



# Equilibrium coordination tests among children: A feasibility study

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## Abstract

**Introduction:** Normative reference scores for most of the equilibrium coordination tests were not established. Hence, we aimed for feasibility of establishing the normative reference scores of sideways walking, tandem walking, cross-stepping, heel walking and toe walking among children so that the methodology, procedures, and limitations could be taken into account when large scale study will be conducted.

**Material and methods:** A cross-sectional study was conducted where 284 children (148 males and 136 females) of age group 8-15 years were recruited from a senior secondary school to perform 5 equilibrium coordination tests. Children were asked to perform all tests in random order and the time taken [in seconds] (s) was recorded. The mean of three readings were used for statistical analysis. The normality of the data was assessed through the Kolmogorov Smirnov test. The descriptive statistics have been described in geometric mean (GM) and 95% confidence interval (CI).

**Results:** Age, weight, height, and BMI of the recruited children were  $10.8 \pm 2.4$  years,  $33.2 \pm 10.6$  kg,  $138.6 \pm 11.7$  cm, and  $16.8 \pm 2.9$  kg/m<sup>2</sup> respectively. The normative data of the trial for sideways walking, tandem walking, cross stepping, heel walking, and toe walking come out to be  $23.7 \pm 8.8$  seconds,  $37.7 \pm 6.7$  seconds,  $33.9 \pm 11.3$  seconds,  $18.6 \pm 8.8$  seconds, and  $14.5 \pm 11.2$  seconds respectively.

**Conclusions:** The study was found to be feasible to conduct a large scale study more sample population such that the data can be generalized to the global population.

**Keywords:** children, walking, coordination, postural balance, normal range

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## Introduction

Coordination deficits make movement performance becomes difficult in instances such as developmental coordination disorder (DCD), cerebellar lesions, attention deficit hyperactive disorder etc. [1]. In children, incoordination appeared as clumsy movement i.e. there is deficit in gross motor movements which include walking, running or jumping during their developmental age. Significance of coordination during walking (equilibrium coordination) lies in the fact that it requires more attention and any disorder in this equilibrium during walking, will result in fall or destabilization of the body specifically during swing phase of walking cycle [2]. Therefore, it is necessary to assess coordination and compare with the reference values before engaging in any physical activity in order to prevent further injuries.

Coordination tests have been categorized into non-equilibrium tests and equilibrium or balance tests. Non- equilibrium tests used to examine the movement capabilities through limb coordination while equilibrium or balance tests maintain the static and dynamic balance of the body during perturbations [3]. There are approximately 25 equilibrium coordination tests and out of those, few of them have the reference norms such as single leg standing [4,5], tandem stance [5], multi directional reach tests [6], Sharpened Romberg's test [6]. But none of these tests have reference values for equilibrium in walking to the best of the authors' knowledge so that any variations can be noticed in the measuring group when compared with the characteristics of the reference population. Thus, the extent of deviations from the benchmark can also be demonstrated [3].

Hence, there is a need to establish the reference values of some of the basic equilibrium coordination tests which require walking so that these values can be used by clinicians and researchers to differentiate between normal and abnormal coordination. But in order to generalize the results, one requires to find the feasibility of the whole procedure. Feasibility studies are used to decide whether an intervention is suitable for future testing; in other words, they allow researchers to judge whether or not the concepts and findings can be fashioned to be applicable and long-lasting. Such study may reveal not just what, if anything, needs to be changed about the research protocols or methodologies, but also how those changes might take place [7]. Hence, the present study aimed to report the feasibility of methodology, procedure and limitations for conducting a large scale study while establishing the reference values of five equilibrium coordination tests i.e. sideways walking, tandem walking, cross-stepping, heel walking and toe walking among age group 8-15 years.

