

Reference Values of Multi Directional Reach Test Among Children Aged Between 5 -17 Years: A Normative Research

Kavita Sharma, Shantha Kumar

Abstract

Background: Balance assessment is very important to assess the balance abilities of an individual. Functional Reach Test (FRT) is a test which is used for assessing balance. The result of this test has been found to be influenced by the age of the children. Multi directional Reach Test (MRT) is a test which is used for assessing balance abilities by making the individual reach in four different directions without flexing limbs or losing balance.

Objective: The objective of the present study is to establish the normative values for reference of MRT among children between 5 to 17 years of age group.

Methodology: In the present study a self-designed MRT instrument was used to fulfill the purpose. The instrument is made up of three wooden frames placed adjacent to each other. It consists of two metallic rulers at the top of the wooden frames such that one ruler is present between set of two adjacent wooden frames. Each ruler is 600 mm in length. To perform this test, the subject was asked to remove the shoes and stand in front of the instrument. The rulers were adjusted according the level of the acromion process of the subjects. Next they were asked to stand with outstretched hands such that the shoulder is at 90° and feet together and firmly in support with the ground. Subjects then attempted to reach in all four directions namely forward reach (FR), backward reach (BR), left lateral reach (LLR) and right lateral reach (RLR). Measurements were taken for all the four directions from initial position to the end position up to which the participant could reach without losing balance. The middle finger was taken as the reference for taking all the measurements.

Result: The results of the present study reveal that MRT scores increases with advancing age according to the trends observed among different age groups of children. The result of the present study also showed that maximum reach score was obtained in forward reach among 12-year-old age group [score 21.33 (skewness 0.08 kurtosis 0.97)] whereas the lowest score was obtained in backward reach among 8-year-old age group [score 6.58 (skewness 1.20 kurtosis 0.91)]. In all the age groups it has been found that the scores of forward reach are higher than the scores of backward reach.

Conclusion: MRT instrument is an effective and time saving tool for assessing balance abilities among children. It is an instrument which is easy to understand and use without any special knowledge or training. The normative reference scores for the given age group has also been established in this study.

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Introduction Balance is regulated by the integrated functioning of vestibular, visual and somatosensory system. Impairment in either of

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Keywords

Multi-directional reach test, balance test, normative study

these systems can lead to development of balance deficits. Further, any sort of gait disorder can also result in balance impairment [1]. Posture control is directly associated with balance. In case of children, balance is intricately related to development of motor functions and fundamental movement abilities. Around six or seven years of age, children start developing balance abilities similar to adults. However, this ability can vary if the child or adolescent undergoes any type of training in adaptive variability. Both static and dynamic balance is often used by healthcare professionals to assess neuromuscular control. It is also assessed as an adjunct when the patient has complaints associated to pain, loss of muscle strength or endurance [2] It has been found that any type of alterations either in the sensory system or the motor system has an impact on balance. The proprioception of the lower limb also plays a major role in maintenance of balance.[3] Children begin to learn how to integrate and use the three systems namely the vestibular, visual and the somatosensory system between 3 to 6 years of age. The proprioceptive abilities of the children mature by 3-4 years of age. Hence, this balance development ability during childhood plays a vital role in human adult balance ability. If in any case, the development of balance function is hampered during the early stages of growth, it will lead to difficulty in mastering complicated motor functions and in the future will limit the individual's participation in sports or any high intensity activity.[4] Sporting activities tends to support and enhance balance developments among children. The stimulus perceived during the sporting activities helps in improving balance by inducing changes in proprioception. [5] Other recreational activities such as dance and gymnastics also tend to enhance balance abilities among children. This is due the fact that all these activities provide stimulus to the body. These stimulus act as perturbations and hence they assist in improvising the strategies such as ankle strategy and hip strategy to balance out. [6]

Balance assessment is very important to assess the balance abilities of an individual. Functional Reach Test (FRT) is a test which is used for assessing balance. The result of this test has been found to be influenced by the age of the children. As per a study conducted by Habib *et al.*, (1999) there was a revelation that age and gender had a major influence on the balance abilities of the children. They reported that balance function showed improvement with growing age whereas it was found that there was variation in balance abilities based on gender and socio-economic status. In the higher socio economic groups boys demonstrated better balance abilities than the girls. However, in case of lower socio-economic group girls exhibited good balance abilities as compared to boys. Time up and go test is another test which is used to assess balance. In a study conducted by Norris *et al.*, (2008)[8] it was reported that weight of the child acts as a major predictor of functional

reach test result. Apart from age, anthropometric measurements have been observed to be a major influencer in determining the balance performance among children. Arm length is a major anthropometric measurement which influences reach test [9] .

