trial with the least sway). The children were asked to maintain balance for 30 seconds or until a new postural adjustment occurred in all test positions. If the child made a postural adjustment (by moving their hands, feet, or eyes), the timing was stopped.

The child's performance in all test conditions was recorded with a camera. The children were placed in front of a floor marked with 2-degree increments to measure the amount of sway. A background with millimeter markings was placed behind the children in a 1x1 meter area, to assess the degree of sway. A paper screen with lines spread across a total of 32 degrees in 2-degree increments was used to measure the degree of sway. After the tests were completed, the camera recordings were reviewed by two audiologists, and the amount of postural sway and test duration were recorded for each condition. The materials used in the sway analyses are shown in Figure 1.

Test Duration

Before each task, the participants were shown the postures, and measurements began after they assumed the correct posture. The standing duration (static balance) and the degrees of medial-lateral and anterior-posterior sway were recorded. The standing duration was defined as the time from the start of the test until a new postural adjustment occurred, and this time was measured in seconds using a stopwatch. To prevent fatigue in children, the maximum standing duration was set to 30 seconds. Movement of one or both feet from the starting position, opening of the eyes in the closed-eye condition, or the need for assistance from the researcher to prevent a fall were defined as "postural adjustment", and participants were recorded as having "fallen" (18). The test scores of the participants were determined based on the duration of the posture in the given conditions. The scores were determined as follows.

Scoring points:

0. The child cannot assume any position,

I. Test duration less than 3 seconds,

II. Test duration between 4-10 seconds,

III. Test duration between 11-29 seconds or sway greater than 15 degrees for 30 seconds,

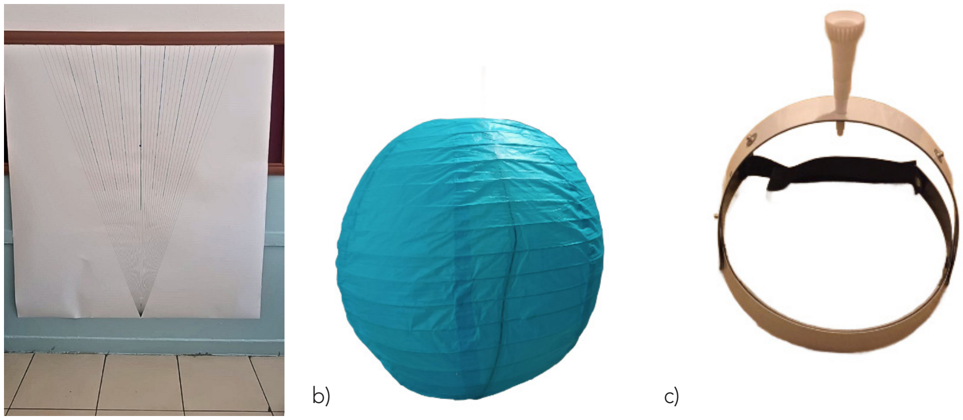


Figure 1. Experimental materials.
a) A paper screen with 1x1 m dimensions, containing lines spread over 32 degrees with 2-degree increments, b) visual conflict dome, c) a cap for measuring the degree of sway

IV. Test duration of 30 seconds, with sway between 6-15 degrees,

V. Test duration of 30 seconds, with sway less than 5 degrees.

In our study, evaluating the P-CTSIB test performance, recording, and reviewing for each child took approximately 60 minutes in total.

Statistical Analysis

The IBM SPSS Statistics Version 23 software program was used to analyze the data. The normality of the data distribution was evaluated using histograms, probability plots, and the Kolmogorov-Smirnov/Shapiro-Wilk tests. Because the data did not show a normal distribution, the Kruskal-Wallis test was used to compare the data among the four groups. The chi-square test was used to compare gender between groups. The statistical significance level was set at $p<0.05$. In case of a significant difference between groups, the Dunn-Bonferroni post-hoc test was applied. Descriptive statistics included the use of mean, median, minimum, maximum, 25th and 75th percentile.

RESULTS

Table 3 shows the distribution of gender across the groups. There was no significant difference between the groups in terms of gender.

Sway Percentage Normative Data

Table 4 presents the normative data for anterior-posterior sway obtained in the feet-together position and medial-lateral sway obtained in the heel-toe position for all groups. The corresponding column graphs are presented in Figure 2 for the feet together position and in Figure 3 for the heel-toe position.