## Materials and methods

### *Participants*

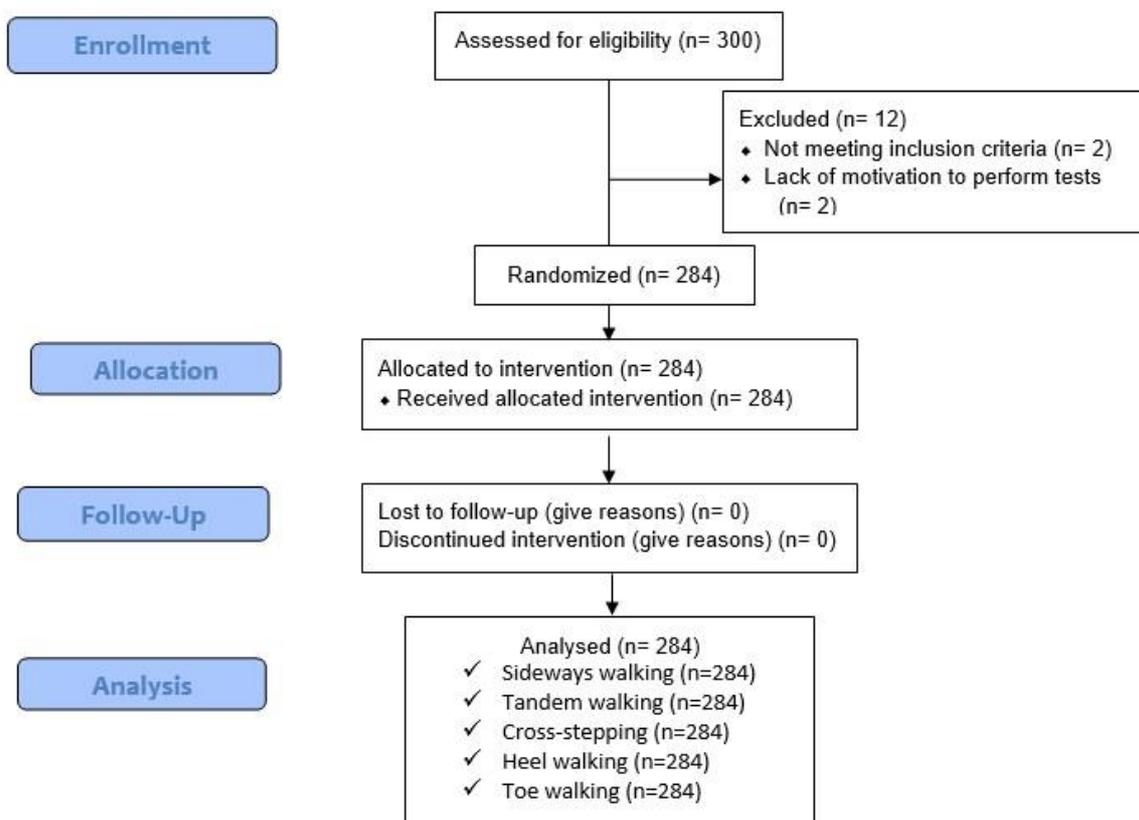
A cross-sectional feasibility study was conducted in a local community and in a senior secondary school. As a feasibility trial, minimum sample size required lies between 50 and 100 [8,9] but for the present study, 300 subjects were screened, out of which 284 subjects were recruited from August 2021 to June 2022, keeping in view, the maximum participation can be done till the date of recruitment. The protocol of this cross-sectional study has been approved by Research Advisory Committee of the institute on August 10<sup>th</sup> 2021. Ethical approval was obtained from Institutional Ethics Committee of a recognized institution with registration number MMDU/IEC-2153. The study has been registered in WHO registry with Universal Trial Number: U1111-1269-9876. The trial has been registered on Clinical trials with registration Id: NCT05159297. Guidelines of Declaration of Helsinki (2013) and National Ethical guidelines for the Biomedical and Health Research involving Human participants given by Indian Council of Medical Research (2017) were followed for the study. Children with age group 8-15 years, both male and female who were able to walk independently and follow verbal commands were included. The exclusion criteria comprised of children with any fracture of lower limb in last 6 months, any congenital anomaly affecting lower limb, any developmental disorder affecting lower limbs, any open wounds in the lower extremities, those who are using any kind of lower extremity assistive devices, any condition that affect the health status of the participants during the study.

