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Age Expansion of Multi-Directional Reach Test to Measure Limits of Stability in Children with Typical Development: A Research Protocol

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Abstract

Background: Physical therapists regularly use various assessment tests to examine static and dynamic components of balance for children with typical development (TD) and with disabilities at various ages. One among them is multi-directional reach test (MRT). But till date, there is no normative data available for MRT in children with TD. *Objective:* To estimate the age expansion of MRT to measure the limits of stability in children with TD. *Study setting:* **S**ubjects will be taken from recognized primary school (Maharishi Markandeshwar International School, Mullana and Govt. Primary School, Mullana). *Procedure:* 194 will be asked to perform MRT and their maximum reaching ability in four directions, forward reach (FR), backward reach (BR), left lateral reach (LLR) and right lateral reach (RLR) will be measured. *Statistical analysis:* Kolmogorov Smirnov test will be used to establish normality and descriptive statistics for reporting the normative data of MRT. *Conclusion:* The normative data of MRT will be reported at end of the study might be beneficial in the assessment of balance in clinical practice.

Keywords: Balance; Functional Reach Test; Normative Data; Primary School; Reference Value.

Introduction

Balance is essential when an individual change his/her position in relation to the environment with feet stationary on the floor during activities like forward, backward, side bending and reaching [1]. Balance maintains body in equilibrium either at rest or during activity in context to centre of gravity (COG) and base of support (BOS). In balanced state forces acting on the body are balanced such that centre of mass (COM) lies within BOS with minimal sway [2-4]. Person's balance is greatest when COG or COM is maintained over BOS [2]. Balance results from the combined interaction of sensory, motor as well as central nervous system [3].

Balance is described in terms of COM, COG, BOS and limits of stability (LOS). BOS is the area of contact between body and its supporting surface. LOS refers to dynamic equilibrium, the boundaries within which individual maintains his/her centre of gravity with fixed BOS [2].

An attempt to save from sudden hazards, involves shifting of COG with fixed BOS to maintain balance [5]. When COG moves outside BOS an automatic strategy is executed to maintain balance either by realigning COG or establishing new BOS. If strategy does not act then person falls [6]. Postural stability is important to maintain balance by maintaining COG within LOS by interacting with musculoskeletal system [7].

Postural orientation is the control of positions of body parts with respect to each other and gravitational forces acting on body [2]. Postural control system aims at maintaining stability and function of the body which is achieved through integrated action of central nervous system. In normal development, postural stability proceeds in cephalo-caudal direction. Infant achieves neck control first followed by trunk and then limbs. Child achieves his complete balance and postural stability by the age of 6 to 10 years [4].

As infants grow they experience postural control difficulties due to change in their neural, sensory and musculoskeletal system with growing age [5]. Postural stability is crucial for maintenance of upright posture and gait. Stability maintenance is

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dynamic process that need continuous processing of sensory input from visual, vestibular and proprioceptive receptors in orders one supervising other [8]. Complex interaction between these systems results in condition that affects the potential to achieve stable posture [4].

There are many factors that interfere with normal balance which includes age of individual, diseased state, developmental or postural disorders like scoliosis, kyphosis [9] variability in movements [10] overweight [11] etc. These conditions in turn lead to falls which in turn leads to death or life long disabilities leads to state of psychological stress. These unintentional injuries due to falls are leading cause of death in elderly [11, 15] and leading cause of functional disability in children [13]. Failure to maintain COG leads to disturbance in balance results in falls which can occur in any age either in elders, adults or even in children [1-7].

Like elderly, balance is equally important in children as children are more prone to falls because of variability in their movement [10]. Children are engaged in more complex motor activities like swimming, sports activities, tracking, dancing, skating, mock-drills etc. [4, 8], which increases their risk of fall. Several factors are responsible for balance in children like age, gender, height, weight, BOS which are considered important in maintenance of balance.

Falls account for considerable morbidity in childhood [12]. Children exposure to traumatic injuries resulting from balance or any other cause hampers the normal patterns of proximal and distal development [13]. Falls lead to functional disability in children which leads to a state of distress. These injuries acts as source of private suffering and has its adverse effect on biological, psychological and social development [13].

In order to avoid falls during functional activities, it is important to establish functional balance norms to estimate risk of falls [14]. Therefore precautions can be taken in those who have less balance as per prescribed norms. There are various clinical tests to test static and dynamic balance ability of children with or without disabilities in any of the age groups [15]. These balance tests are helpful to know the present balance status of an individual and to find underlying cause for balance dysfunction so that intervention is given timely in case of altered balance [16]. Some tests are designed individually to access balance and some are framed to examine gross motor function including evaluation of balance [17].