Normative Data for Test Durations

Table 5 presents the normative data for test durations obtained in the heel-toe position across all groups. Since all individuals were able to maintain a standing feet-together position for 30 seconds in each test phase , the data obtained from this test position are not presented. The corresponding column graphs are presented in Figure 4.

Test Scores Normative Data

Table 6 presents the normative data for the test scores obtained in the feet together and heel toe positions across all groups. The corresponding column graphs are presented in Figure 5 for the feet together position and in Figure 6 for the heel-toe position.

Table 3. Distribution of gender by groups

Grup	Female (n)	(%)	Male (n)	(%)	p-value
Group 1	9	47	10	53	
Group 2	11	61	7	39	
Group 3	14	61	9	39	0.686
Group 4	10	48	11	52	
Total	44	54	37	46	

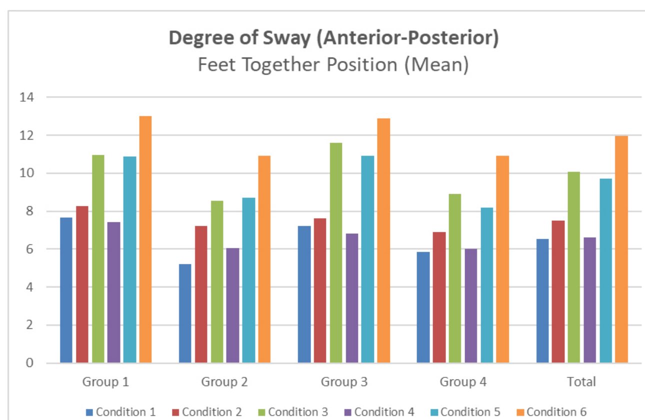


Figure 2. Normative anterior-posterior sway values (mean) in the feet together position (column graph)

Table 4. Normative values of sway (anterior-posterior and medial-lateral)

Degree of sway (anterior-posterior)				
Feet together position				
Variables	**Mean**	**Median**	**SD**	**Min./25%/75% percentile/max.**
Group 1 (n=19)				
Condition 1	7.68	7	2.60	4/6/10/13
Condition 2	8.26	8	2.55	4/6/10/13
Condition 3	10.94	11.5	2.72	5.5/10/12.5/17
Condition 4	7.4	7	1.77	5/6/8/11
Condition 5	10.89	10.5	2.30	8/9/12.5/16.5
Condition 6	13	12	3.70	7.5/11/15/21.5
Group 2 (n=18)				
Condition 1	5.2	4.5	1.60	3/4/7/8
Condition 2	7.2	7.5	1.93	4/5.7/9/11
Condition 3	8.55	8	3.42	0/7/9.62/17
Condition 4	6.05	6	2.13	2/4.5/8/10
Condition 5	8.69	9	3.02	0/6.8/10.37/12.5
Condition 6	10.9	12	3.7	0/16.5/13.12/8.7
Group 3 (n=23)				
Condition 1	7.2	7	2.39	3/6/10/11
Condition 2	7.6	7	2.14	4/6/9/12
Condition 3	11.6	10	4.65	7/8.5/14/28
Condition 4	6.8	6	1.86	5/12/8/5
Condition 5	10.91	10.5	2.74	7/9/12.5/19.5
Condition 6	12.87	11.5	4.5	7.5/10/17.5/24
Group 4 (n=21)				
Condition 1	5.85	6	2.85	3/4/6.5/16
Condition 2	6.9	6	2.71	4/5/9/14
Condition 3	8.9	9	2.37	5.5/7/10.75/13.5
Condition 4	6	6	1.80	3/4.5/8/9
Condition 5	8.2	8.5	1.99	4.5/7.5/9/14.5
Condition 6	10.9	10	3.03	6.5/19.5/12.5/8.7
Total (n=81)				
Condition 1	6.55	6	2.57	3/4/8/16
Condition 2	7.51	7	2.36	4/6/9/14
Condition 3	10.08	9.5	3.64	0/7.5/12/28
Condition 4	6.61	6	1.93	2/5/8/12
Condition 5	9.72	9.5	2.78	0/8/11.25/19.5
Condition 6	11.96	11.50	3.85	0/9.5/14/24
Heel toe position (medial-lateral)				
Group 1 (n=19)				
Condition 1	13.42	11	6.7	5/8.5/17/29
Condition 2	16	15	5.3	6.5/13/21/25
Condition 3	17.5	17	7.36	6/12/21/35
Condition 4	11.68	11	4.18	6/8/14/21.5
Condition 5	22.18	23	6.61	13/16.5/28/32
Condition 6	24.69	25	7.12	12/17.7/28.75/39