Multi directional Reach Test (MRT) is a test which is used for assessing balance abilities by making the individual reach in four different directions without flexing limbs or losing balance. It was developed by Newton to measure the balance excursion in four directions namely forward, backward, right lateral and left lateral. This is a simple, valid and reliable tool used for assessing dynamic balance and line of support in anteroposterior and mediolateral directions [10]

The standard values established for this test has been derived by doing study on elderly population. No such study has been done to derive the standard value in case of youth and children. Moreover, the Asian population has also not been studied for this. The anthropometric measurements for the Asian population and specifically the Indian subcontinent is different than the European and American standard anthropometry. The variation in anthropometric measurements will have an influence on standard values of multi-direction reach also. Therefore, a study was required to establish the standard values of this test among Indian population. Since it is a very vast topic and a lot of resources is required for the same so in this present study only the normative scores of multi-directional reach test among children was focused. The aim of the present study is to establish the normative values for reference of MRT among children between 5 to 17 years of age group.

Material and Methods

Sample Recruitment This was an observational study which included both children and adolescents as subjects. Children and adolescents aged between 5 and 17 years of age were considered as the population for the study. 100 children from each age group aged between 5 years to 17 years resulting in a total of 1300 children were recruited for the study. The subjects for the study were shortlisted based on the inclusion and exclusion criteria. The inclusion criteria were (1) children between 5 years to 17 years of age (2) children having normal body mass index. The exclusion criteria included (1) Children who were non-cooperative (2) Children having any musculoskeletal disorders (3) Children suffering from any medical condition (4) Children who were regularly participating in any sports activity were excluded from the study. Stratified sampling method was used for data collection. Data was collected from the recognized and affiliated schools both private as well as government. This study was carried out from 2021 to 2024. The sample size was 1300 which was estimated on the basis of a pilot study conducted Sharma *et al.*, (2015).[11] The children and their parents were informed appropriately about the study. They were given proper details about the procedure to be followed and the reason for the conduct of study.

Following this assent from the children and informed consent from the parents and/or legally authorized guardians was obtained. Research protocol was approved by institutional research and ethics committee (MMU/IEC/2318). The study protocol was registered in the clinical trial registry as CTRI/2023/05/052522 and was accomplished as per the guidelines directed by Indian council for medical research, ethical guidelines for biomedical research on human participants (revised 2006) and Helsinki Declaration (World Medical Association, 2013).

Procedure

The aim of this study was to establish the normative reference scores for Multi-Directional Reach test (MRT). For this purpose, initially the anthropometric measurements which included height, weight, upper limb length, waist circumference and hip circumference were recorded using the appropriate tools and instruments. All the anthropometric measurements were taken according to the guidelines of International Standards for Anthropometric Assessment (ISAK) (Mugge et al., 2010). In order to avoid any type of disparity in the measurements, all the recordings were done at the same. Participants were informed to come in snugly fitted clothes to prevent any discomfort while taking the measurements. Body mass index (BMI) was calculated of each subject using their weight and height. Following the anthropometric measurements, MRT readings of all the selected subjects were taken. Only those children who fulfilled the criteria of having normal BMI were asked to proceed for MRT reading. The investigator ensured that the place where the MRT readings were being taken was a well-lighted and distraction free space.

MRT is a test which is used to assess balance abilities. In the present study a self-designed MRT instrument was used to fulfill the purpose. The instrument is made up of three wooden frames placed adjacent to each other. It consists of two metallic rulers at the top of the wooden frames such that one ruler is present between set of two adjacent wooden frames. Each ruler is 600 mm in length. To perform this test, the subject was asked to remove the shoes and stand in front of the instrument. The rulers were adjusted according to the level of the acromion process of the subjects. Next they were asked to stand with outstretched hands such that the shoulder is at 90° and feet together and firmly in support with the ground. Subjects then attempted to reach in all four directions namely forward reach (FR), backward reach (BR), left lateral reach (LLR) and right lateral reach (RLR). Measurements were taken for all the four directions from initial position to the end position up to which the participant could reach without losing balance. The middle finger was taken as the reference for taking all the measurements.

