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Equilibrium coordination tests among children: A feasibility study

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Abstract

Introduction: Normative reference scores have not been established for most equilibrium coordination tests. Hence, the aim of the present study was to confirm the feasibility of the methodology and procedures, and limitations, for of large-scale studies establishing normative reference scores for sideways walking, tandem walking, cross-stepping, heel walking and toe walking among children.

Material and methods: In this cross-sectional study, 284 children (144 boys and 140 girls) aged 8-15 years were recruited from a senior secondary school to perform five equilibrium coordination tests. The children were asked to perform all tests in a random order, and the time taken in seconds (s) was recorded. The mean values were subjected to statistical analysis. The normality of the data was assessed with the Kolmogorov Smirnov test. The descriptive statistics are presented as geometric mean (GM) and 95% confidence interval (CI).

Results: The age, weight, height, and body mass index of the recruited children were 11.1 ± 2.1 years, 37.9 ± 9. kg, 141.3 ± 10.7 cm, and 18.7 ± 3.1 kg/m^2 respectively. The normative data of the trial for sideways walking, tandem walking, cross stepping, heel walking, and toe walking were 23.7 ± 8.8 s, 37.7 ± 6.7 s, 33.9 ± 11.3 s, 18.6 ± 8.8 s, and 14.5 ± 11.2 s, respectively.

Conclusions: The findings indicate that it is feasible to conduct a large-scale study with a larger sample population to allow the data to be generalized to the global population.

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

Introduction

The deficits in coordination observed *inter alia* in developmental coordination disorder (DCD), cerebellar lesions and attention deficit hyperactive disorder result in lower movement performance [1]. In children, such deficits appear as clumsy movements, for example, problems associated with gross motor movements such as walking, running or jumping, during their developmental age. Coordination plays a key role during walking (*equilibrium coordination*) as any disorder in this equilibrium during walking will result in fall

or destabilization of the body, specifically during the swing phase of the walking cycle [2]. In such cases, in order to prevent further injuries, the coordination of the child should be assessed and compared with reference values before engaging in any physical activity.

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]. Although there are approximately 25 equilibrium coordination tests, such as single leg standing [4,5], tandem stance [5], multi directional reach tests [6], Sharpened Romberg's test [6], none have reference values for equilibrium in walking. As such, it is difficult to compare any variations demonstrated by the measured group with a reference population and thus, determine the extent of deviations from the benchmark [3].

Hence, there is a need to establish reference values for certain basic equilibrium coordination tests which require walking. However, before such results can be generalized, it is necessary to determine the feasibility of the tests and their limitations, if any. 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 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]. 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 children aged 8–15 years.

Materials and methods

Participants

A cross-sectional feasibility study was conducted in a local community and in a senior secondary school. Although a feasibility trial requires minimum sample size between 50 and 100 [8,9], the present study screened 300 subjects. Of these, 284 subjects were recruited from August 2021 to June 2022; it is important to note that maximum participation can be achieved by the recruitment starting date.

The protocol of this cross-sectional study was approved by the Research Advisory Committee of the Maharishi Markandeshwar Institute of Physiotherapy and Rehabilitation, Mullana-Ambala, Haryana, India, on August 10th 2021. Ethical approval was obtained from the Institutional Ethics Committee with the 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 and National Ethical guidelines for the Biomedical and Health Research involving Human participants given by Indian Council of Medical Research were followed.

The study included children aged 8-15 years, both male and female who were able to walk independently and follow verbal commands. The exclusion criteria comprised children with any fracture of lower limb in last six months, any congenital anomaly affecting the lower limbs, any developmental disorder affecting the lower limbs, any open wounds in the lower extremities, the use of any kind of assistive devices for the lower extremities, any condition that affects the health status of the participants during the study.