Table 4. continued

Degree of sway (anterior-posterior)				
Feet together position				
Variables	**Mean**	**Median**	**SD**	**Min./25%/75% percentile/max.**
Group 2 (n=18)				
Condition 1	8.13	8	2.31	4/6/9.75/13.5
Condition 2	14.55	14.25	7.25	0/9.8/19.25/30
Condition 3	15.44	15.25	8.75	0/8.3/19.37/36
Condition 4	8.5	7.5	3.47	5.5/18/10/6
Condition 5	13.94	15	8.38	0/9/21.25/27
Condition 6	16.59	15	6.85	6/12.5/20/34
Group 3 (n=23)				
Condition 1	12.21	10.9	6.92	5.5/7.5/12.5/34.5
Condition 2	15.53	14	7.38	0/11/19.5/30
Condition 3	16.65	14	8.48	6/10.5/20/39.5
Condition 4	12.13	9	7	5/7.5/17/29.5
Condition 5	20.71	20	9.93	8/12/28/45
Condition 6	18.13	17	7.20	6/12.5/18/38
Group 4 (n=21)				
Condition 1	8.09	7	4.67	3/5/9.75/24
Condition 2	14.88	13	6.72	7/10.5/17.75/34
Condition 3	12.11	13	4.02	6/8.5/15/19.5
Condition 4	8.78	7	4.27	5/5.74/11.25/24
Condition 5	15.90	15	8.36	0/9.5/23.50/32.5
Condition 6	18	16.50	5.92	10/34/20/14
Total (n=81)				
Condition 1	10.52	8.5	5.97	3/7/12/34.5
Condition 2	15.25	14	6.65	0/10.75/19/34
Condition 3	15.42	14	7.53	0/9.5/18.25/39.5
Condition 4	10.37	8.5	5.23	5/7/11.87/29.5
Condition 5	18.36	18	8.96	0/11.5/24/45
Condition 6	19.29	17.25	7.31	6/14/24.5/39

SD: Standard deviation, Min.: Minimum, Max.: Maximum

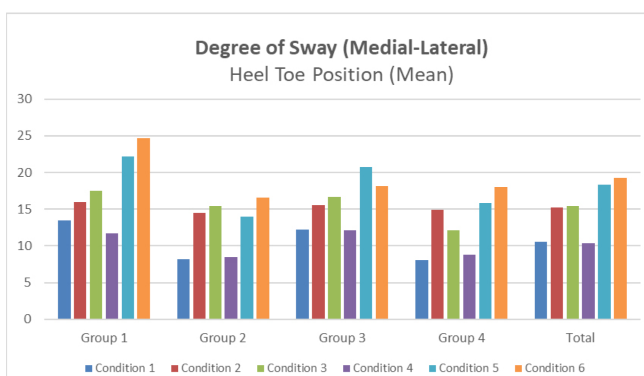


Figure 3. Normative medial-lateral sway values (mean) in the heel toe position (column graph)

Intergroup Comparison

In the feet together position, significant differences were found in the anterior-posterior sway scores between four groups in Condition 1, 3, and 5 ($p<0.05$). In the Dunn-Bonferroni post hoc analysis, pairwise comparisons showed a significant difference only in Condition 1 between Group 4 and Group 1 ($p=0.001$) and between Group 4 and Group 3 ($p<0.001$).