### *Procedure*

The participants who met the selection criteria were recruited for the study and the data was collected from August 2021 to June 2022. As the minimum risk was involved in the study, oral assent of the participants was taken and written consent can be waived off [10,11] still the consent from children, parents and permission from the Principal of the respective school were obtained. The demographic details like age, gender, and height (measured through stadiometer), weight (through weighing machine), BMI, limb length and hip circumference (through measuring tape) of the recruited participants were measured. All the measurements were taken between 10:00 am and 12:00 noon of the day and thus reduced the performance bias of the children.

Children were asked to perform five equilibrium coordination tests i.e. sideways walking, tandem walking, cross-stepping, heel walking and toe walking one by one following a demonstration of each test but the order of each test was randomized through chit method. 5 chits with names of each test written on each test, were put in a container. Then each child was asked to pick all the 5 chits one by one, after shaking the container. The order in which the chits were picked, the same order was followed for the performance of each test. Children were asked to wear comfortable clothing with usual footwear. If any child would have refractive errors, then he/she have to wear corrective eye glasses. Three readings were noted for each test and then average of three readings were calculated which were considered as the reference norms for that respective outcome measure.

A mobile-based application stop-watch with Android version 10 QKQ1.190910.002 was used to record the time for all observations as the child began to move. All the measurements were taken during physical activity class/sports period/games period on even or leveled surface as per the scheduled time-table of the particular class. Figure 1 shows study flowchart which is following the guidelines of strengthening the reporting of observational studies in Epidemiology (STROBE) and its checklist (Fig. 1).



**Fig. 1.** Study Flowchart

*Outcome Measures*

The child was asked to walk on a walkway of 10 meters in length and two helpers were made to stand on either side of the walkway so as to make the distance of the pathway clearer to the participant and the time taken was noted during:

1. **Sideways walking** – Child was instructed to walk sideways on the walkway. The feet of the child rested on the starting point. When the examiner signals to start by saying, “walk sideways at your comfortable speed up to the mark and GET SET GO”. Child started walking with his governing leg abducted followed by the adduction of the subordinate leg by touching the medial sides of feet together. Step count along with the time was noted.
2. **Tandem walking** – Both hands were placed on the anterior superior iliac spine. The instruction given to the child was “Walk with your comfortable speed up to the mark and GET SET GO”. The child was asked to make a contact of heel of one foot with the toes of other foot and then walk along a straight line. Then place the rear foot ahead of the front foot keeping the same contact of heel of rear foot (now front foot) to toes of front foot (now rear foot).
3. **Cross-stepping** – The child was asked to stand with feet together and arms hang by the side of the body. Instructions given to the child were “Walk at your comfortable speed and GET SET GO”. Then the child was asked to lift the dominant leg to cross the front of the non-dominant leg with whole body weight supported on non-dominant leg with arms swinging outside. Next the non-dominant leg was brought back to meet the dominant leg and the process was repeated with the other leg.
4. **Heel walking** – Both hands were placed on the anterior superior iliac spine. The child was instructed to walk at the comfortable speed up to the mark and start at the words, GET SET GO. Child was asked to walk on heels with forefoot lifted from the ground and toes pointed upwards and lift the left foot first and place it ahead of right foot with arms swinging by the side of the body and vice-versa.
5. **Toe walking** – The child was instructed to walk at the comfortable speed up to the mark and start at the words, GET SET GO. The child was asked to walk on toes with heel and hind foot rose from the ground and placed the toes of left foot first by lifting the heel and hind foot of the same foot and arms were hanging by the side of the body. Next place the toes of right foot with raised heel and hind foot of the same.