For FR and BR subjects stood parallel to the instrument such that their shoulder was adjacent to the MRT instrument. For RLR and LRR subjects were made to stand with the back towards the instrument.

For FR and BR subjects were asked to bend forward and backward respectively without losing balance. For RLR and LRR they were asked to bend sideways on either side. Three consecutive measurements were recorded for each FR, BR, RLR and LRR.

Data Analysis

The data was analyzed using Statistical Package for Social Sciences 16 (SPSS Version 16). In this study the data did not follow a normal distribution therefore descriptive data was expressed in terms of median along with skewness and kurtosis. For this study, the p value ≤ 0.05 is taken as statistically significant. To calculate the gender specific MRT values Mann Whitney U test was used. Subjective values which included age wise distribution of FR, BR, RLR, LLR were also calculated using the same test with 95% confidence interval.

Result

A total of 1300 children were recruited for the study based on the inclusion and exclusion criteria. Out of this total 688 were males and 612 were females. Table 1 represents the demographic details of the subjects in terms of median, skewness and kurtosis depicted at a confidence interval of 95%. It also contains the gender wise descriptive statistics expressed in median along with skewness and kurtosis. Table 2 depicts the normative reference scores of MRT among different age groups for children between aged between 5 to 17 years. It is also expressed in terms of median along with skewness and kurtosis at a confidence interval of 95%. Figure 1 represents the trends of MRT score among the children of different age groups. Following data analysis of the results obtained from the study revealed that multidirectional reach test was easy to administer. The scores obtained showed that forward reaching measurement was higher in all the age groups as compared to backward reach measurements. In the result, it was also seen that in all of the age groups the score of right lateral reach was higher as compared to that for left lateral reach. The result of the present study also showed that maximum reach score was obtained in forward reach among 12-year-old age group [score 21.33 (skewness 0.08 kurtosis 0.97)] whereas the lowest score was obtained in backward reach among 8-year-old age group [score 6.58 (skewness 1.20 kurtosis 0.91)].

The purpose of this study was to establish the normative reference values for MRT test among children. Following data collection, it was found that the data does not follow a normal distribution so the results were expressed in median along with skewness and kurtosis. During data collection it was observed that MRT using the MRT instrument is a time saving process for assessing balance abilities among children. It does not require any high end, sophisticated or power run equipment. It is a simple instrument which is simple to understand and use. Moreover, it was observed that the duration required for the conduct of test is also very less. The maximum time of MRT were easily recorded. This proved this taken by

any subject to perform the test was two minutes. In two

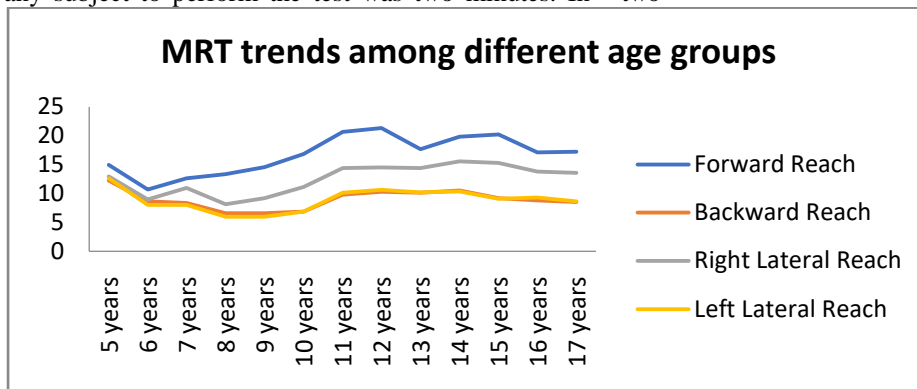


Fig1: MTR trends among different groups

Table 1 Demographic characteristics:

Discussion

minutes’ duration the scores of all the four directions

increasing the fear of fall and limiting the excursion in backward direction (Schedler *et al.*, 2020). Promsorn