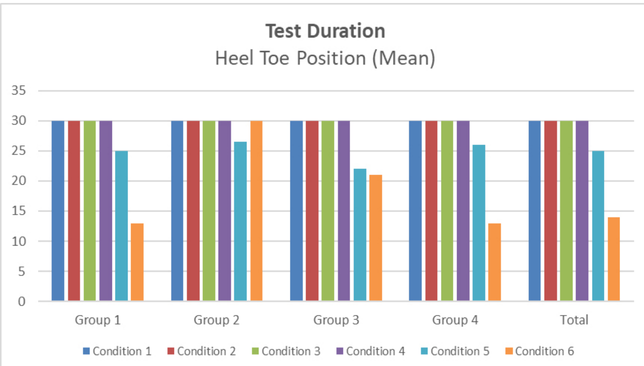


Figure 4. Normative values (mean) of test duration in heel toe position (column graph)

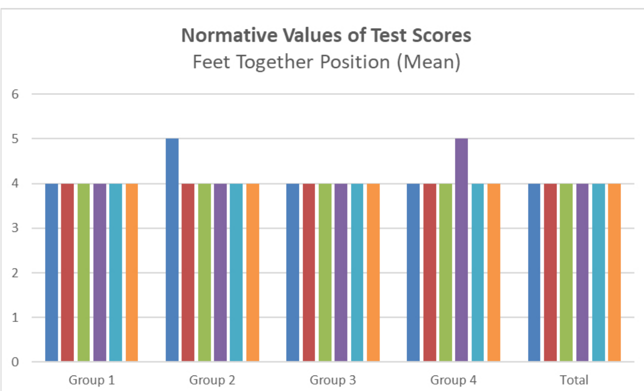


Figure 5. Normative values (mean) of test scores in the Feet Together position (column graph)

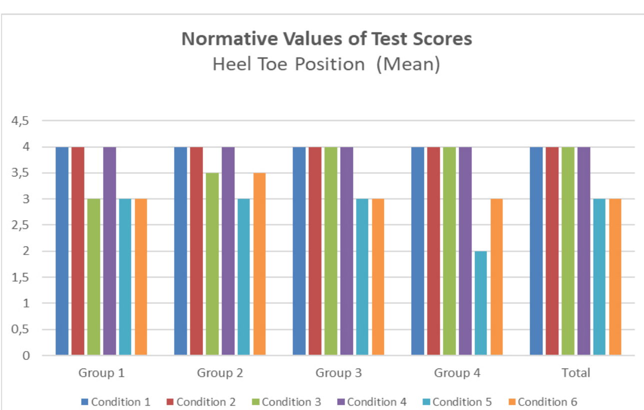


Figure 6. Normative values (mean) of test scores in heel toe position) (column graph)

In the heel-toe position, significant differences were found in the medial-lateral sway scores among four groups across Conditions 1, 4, 5, and 6 ($p<0.05$). In the Dunn-Bonferroni post-hoc analysis pairwise comparisons showed significant differences between Group 4 and Group 1 in Condition 1 ($p=0.002$), and between Group 1 and Group 2 in Condition 6 ($p=0.004$) (Table 5).

Table 5. Normative values of test duration (heel toe position)

Test duration				
Heel toe position				
Variables	**Median**	**Mean**	**SD**	**Min./25%/75% percentile/max.**
Group 1 (n=19)				
Condition 1	30	30	30	30/30/30/30
Condition 2	29	30	4.35	11/30/30/30
Condition 3	28	30	4.3	17/30/30/30
Condition 4	27	30	7.06	4/30/30/30
Condition 5	22.47	25	7.82	10/14/30/30
Condition 6	15	13	9.39	3/7/23/30
Group 2 (n=18)				
Condition 1	30	30	30	30/30/30/30
Condition 2	23.75	30	10.17	2/14.1/30/30
Condition 3	25	30	8.24	6/24.7/30/30
Condition 4	29.6	30	1.64	23/30/30/30
Condition 5	20.27	26.5	10.99	3/8/30/30
Condition 6	20.41	30	11.7	3/7/30/30
Group 3 (n=23)				
Condition 1	28.21	30	4.57	11/30/30/30
Condition 2	24.78	30	8.76	5/20/30/30
Condition 3	27.5	30	5.41	12/30/30/30
Condition 4	26	30	8.44	6/28/30/30
Condition 5	19.71	22	10.60	3/9/30/30
Condition 6	19.30	21	10.56	4/8.5/30/30
Group 4 (n=21)				
Condition 1	28.26	30	5.76	5/30/30/30
Condition 2	27.85	30	6.1	5/30/30/30
Condition 3	28.76	30	3.30	18/30/30/30
Condition 4	29.04	30	4.36	10/30/30/30
Condition 5	20.69	26	10.69	3.5/10.2/30/30
Condition 6	15.97	13	9.92	3/7.7/30/30
Total (n=81)				
Condition 1	29.04	30	3.85	5/30/30/30
Condition 2	26.34	30	7.82	2/30/30/30
Condition 3	27.53	30	5.56	6/30/30/30
Condition 4	27.99	30	6.17	4/30/30/30
Condition 5	20.7	25	10	3/11/30/30
Condition 6	17.67	14	10.46	3/8.2/30/14