Procedure

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

The children were asked to perform five equilibrium coordination tests, *viz.* sideways walking, tandem walking, cross-stepping, heel walking and toe walking, one test at a time, with a demonstration preceding each test. The order of the tests was randomized through the chit method. Briefly, five chits with the names of each test written on each chit, were put in a container. Then, each child was asked to shake the container and pick out all the five chits, individually; the adorer in which they were drawn determined the order for the performance of the tests. The children were asked to wear comfortable clothing with usual footwear. Any children with visual impairment were asked to wear corrective eye glasses. Three readings were noted for each test; the mean value of the readings was calculated and this was used as the reference norm for the outcome measure.

A mobile-based stop-watch application running on Android version 10 QKQ1.190910.002 was used to

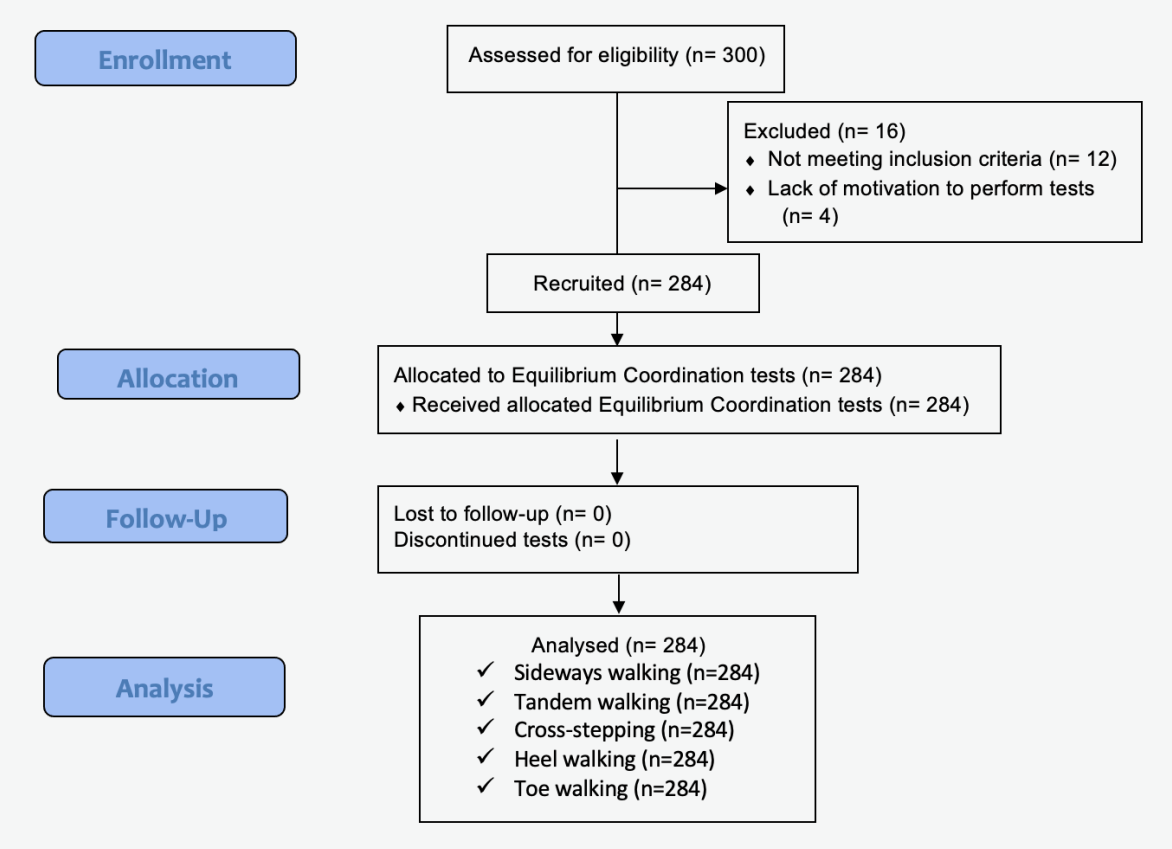

Fig. 1. Study Flowchart

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 an even or leveled surface as per the scheduled time-table of the particular class. Figure 1 present a study flowchart based on guidelines of strengthening the reporting of observational studies in Epidemiology (STROBE) and its checklist (Fig. 1).