Traits	Total (n=1300)			Male (n=688)			Female (n=612)		
	Median	Skewness	Kurtosis	Median	Skewness	Kurtosis	Median	Skewness	Kurtosis
Descriptive statistics									
Age	11.00	0.00	-1.22	11.00	-0.06	-1.17	11.00	0.06	-1.26
Height	144.50	-0.38	-0.85	148.0	-0.52	-0.75	140.0	-0.28	-0.91
Weight	45.00	-0.14	-0.98	46.0	-0.23	-0.95	42.0	-0.15	-1.12
BMI(Kg/m²)	20.82	0.44	-0.60	20.71	0.50	-0.58	20.93	0.38	-0.62

instrument to be a time saving equipment which can be easily used by anyone without much training required. The results of the present study reveal that MRT scores increases with advancing age according to the trends observed among different age groups of children. This revelation is supported by the findings of a study conducted by [12] Cumberworth *et al.*, (2007) in which they reported that balance functions improved with progression in age. They attributed this improvement to the fact that as the children grow, their vestibular functioning develops with age. Moreover, the increase in height with age contributed to improved visual sensation which is another factor responsible for balance improvements.

The result of the present study showed that maximum reach score was obtained in forward reach among 12-year-old age group [score 21.33 (skewness 0.08 kurtosis 0.97)] whereas the lowest score was obtained in backward reach among 8-year-old age group [score 6.58 (skewness 1.20 kurtosis 0.91)]. In all the age groups it has been found that the scores of forward reach are higher than the scores of backward reach. This result is in agreement with the findings of a study conducted by Newton (2001)[7] in which it was found that FR scores are higher as compared to BR scores. This can be attributed to the fact that while performing FR visual feedback is present which plays a vital role. Apart from that while bending forward the centre of gravity is moving towards the boundaries of stable support. This movement can result in greater excursion while performing FR in MRT. On the other hand, while one is reaching backwards, the visual feedback is absent. Further, the centre of gravity also tends to move out of the stable base of support thus

and Taweetanalarp (2021) [13,14] conducted a study among children having Down’s Syndrome and aged between 7 to 9 years to assess the scores of multi directional reach test. In this study they found that forward reach scores were higher when compared to backward reach. This part of the finding was in agreement with our result. The results of the multi directional reach test is also associated with the strength of the lower extremities. The knee and hip musculature plays a major role in determining the range of excursion in all the four directions.

It is because optimal co-activation of the agonist and antagonist muscles is required to reach in all the four directions without losing contact of the feet with ground or by loss of balance. This finding is reflected in the study conducted by Hirunyaphinunet *al.*, 2019.[15] In their study they also cited the reason for having low scores in backward reach and higher scores in forward reach. They reported that hip angle. Forward reaching requires flexion of the hip whereas backward reach requires hip extension. When this is correlated it implies that since hip flexion range is more in humans therefore the forward reach excursion will also be higher. On the other hand, hip extension range is less which can be attributed as one of the facts for having lower scores in backward reach. extension angle is less as compared to hip flexion One more factor which they added was that most of the daily activities are carried out in forward direction and balance abilities are well developed for such activities in individuals. Therefore, task of forward reach doesn’t appear to be highly challenging. The body tends to lose balance when the activity being carried out is more challenging. Since in backward bending