SD: Standard deviation, Min.: Minimum, Max.: Maximum

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Table 6. Normative values of test scores (heel toe position)

Variables	Median	Mean	SD	Min/25%/75% percentile/max
Test scores				
Feet together position				
Group 1 (n=19)				
Condition 1	4.11	4	0.31	4/4/4/5
Condition 2	4.11	4	0.31	4/4/4/5
Condition 3	4.05	4	0.22	4/4/4/5
Condition 4	4.11	4	0.31	4/4/4/5
Condition 5	4	4	0	4/4/4/4
Condition 6	3.79	4	0.4	3/4/4/4
Group 2 (n=18)				
Condition 1	4.5	5	0.51	4/4/5/5
Condition 2	4.2	4	0.42	4/4/4.25/5
Condition 3	3.67	4	1	0/4/4/4
Condition 4	4.11	4	1.13	0/4/5/5
Condition 5	3.7	4	0.94	0/4/4/4
Condition 6	3.7	4	0.95	0/4/4/4
Group 3 (n=23)				
Condition 1	4.2	4	0.42	4/4/4/5
Condition 2	4.13	4	0.34	4/4/4/5
Condition 3	3.74	4	0.68	2/4/4/4
Condition 4	4.26	4	0.44	4/4/5/5
Condition 5	3.83	4	0.57	2/4/4/4
Condition 6	3.70	4	0.47	3/3/4/4
Group 4 (n=21)				
Condition 1	4.33	4	0.73	2/4/5/5
Condition 2	4.36	4	0.49	4/4/5/5
Condition 3	4.10	4	0.30	4/4/4/5
Condition 4	4.52	5	0.51	4/4/5/5
Condition 5	4.14	4	0.05	4/4/4/5
Condition 6	3.95	4	0.21	3/4/4/4
Total (n=81)				
Condition 1	4.3	4	0.52	2/4/5/5
Condition 2	4.21	4	0.41	4/4/4/5
Condition 3	3.89	4	0.65	0/4/4/5
Condition 4	4.26	4	0.66	0/4/5/5
Condition 5	3.94	4	0.57	0/4/4/5
Condition 6	3.79	4	0.56	0/4/4/4
Heel toe position				
Group 1 (n=19)				
Condition 1	3.79	4	0.53	3/3/4/5
Condition 2	3.53	4	0.51	3/3/4/4
Condition 3	3.26	3	0.45	3/3/4/4
Condition 4	3.74	4	0.56	4/4/4/4
Condition 5	3.21	3	0.53	2/3/4/4
Condition 6	2.68	3	0.47	2/2/3/3

Table 6. continued

Variables	Median	Mean	SD	Min/25%/75% percentile/max
Test scores				
Feet together position				
Group 2 (n=18)				
Condition 1	4.06	4	0.23	4/4/4/5
Condition 2	3.22	4	1.1	0/2.7/4/4
Condition 3	3.22	3.50	1.06	0/3/4/4
Condition 4	3.83	4	1.04	0/4/4/5
Condition 5	2.78	3	1.06	0/2/4/4
Condition 6	3.11	3.50	0.96	2/2/4/4
Group 3 (n=23)				
Condition 1	3.83	4	0.49	3/4/4/5
Condition 2	3.48	4	0.66	2/3/4/4
Condition 3	3.61	4	0.49	3/3/4/4
Condition 4	3.65	4	071	2/3/4/5
Condition 5	3.09	3	0.84	2/2/4/4
Condition 6	3.04	3	0.82	2/2/4/4
Group 4 (n=21)				
Condition 1	4.10	4	0.76	2/4/5/5
Condition 2	3.62	4	0.59	2/3/4/4
Condition 3	3.76	4	4.36	3/3.5/4/4
Condition 4	4.14	4	0.65	2/4/4.4/5
Condition 5	3.19	2	0.81	2/2.5/4/4
Condition 6	2.90	3	0.76	2/2/3.5/4
Total (n=81)				
Condition 1	3.94	4	0.55	2/4/4/5
Condition 2	3.47	4	0.74	0/3/4/4
Condition 3	3.48	4	0.67	0/3/4/4
Condition 4	3.84	4	0.76	0/4/4/5
Condition 5	3.07	3	0.83	0/2.5/4/4
Condition 6	2.94	3	0.78	2/2/4/4