Outcome measures

In all cases, the child was asked to walk along a walkway 10 meters in length; two helpers were asked to stand on either side of the walkway to make the distance of the pathway clearer to the participant. The time taken was noted during:

1. **Sideways walking –** The child was instructed to walk sideways on the walkway with both hands placed on the anterior superior iliac spine region. The feet of the child were placed on the starting point. The following instruction was given the child: "walk sideways at your comfortable speed up to the mark and GET SET GO". The child started walking with his governing leg abducted followed by the adduction of the subordinate leg by touching the medial sides of feet together. Both the step count and total time were noted.
2. **Tandem walking –** Both hands were placed on the anterior superior iliac spine region. The following instruction was given to the child: "Walk with your comfortable speed up to the mark and GET SET GO". The child made a contact between the heel of one foot with the toes of the other foot, walk straight forward, then place the rear foot ahead of the front foot keeping the same contact between the heel of the rear foot (now the front foot) to the toes of the front foot (now the rear foot).
3. **Cross-stepping –** The child was asked to stand with feet together and both hands placed on the anterior superior iliac spine region. The following instructions were given to the child: "Walk at your comfortable speed and GET SET GO". The child lifted the dominant leg to cross the front of the non-dominant leg with their whole body weight supported on non-dominant leg and 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 a comfortable speed up to the mark and start at the words, GET SET GO. Child was asked to walk on the heels with the forefoot lifted from the

ground and toes pointed upwards; the left foot was lifted first and placed ahead of the right foot, this was followed by the lifting the right foot and so on.

5. **Toe walking –** The child was instructed to walk at a comfortable speed up to the mark and start at the words, GET SET GO. The child was asked to walk on their toes with both hands placed on the anterior superior iliac spine region: briefly, the child stood on the balls of their feet, and started walking by placing the left foot forward, followed by the right foot and so on. While stepping, the heel of the front foot and the whole back foot were lifted from the ground. The arms were left hanging by the side of the body throughout the movement.

Statistical analysis

The data was analyzed using the Statistical Package for the Social Sciences (SPSS) software (IBM) version 20, SPSS Inc. Chicago II USA. The level of significance was set at < 0.05. First, the normality of the data was determined using Kolmogorov-Smirnov test. In addition, the mean value of each test was calculated and descriptive statistics (mean, standard deviation and standard error mean) were evaluated. The demographic data was found to be normally distributed; hence the descriptive statistics were expressed in mean and standard deviation. As the equilibrium coordination test results did not follow a normal distribution, the descriptive statistics were expressed as geometric mean and 95% confidence interval. As it was a single time-point study, no missing data was reported.

Results

Demographic characteristics are represented as mean and standard deviation, as they follow a normal distribution (Tab. 1).

Among the outcome measures, the results of the Tandem walking and Cross-stepping followed a normal distribution; however, Sideways walking, Heel walking and Toe walking did not. Therefore, in the case of the latter, they were represented as geometric mean with 95% confidence interval and range (Tab. 2).

No significant differences were found between the reference values obtained from male and female children (Tab. 3).

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

Demographic characteristics	Mean ± SD	SEM
Age [years]	11.1 ± 2.1	0.12
Weight [kg]	37.9 ± 9.6	0.57
Height [cm]	141.3 ± 10.7	0.64
BMI [kg/m^2]	18.7 ± 3.1	0.18
Limb Length [cm]	72.9 ± 9.7	0.58
Waist circumference [cm]	59.0 ± 9.4	0.56
Hip circumference [cm]	72.6 ± 9.9	0.59

BMI – body mass index, SD – standard deviation, SEM – standard error mean.

Tab. 2. Descriptive statistics of the 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.

Tab. 3. Comparison of the equilibrium coordination tests results for male and female children

Outcome Measures	Girls (n = 140)		Boys (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
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
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
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
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

CI – confidence interval, GM – geometric mean.