*Statistical analysis*

Statistical Package for the Social Sciences (SPSS) software (IBM) version 20, SPSS Inc. Chicago II USA was used to analyze the data. Level of significance was set at  $< 0.05$ . Statistical analysis of the feasibility study has been done by estimating the normality of the data using Kolmogorov Smirnov test. The mean of each test was calculated and their descriptive statistics explaining mean, standard deviation and standard error mean was evaluated. The demographic data was found to be normally distributed; hence descriptive statistics was expressed in mean and standard deviations. Equilibrium coordination tests does not follow normal distribution; hence descriptive statistics was expressed in geometric mean and 95% confidence interval. As it was a single time study, so no missing data was reported.

## Results

All the measures have been represented in seconds. Demographic characteristics have been represented in mean and standard deviations as they follow the normal distribution (Tab. 1).

**Tab. 1.** Demographic characteristics of the recruited children (n = 284)

Demographic characteristics	Mean $\pm$ S.D.	SEM
Age (in years)	11.1 $\pm$ 2.1	0.12
Weight (in kg)	37.9 $\pm$ 9.6	0.57
Height (in centimeters)	141.3 $\pm$ 10.7	0.64
BMI (in kg/m <sup>2</sup> )	18.7 $\pm$ 3.1	0.18
Limb Length (in centimeters)	72.9 $\pm$ 9.7	0.58
Waist circumference (in centimeters)	59.0 $\pm$ 9.4	0.56
Hip circumference (in centimeters)	72.6 $\pm$ 9.9	0.59

kg- kilograms, S.D.- standard deviation, SEM- standard error mean

Although among outcome measures, Tandem walking and Cross-stepping follow the normal distribution but Sideways walking, Heel walking and Toe walking were not following normal distribution, hence their geometric mean with 95% confidence interval and range has been calculated (Tab. 2).

**Tab. 2.** Descriptive statistics of equilibrium coordination tests

Outcome measures	GM (95% CI)	Range
Sideways walking (s)	22.5 (18.6-28.8)	14.9-43.2
Tandem walking (s)	37.1 (33.8-41.5)	28.6-49.2

Cross- stepping (s)	32.1 (27.3-40.4)	15.9-59.3
Heel Walking (s)	17.1 (13.5-23.6)	11.2-43.8
Toe walking (s)	12.6 (8.1-20.9)	8.2-52.1

CI- confidence interval, GM- geometric mean, s- seconds

Comparison of reference values obtained in male and female children have been demonstrated which showed that there was no significant difference between the values (Tab. 3).

**Tab. 3.** Comparison between male and female children performing equilibrium coordination tests\*

Outcome Measures	Females (n = 140)		Males (n = 144)		p-value
	GM (95% CI)	Range	GM (95% CI)	Range	
Sideways walking (s)	21.6 (20.0-23.1)	9.7-51.8	22.1 (20.7-23.5)	14.3-35.4	0.577 <sup>#</sup>
Tandem walking (s)	32.1 (29.9-34.2)	28.6-49.2	32.3 (30.6-33.9)	20.3-45.2	0.867 <sup>#</sup>
Cross-stepping (s)	32.2 (29.6-34.8)	11.5-66.4	31.7 (29.9-33.6)	16.3-45.7	0.996 <sup>#</sup>
Heel Walking (s)	15.9 (14.4-17.4)	7.2-44.1	16.3 (15.1-17.6)	9.5-44.1	0.423 <sup>#</sup>
Toe walking (s)	12.9 (11.9-13.8)	6.2-20.5	13.6 (12.1-15.1)	6.3-52.4	0.706 <sup>#</sup>

CI- confidence interval, GM- geometric mean, s- seconds, # - p-value > 0.05, represents non-significant difference male and female children, \*- Mann Whitney U test was performed

## Discussion

The purpose of the present study was to find the feasibility of methodology, procedure and limitations for conducting a large scale study while establishing the reference values of five equilibrium coordination tests i.e. sideways walking, tandem walking, cross-stepping, heel walking and toe walking among age group 8-15 years. For the purpose, 284 healthy children were recruited with mean age  $10.8 \pm 2.4$  years with female  $\approx$  male. It is proposed that the children of age group 16 & 17 years can also be recruited for the better generalizability of the results among adolescents.