SD: Standard deviation, Min.: Minimum, Max.: Maximum

In terms of the test score, significant differences were found among 4 Groups: in Condition 1, 3, 4, and 5, in the feet together position; and in Condition 3 and 4, in the heel toe position ($p<0.05$). In the Dunn-Bonferroni post hoc analysis, no significant differences were found in pairwise comparisons (Table 7).

No significant differences were found between females and males in terms of anterior-posterior sway, medial-lateral sway, test duration, and test scores ($p>0.05$) (Table 8).

DISCUSSION

It has been shown that the vestibular system is anatomically developed from birth and can respond functionally (19). The vestibular system continues to develop postnatally in terms of both morphology and function (20). Knowing and understanding

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Table 7. Comparison of sway, test duration and test scores between groups

Condition	p-value of sway (feet together)	p-value of test scores (feet together)	p-value of test duration (feet together)
Condition 1	**0.003**	**0.022**	-
Condition 2	0.309	0.123	-
Condition 3	**0.007**	**0.044**	-
Condition 4	0.113	**0.047**	-
Condition 5	**<0.001**	**0.033**	-
Condition 6	0.251	0.145	-
Condition	**p-value of sway (heel toe)**	**p-value of test scores (heel toe)**	**p-value of test duration (heel toe)**
Condition 1	**<0.001**	0.099	0.091
Condition 2	0.706	0.745	0.041
Condition 3	0.080	**0.017**	0.436
Condition 4	**0.011**	**0.025**	0.118
Condition 5	**0.023**	0.561	0.898
Condition 6	**0.004**	0.391	0.400

Table 8. Comparison of sway, test duration and test scores between genders

Condition	p-value of sway (feet together)	p-value of test scores (feet together)	p-value of test duration (feet together)
Condition 1	0.836	0.794	-
Condition 2	0.160	0.337	-
Condition 3	0.812	0.172	-
Condition 4	0.791	0.374	-
Condition 5	0.875	0.992	-
Condition 6	0.374	0.064	-
Condition	**p-value of sway (heel toe)**	**p-value of test scores (heel toe)**	**p-value of test duration (heel toe)**
Condition 1	0.500	0.189	0.537
Condition 2	0.140	0.230	0.180
Condition 3	0.390	0.219	0.857
Condition 4	0.062	0.225	0.868
Condition 5	0.225	0.577	0.089
Condition 6	0.436	0.062	0.410

the status of vestibular responses in infants, children, adolescents, and adults is of great importance in the assessment and diagnosis of vestibular pathology (21-25). Vestibular disorders occur in children with a frequency of 7% to 15%, and this condition can have negative effects on a child's academic performance and quality of life (26).

During vestibular assessment, children can be tested using any of the techniques employed for adults (27). Most assessment methods can be adapted for children to provide reliable results. Videonystagmography and caloric tests, which are frequently used in assessments, are generally challenging for children (28). The rotational chair test, however, is disadvantageous due to its high cost and unavailability in all clinics. Similarly, the sensory organization test (SOT) in computerized dynamic posturography, used to assess balance performance, provides a more comprehensive balance evaluation (18), however, its clinical use is limited due to high costs and the need for expensive equipment. However, these assessments are not specific to poor postural control and vestibular dysfunction in the pediatric group. Although the P-CTSIB does not provide detailed sway parameters or measures of vestibular function, studies have shown moderate correlations between P-CTSIB performance and posturography findings (29). Gagnon et al. (30) investigated the comparability of the SOT and P-CTSIB in children. They found that although both tests are related to age, they do not measure sensory organisation skills in the same way, suggesting that each provides different and complementary information about children's balance skills. Therefore, the P-CTSIB serves as a useful screening tool to complement more instrumented methods, particularly in large or resource-limited paediatric evaluations.