There are many approaches use to measure balance. Laboratory balance measurement techniques includes stabilography, accelerometer, motion analysis, posturography which are non affordable and having complex functioning [3]. There are many tools available for accessing static as well as dynamic balance in clinical settings for accessing elderly people or people with neurologic deficit like balance berg test, time up and go test, step test etc., [18]. Some test are designed for normal individuals includes unipedal balance test, reach test which includes functional reach test (FRT) and multidirectional reach test (MRT) [19].

FRT was given by Duncan et al which is used to measure dynamic balance in forward direction in elderly population [6]. After a decade Newton gives MRT which incorporate the measurement of balance in all four directions (forward, backward, right lateral, left lateral) in his test that is proved to be more significant [7, 10]. MRT defines the maximal distance which individual can reach forward beyond arms length without loss of BOS in standing position [11, 18].

Disturbing balance in lateral directions with eyes closed are recorded as the increasing cause of falls risk [7]. Clinical assessment tool was developed to measure reach even in medio-lateral directions which was modified form of FRT [7]. MRT proves to be more challenging as it does not provide any security as the person is made to perform test without giving any support [6].

MRT is tool to measure LOS in all four directions [6, 8]. In this individual COG is made to shift with respect to BOS by making movements in different directions [2, 7, 18]. It is a reliable tool for assessing dynamic balance and LOS in antero-posterior and medio-lateral direction in elderly [19]. MRT is a single task test which examines voluntary postural responses of upper limb and limits of stability in different directions [2]. MRT proves to be very useful assessment tool for postural and balance control [19].

As children have variability in their movements we think that MRT will prove to be more beneficial in assessment of their functional balance. In response to findings of elder's accidently falling backward and lateral side, Tantisuwat et al, performed MRT on population range 20-79 years of age to determine LOS in this age group [19]. To our knowledge, this is the first published study will be available to investigate reach test in different directions in different age groups. Newton reveals that values of MRT decreases with age. There is no study which emphasize on limits of stability of children and adolescent. Therefore aim of this study is to quantify limits of stability of children aged between 5-12 years.

Review of literature

Balance is a complex process which involves the reception and integration of sensory inputs for planning and execution of meaningful movements, in order to achieve a upright posture (Leslie Allison) [19]. In system approach, the dynamic system's model for dynamic equilibrium recognizes that balance is a result of combined interaction between individual, task performed by the individual and the corresponding environment in which individual is asked to perform task [19-20].

Nasher explains various specific motor synergies which are achieved through synergistic actions of muscles. These strategy patterns for postural movements are executed to maintain equilibrium in various different situations [22]. Factors that influence balance ability include anthropometric measurements like height, weight, foot size etc, cognitive abilities, physical activity lifestyle and injury to limbs. Thus assessment of balance is necessary in examination of balance in order to frame effective rehabilitative measure or to prevent risk of injury [3].

There are various different techniques which are used to access balance which includes laboratory as well as clinical methods. Emery et al (2005) describes various different technical methods to access balance which includes stabilography, accelerometer, motion analysis etc., which have complex functioning and are unaffordable [3].

Berg et al demonstrates clinical methods of balance evaluation includes tinetti performance test, berg balance test, time up and go test. They conducted a study in which they came to a conclusion that clinical functional balance assessment measures were superior to laboratory measures in the measurement of dynamic balance during functional activity [22]. According to Powell et al (1995) balance assessment became more oriented to functional aspects, leads to development of test based on dynamic activities. Thus FRT came into existence which is a dynamic balance test developed to access dynamic balance test in elderly [23].

FRT is a single task test given by Duncan et al (1990) to access problems related to balance in older adults. It examines normal synergy patterns of upper limb and its limits of stability. It examines the maximal distance reached beyond arms length with feet stationary on the ground in standing position with palm facing upward. Purpose of his study was to find the validity of FRT in elders predisposed to recurrent falls. He included 217 males aged between 70-104 years with history of two or more falls within six months.