Discussion

The purpose of the present study was to confirm the feasibility of the methodology and procedure, and the limitations, for conducting a large-scale study establishing the reference values of five equilibrium coordination tests, *viz.* sideways walking, tandem walking, cross-stepping, heel walking and toe walking, among children aged 8–15 years. Therefore, 284 healthy children with a mean age 11.1 ± 2.1 years were recruited, with more or less equal numbers of boys and girls. It is proposed that children aged 16 and 17 years can also be recruited to allow better generalizability of the results among adolescents.

Feasibility studies help researchers confirm the appropriateness of any long-term trial i.e. they provide an indication as to whether or not the concepts and findings may be applicable and long-lasting. The findings 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 provide a base by which the results can be generalized to a wider population; this will be of benefit to both clinicians and researchers [7].

The reference values of five coordination tests obtained as the mean values of three readings are given in Table 2. During the procedure, it was observed that the presence of footwear can be a confounding variable for the reference values [12]. Therefore, the existing protocol has been amended to date as three readings with footwear and three readings without footwear on a leveled surface.

The reference values can be used to identify any abnormality in equilibrium coordination tests among children aged 8–15 years. As the data of each age group will be established in the final study, our findings would allow accurate comparisons of age-related changes among the children. Studies can be conducted within the specified age group, as the executive attention and cognitive function required to control posture and maintain balance are substantially developed after the age of eight years [13,14]. Hence, 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, it is essential to evaluate and assess each variable so as to enhance the knowledge of the normal and the impaired activities; this can further assist with confirming the clinical presentation of the individuals and with formulating appropriate interventions [14,16–18].

The available literature contains reference values 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 these studies establish any reference values which involve equilibrium coordination tests such as sideways walking, tandem walking, cross-stepping, heel walking and toe walking. Although timed walk tests have been performed among different age groups where the subjects were asked to cover distances within a specified time duration, either barefoot or with footwear, but no description of footwear is given in any article [20,26,28,30]. Therefore, this also needs to be mentioned in further studies.

Our secondary analysis indicates different values for boys and girls (Table 3) and thus, separate norms could be established for both sexes; this could be helpful in determining any variation due to gender disproportions. No significant difference was found between boys and girls in the present study, indicating that all children took same time to complete the task. In a previous study, no significant difference was found between the values of the six-minute walk test and the sex of the children aged 6–12 years, which supports the results of the present study [31]. Another study also found no significant difference between the normative values obtained for healthy boys and girls performing a 10 meter walk test [32]. Hence, it appears that our present findings are in line with that of the available literature. Although there are no significant differences among both sexes, it was found that that girls tended to walk slower than the boys, particularly the older age groups; this may be due to the development of secondary sexual characteristics or menarche, which may affect their walking speed. [33] nevertheless, it should be emphasized that no significant differences were obtained, which may be due to the fact that the younger girls matched the speed of the boys and in some instances, were even faster.

The limitations of the study were: first, the level of motivation among children was not measured; a child might not walk at the comfortable speed if unmotivated. Second limitation was the presence of other non-participating children might have served as a distraction to the participant and affect their performance. In addition, the study was performed in multiple centers and not limited to a particular geographical area; as such, the participants may have varied demographic characteristics. Furthermore, the present research is intended as a feasibility study with a limited sample size; hence, caution is needed while generalizing the results. Despite this, the tests are very simple to understand and administer, and the children could perform them easily, which can be seen as a strength of the study.

Recommendations can be given for the proposed large-scale study intended for the generalization of the results. An automatic stop watch can be used to measure the time taken by the children from starting walking until the test is complete. Also the reliability and validity of the outcome measures used in the study can also be evaluated in the large-scale study.

Conclusions

The feasibility of a long-term study evaluating 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: the readings should be taken with and without footwear, and menarche may prove to be a variable worth studying. It is also proposed to include children aged 16 and 17 years to include late teens and allow greater generalization of the results.

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Conflicts of Interest
The authors have no conflict of interest to declare.

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