In our study, we used the P-CTSIB test, assesses postural control. The obtained data provided insights into balance performance in different standing positions, the ability of children to process inputs from visual, somatosensory, and vestibular systems, and

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the integration skills of sensory systems. This study provided normative data for a more practical, and easily applicable method of clinically adapted sensory interaction in the pediatric population. No other study has been found in our country that obtained normative data for Turkish children using P-CTSIB.

In our study, normative data for anterior-posterior sway, test duration, and test scores in six different test positions were obtained for Turkish children. These normative data are intended to serve as baseline data in studies where postural control will be evaluated in children with balance disorders. In our study, significant differences were found between age groups in terms of anterior-posterior sway, medial-lateral sway , and P-CTSIB test scores. In pairwise comparisons, significant differences were found in anterior-posterior sway in Condition 1 between Group 4 and Groups 1 and 3 in the feet-together position, while in medial-lateral sway in Condition 6, significant differences were found between Group 1 and Group 2 in the heel-to position. These differences were attributed to less sway in the older age groups. The sensory organization system in younger children is less efficient than older children (31). This result is consistent with previous reports that found significant differences in balance performance between age groups (32,33). This finding is consistent with the view that the development of postural control ability results from the development of the proprioceptive, visual, and vestibular systems, and that observable improvements in balance tests occur with age throughout childhood (34). Similar to our study findings, Riach and Hayes (32) found significant differences in postural sway between age groups: older children were more stable compared to younger children. Similar to our study, Deitz et al. (33), in their study examining balance performance with P-CTSIB in children aged 6-9, showed that older age groups were able to maintain their balance better under challenging sensory conditions. The study by Pandian et al. (35) on healthy children aged 7-12, found that the P-CTSIB test scores increased with age, indicating an improvement in balance control skills, which is consistent with the findings of our study.

Sayadi et al. (36) stated that the P-CTSIB is an effective test method for identifying sensory integration difficulties in assessing postural control in children aged 4-6. Improvements in balance have been observed with increasing age, including longer static stance duration and less sway.

Similarly, other studies (37,38) have validated the reliability of P-CTSIB in measuring anterior-posterior sway, test duration, and other balance variables, highlighting its usefulness as a clinically applicable alternative. The heel-toe position reflects the degree of postural stability in the medial/lateral direction, and has been used as an indicator of proprioceptive system abnormalities (39).

Our study focused solely on children with typical development. Future research is recommended to include studies involving larger populations, and children with sensory-motor issues. Additionally, the normative data obtained can serve as a foundation for more effective applications in both clinical and educational settings. In future studies with children who have balance problems, individual differences (such as physical activity level or motivation) and factors that may affect performance can also be examined.

Study Limitations

While these findings contribute significantly to the understanding of postural stability and balance, this study has several limitations, including the prolonged testing duration, which may have caused fatigue in children, potentially affecting their performance. In our study, no additional tests were applied to compare the measured postural sway. Including such tests could have provided a more comprehensive evaluation and strengthened the study's findings.

Conclusion

P-CTSIB is a cost-free test that can measure postural sway under different static test conditions without the need for any equipment. Measuring postural sway provides valuable information in the assessment of balance. It is expected that our findings will serve as a basis for ensuring the usability of P-CTSIB in children with balance disorders in our country. Age-specific normative data obtained from Turkish children using the P-CTSIB test will provide reference data for future studies involving children with balance-affecting pathologies.

Ethics

Ethics Committee Approval: This study was approved by the Ethics Committee of the Ankara Yıldırım Beyazıt University Health Sciences Ethics Committee (decision no: 835, date: 06.01.2022).

Informed Consent: Patient consent was obtained for this study.

Footnotes

Author Contributions: Concept - B.M., Ş.Ç., H.M.K., S.Ö., F.D.Ş.; Design - B.M., Ş.Ç., H.M.K., S.Ö., F.D.Ş.; Data Collection and/or Processing - B.M., Ş.Ç., H.M.K., S.Ö., F.D.Ş.; Analysis and/or Interpretation - B.M., Ş.Ç., H.M.K., S.Ö., F.D.Ş.; Literature Search - B.M., Ş.Ç., H.M.K., S.Ö., F.D.Ş.; Writing - B.M., Ş.Ç., H.M.K., S.Ö., F.D.Ş.

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