Bartlet and Birmingham (2003) conduct study to develop and evaluate the validity and reliability of a Pediatric Reach Test (PRT) [9]. In order to modify FRT he included side reaching component along with forward reaching both in sitting and standing positions. He took 19 normal children aged between 3 to 12.5 years. Children were made to complete session of PRT in standing position followed by laboratory force platform tests of dynamic balance. On different time, two different individuals evaluated 10 children with cerebral palsy aged between 2.6 to 14.1 years both in the sitting and standing sections of the PRT. ICC was found to be 0.84 for sitting section and 0.71 for forward reach, 0.75 for right reach and 0.82 left reach in sitting position. Score was 0.97 for standing Section and 0.86, 0.88, 0.94 for forward reach, right reach and left reach respectively in standing position .This study provides evidence that the PRT is a simple, tool with validity and reliability which can be used in children with cerebral palsy. Addition of a sitting component enables us to use the test in children with various classifications of cerebral palsy, including those children who are not able to stand on their own. Addition of lateral reach components both in sitting and standing positions, and use of orthoses and walking aids during performance of test indicates the functional aspects of balance in a more typical context than standing barefoot without aides.

Volkman et al (2007) perform study for examination of FRT scores for the effects of traditional and alternate methods and subject characteristics [11]. He took 80 subjects aged between 7 to 16 years. He tries to define a relationship among the effects of measurement method and style of reach. He concluded that FRT scores were affected both by style of reach and its method of measurement. Mean reach scores were compared among the 4 FRT methods. Summarizing across height, gender and strategy categories, the least squares mean ± standard error values for the reach scores were 30.92 ±0.80 cm for the 1 arm finger to finger approach, 82.32 ± 1.38 cm for the 1 arm toe to finger approach, 31.08 ± 0.79 cm for the 2 arm finger to finger approach, and 76.02 ± 1.28 for the 2 arm toe to finger approach. Significant interaction between the 2 variables of style of reach (1-arm or 2-arm) and also measurement method (finger-to-finger or toes-to finger) were defined. Different method for the calculation of FRT from toes to fingers was explored during this study. In this method, the FRT was measured as the distance between the starting point of the meter stick and the fingertips at the end of reach. For the calculation of the toe-to-finger score, there was no measuring of initial hand position as for the finger to-finger score.

The toes were aligned with the edge of the paper and the end of the measuring stick as previously. This method was applied for both the one-arm and the two-arm reach tests.

Norris et al (2008) perform study on FRT scores in young children to define the relationship between anthropometric measures and FRT scores. He took 121 normal children aged between three and five years in this study [16]. He analyzed mean of three successive trials on the basis of which he came to a conclusion that FRT is a feasible test to examine the balance of four and five year-old children and should be administered with care in three year old children. Mean standard deviation was calculated for all age groups. Values were: three year old children reached11.4 ± 2.6 cm, 4-year-old children 13.6 ±3.0 cm, and 5-year-old children 15.7 ± 4.4 cm. The 95% confidence intervals for the mean and the average reach value for 2 standard deviations below the mean are reported. He further concluded that significant predictor for FRT was weight in children and there is no affect of age, gender, height, arm length on functional reach in children as children used various strategies when challenged to do some action as explained by Nasher.

Deshmukh et al (2011) conducted a research in order to define normative values for reach in forward (FR) and lateral directions (LR) in school children and their relationship with anthropometric measurements like height, weight, gender etc. He included 350 children aged between 6 and 12 years by random sampling. On the basis of test performed and scores obtained he found value ranging between 22.7 cm to 37 cm for FR and 16.3 cm to 22.5 cm for LR. He established that height has significant relation with both FR and LR [4].

Later study was conducted by Deshmukh (2014) in order to find out the relationship of anthropometric measurements to the normal values of functional reach (FR) and lateral reach (LR) in school children with knee joint hyper-mobility (KJH). One hundred and forty children aged between 6 and 12 years with typical development (TD) and who have significant hyper-mobility of both the knee joint greater than 10° of hyper-extension were included in his study [25]. The values of FR for children with bilateral KJH ranged from 24.37±1.97 to 28.77±3.22 cm, and LR mean values ranged from 17.30±0.97 to 19.20±1.79cm in the age group of 6 to 12 years. Three successive trials of FR and LR tests were taken and analyzed. On the basis of his results he concluded that Height of children and hyper-mobility of their knee joint affect children scores in terms of functional reach. Successful significance of FRT was proved on the basis of different studies. But as children have variability in their movements it was thought that establishment of forward reach values are not sufficient to assess balance which leads to exploration of multidirectional reach test (MRT).