Feasibility studies help the researchers to test the appropriateness of any long term trial i.e. they allow researchers to judge whether or not the concepts and findings can be fashioned to be applicable and long-lasting. Such study may reveal not just what, if anything, needs to be

changed about the research protocols or methodologies, but also how those changes might take place. These studies provides a base on which the actual results rely which can be generalized to the population and the clinicians or the researchers can be benefitted [7].

Table 2 demonstrated the sample of reference values of five coordination tests which were obtained from mean of three readings. During the procedure, it was observed that the presence of footwear can be a confounding variable for the reference values to be obtained [12]. Therefore, it is proposed that three-three readings should be taken with footwear and without footwear on a leveled surface.

The reference values help to identify any abnormality in the equilibrium coordination tests among children with age group 8-15 years. As the data of each age group would be established in the final study, it would facilitate the comparison of age related changes among children. The study within the specified age group can be conducted as the executive attention and cognitive function required to control posture and maintain balance are substantially developed after the age of 8 years [13,14]. Thereby, it is anticipated that these values would also help to identify any attention and cognitive dysfunction among this age group.

Outcome measures or assessment tools are required in every clinical and research settings to find any deviation from what is considered as the typical or normal for the respective variable [15]. For a clinician, the evaluation and assessment of a variable is very essential so as to enhance the knowledge of the normal and the impaired activities which further assist in keeping a check on the clinical presentation of the individuals along with the formulation of interventions accordingly [14,16–18].

The available literature showed that the reference values are available for various coordination and balance tests among children [11,19–23], young adults [22,24–26], and older adults [2,5,6,24,27–29] but none of the studies established the reference values which involve equilibrium coordination tests such as sideways walking, tandem walking, cross-stepping, heel walking and toe walking. Timed walk tests were performed among different age groups where the subjects were asked to cover distances as per the required time duration, either barefooted or with footwear but no description of footwear have been mentioned in any of the article [20,26,28,30]. Therefore, this also needs to be mentioned in further studies.

Further in secondary analysis, different values for males and females have been accounted in Table 3 and thus, separate norms could be established for both sexes which are helpful in determining any variation due to gender disproportions. The present study showed that there was no significant difference found between males and females children which elaborate that all children took same time to complete the task. In the previous study, no

significant difference was found between the values of 6 minute walk test and the sex of the children of age group 6-12 years of which supports the result of the present study [31]. Another study also declared that there was no significant difference between the normative values obtained for male and female healthy children performing 10 meter walk test [32]. This showed that the result of the present study was in line with that of the available literature. Although there are no significant differences among both sexes, still it was observed that speed of walking among females is slower than that of males specifically the elder age groups. It might be due to their development of secondary sexual characters or menarche which may affect their walking speed. [33] But still no significant differences were obtained which may be due to the fact that the younger females matched the speed of the males and in some instances, even much greater than that of males.

The limitation of the study was that the level of motivation among children was not measured. If the child was not motivated, then he/she might not walk with the required speed. Presence of other non-participating children around the participants might distract them and affect their participation. As it was a feasibility study and the sample size was limited, hence one should be cautious while generalizing the results.

The study was done as a multi-center study and not limited to a particular geographical area, so there was wide variety of children who were the potential participants with different demographic characteristics. Also the tests are very simple to understand and administer, thus the children were not feel cumbersome to perform. This might proves as the strength of the study.

Future recommendations can be figured on with the large scale study for the generalization of the results. An automatic stop watch can also be used which may measure the time taken by the children as they would start walking for a particular test and stops, when the test will complete. Also the reliability and validity of the outcome measures used in the study can also be evaluated.

## **Conclusions**

The feasibility study which evaluated the normative values of sideways walking, tandem walking, cross-stepping, heel walking and toe walking among children with age 8-15 years has been verified. It has been proposed that some modifications are required in the methodology with the readings should be taken with and without footwear, another variable of menarche can

be studied. It is also proposed to include children of age 16 & 17 years so that under-adult children can be undertaken and values can be generalized.

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### **Conflicts of Interest**

The authors have no conflict of interest to declare.

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