Age(years)	Descriptive statistics	FR (cm)	BR (cm)	RLR (cm)	LLR (cm)
5	Median	14.95	12.25	13.00	12.66
	Skewness	-0.21	0.08	0.04	1.15
	Kurtosis	-0.32	-1.08	-0.43	5.00
	95% CI	13.9-15.5	11.3-12.9	12.00-13.7	11.3-13.2
6	Median	10.70	8.66	9.00	8.10
	Skewness	3.67	1.25	0.89	1.31
	Kurtosis	22.70	1.50	-0.24	1.27
	95% CI	11.0-13.5	9.00-10.5	9.3-11.0	8.4-9.6
7	Median	12.66	8.38	11.00	8.05
	Skewness	0.57	0.73	-0.55	1.21
	Kurtosis	0.92	0.26	-0.19	1.85
	95% CI	12.3-13.5	8.2-8.7	10.33-11.1	8.1-8.9
8	Median	13.33	6.58	8.20	6.00
	Skewness	0.60	1.20	1.04	2.40
	Kurtosis	-0.47	0.81	0.85	6.66
	95% CI	13.3-15.1	7.0-8.1	8.4-9.6	6.2-7.2
9	Median	14.60	6.60	9.30	6.00
	Skewness	3.17	2.00	1.11	1.60
	Kurtosis	18.70	3.73	0.15	1.21
	95% CI	14.4-16.7	6.8-7.7	9.7-11.2	7.5-9.4
10	Median	16.90	6.90	11.2	6.92
	Skewness	0.30	1.14	0.70	1.16
	Kurtosis	-0.77	0.94	-0.14	0.81
	95% CI	15.8-18.1	7.4-8.5	10.7-12.3	7.9-9.5
11	Median	20.66	9.83	14.43	10.17
	Skewness	-0.08	-0.30	0.53	1.23
	Kurtosis	-0.48	-0.30	1.79	1.07
	95% CI	19.7-21.1	9.1-10.0	14.1-15.2	10.5-11.5
12	Median	21.33	10.33	14.6	10.70
	Skewness	0.08	-0.47	0.13	1.53
	Kurtosis	0.97	-0.33	-0.30	3.54
	95% CI	20.3-22.0	9.5-10.4	13.8-15.1	10.5-11.5
13	Median	17.70	10.21	14.42	10.20
	Skewness	0.83	0.14	-0.10	1.21
	Kurtosis	1.24	-0.61	-0.72	4.41
	95% CI	17.6-18.9	9.9-10.5	13.9-14.8	9.9-10.7
14	Median	19.83	10.50	15.60	10.41
	Skewness	0.45	0.30	0.11	-0.01
	Kurtosis	0.64	0.80	0.20	-0.80
	95% CI	19.5-20.7	10.4-11.1	15.00-16.4	10.3-11.0
15	Median	20.20	9.17	15.33	9.13
	Skewness	-0.18	0.53	0.10	0.13
	Kurtosis	0.68	0.34	0.30	-0.50
	95% CI	19.3-20.3	8.8-9.4	14.9-15.8	8.8-9.4
16	Median	17.10	8.90	13.83	9.33
	Skewness	-0.33	0.25	0.10	0.32
	Kurtosis	1.30	-0.30	-0.37	0.30
	95% CI	16.6-17.7	8.8-9.2	13.4-14.5	9.1-9.6
17	Median	17.21	8.50	13.60	8.70
	Skewness	3.40	0.81	4.51	1.00
	Kurtosis	17.40	0.89	25.7	1.02
	95% CI	17.0-19.5	8.6-9.3	13.2-15.8	8.7-9.4
5-17	Median	17.21	9.00	12.83	9.33
	Skewness	1.02	0.90	1.55	1.30
	Kurtosis	6.41	1.50	13.6	4.50
	95% CI	16.7-17.3	9.1-9.4	12.6-13.1	9.3-9.7

TABLE 2 Normative reference values of MRT (5-17 YEARS)

the hip extension range is also less and there is no visual feedback also, so the task appears to be more challenging therefore decreasing the reach ability of backward reach. In this study, it is also observed that the RLR scores are comparatively higher than the LRR among most of the age groups. This result can be attributed

to the fact that among Indian population most of the people are found to be right hand dominant. As a result of this the excursion towards the right hand side comes out to be more compared to that on the left hand side.

Holbein-Jenny *et al.*, performed a study to examine and compare the construct validity and reliability of Berg Balance Scale (BBS), Multi Directional Reach Test (MDRT) and Activity Specific Balance Confidence Scale (ABC). The study was carried out upon elderly people aged between 70 to 90 years of age. Following the results of the study they concluded that all the three tools were reliable for assessing balance and estimating the risk of fall in the mentioned population but they found that although ABC was a valid measure but it was quite difficult to administer this tool among the geriatric population. On the other hand, they reported that BBS and MDRT were valid measures for psychomotor skills and they were more appropriate to assess reaching abilities. In the present study also primary goal was to establish normative scores for multi-directional reach. So the study results of Holbein-Jenny *et al.*, [16] supported the use of MDRT instrument for fulfilling the objective. The normative reference scores for determining balance abilities has been established in this study for children aged between 5 to 17 years and it will remain the standard reference value.

Conclusion

According to the results of the present study, it is concluded that MRT instrument is an effective and time saving tool for assessing balance abilities among children. It is an instrument which is easy to understand and can be used without any special knowledge or training. The normative reference scores for the given age group has also been established in this study.

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