Newton (1999) performed a study which aims at developing portable and valid tool to measure limits of stability in all four directions (anterior, posterior, medial, lateral) [7]. He included 254 community-dwelling older persons. They were administered the Berg Balance Test (BBT), the Timed Up & Go Test (TUG), and the Multi-Directional Reach Test (MRT). For the MRT to perform, subjects were asked to reach maximal with the outstretched arm in all four directions. Based on his results he demonstrated that MRT has significant correlation with the BBT sum and significant inverse relationship with the scores on the TUG [1]. Mean scores on the MRT were 8.89±3.4 for reach in forward direction, 4.64±3.07 in backward direction, 6.15±2.99 in right lateral and 6.61±2.88 in left lateral direction. Interclass Correlation for the reaches were greater than 92. According to results obtained, scores on the MRT were directly affecting the scores of the BBT which concludes that more score scored on the BBT scale, the greater will be the distance reached in all four directions.

MRT scores shares inverse relationship with scores on the TUG which demonstrates faster the individual performed the TUG, the greater will be the distance reached in all directions. This significant relation in between the scores of MRT, TUG and BBT indicate that these screening measure to access balance are although similar but each shares unique aspects of balance abilities. Therefore, it will be justified to perform these tests in combination with one another to obtain a more improved and precise assessment of balance abilities. On the basis of these results he proves MRT as an inexpensive tool with adequate validity and reliability, for screening the limits of stability obtained by making the subject to reach in all four directions and this test can be performed including BBT and TUG test to obtain comprehensive clinical measure of balance abilities.

Hardy et al (2008) performed a study to determine prophylactic ankle braces affect on MRT distances during a test of dynamic balance [26]. Study was conducted to determine the effect of any prophylactic ankle braces on MRT score during a test of dynamic balance. Thirty six healthy, physically active volunteers were included in the study. Participants were asked to performed balance test first without brace, then perform test wearing a semi rigid ankle brace, and in last wearing a lace-up ankle brace. They used the Star Excursion Balance Test as an outcome

measure. Calculation was made by the mean of results obtained in three trials performed in eight directions. On the basis of results he came to a conclusion that orthrosis had no effect on any of the Star Excursion Balance Test directional measures [26].

Tantisuwat et al (2013) then conducted a study which aims at establishing MRT a validity and reliable tool for measurement of limit of stability. He aims at proving that MRT is a simple and inexpensive tool for assessment of balance. Basic aim of this study was to quantify the limits of stability of people aged between 20 and 79 years using the MRT. He included 180 subjects which were divided those subjects into the six groups in increasing order of their ages. The MRT performed in all four directions was used to measure the limits of stability. Subjects were asked to perform test by maximally outstretching their arm beyond their limits of stability with their feet flat over the examination area. Scores on the multi-directional reach test MRT (in cm) for different age groups were estimated and found to be decline with age . He found significant differences in values of test performed in the forward, leftward and rightward directions. No significant differences in scores were seen in the test performed in backward direction. Subjects in all age groups showed the greatest value of MRT in the forward direction, whereas the lowest values of MRT are obtained in the backward direction. This may be due to the biomechanics of the joints of lower limb, which allows greater capacity for forward reach than that for backward. This is thought to happen because majority of the activities of daily living are commonly performed in front of the body means in forward direction which proves to be helpful for subjects to have better control of balance in the forward direction. This study proves that MRT appears to be a useful assessment tool for Postural control and balance for older age group [19].

Sharma et al (2014) conducted a study in order to find the minimal detectable change of multi directional reach test in children and adolescent aged between 5 and 19 years. Eighteen children were included in study recruited in the study by convenience sampling technique. Measurement of height and weight was taken before initiation of the study. Evaluation is done using instrument consists of two metallic rulers and an adjustable wooden frame. Children were asked to perform test in all four directions with their feet flat on floor and shoe off. Three trials were taken in each direction and mean of three was calculated. Intra observer reliability was measured on intervals.ICC was calculated as 0.94, 0.93, 0.95, 0.79 and MDC values were 5.18, 4.46, 4.01, 7.87 for forward, backward, left lateral and right lateral directions respectively. At the end of the study MDC of MRT is established [27].

Need of the study

MRT is a tool which lacks in normative data for children. This study will help in establishing normal MRT values for children and adolescent.

Methodology

Sample size

It will be calculated using following formula

$$n = (Z\alpha\sigma / d)^2$$

$$n = 194$$

Sampling

Sequence sampling

Subjects selection criteria

Inclusion criteria

1. Children with typical development
2. Co-operative children
3. Aged between 5 and 12 years
4. Children with age appropriate height and weight

Exclusion criteria

1. Children having any visual impairment
2. Children having any vestibular impairment
3. Children with any hyper or hypo mobility
4. Children with previous history of upper or lower limb fracture
5. Functionally dependent children
6. Children with psycho-social disorder
7. Children suffering neurological disorders
8. Children with cognitive impairment
9. Non co-operative children
10. Other medical condition

Materials used for assessment

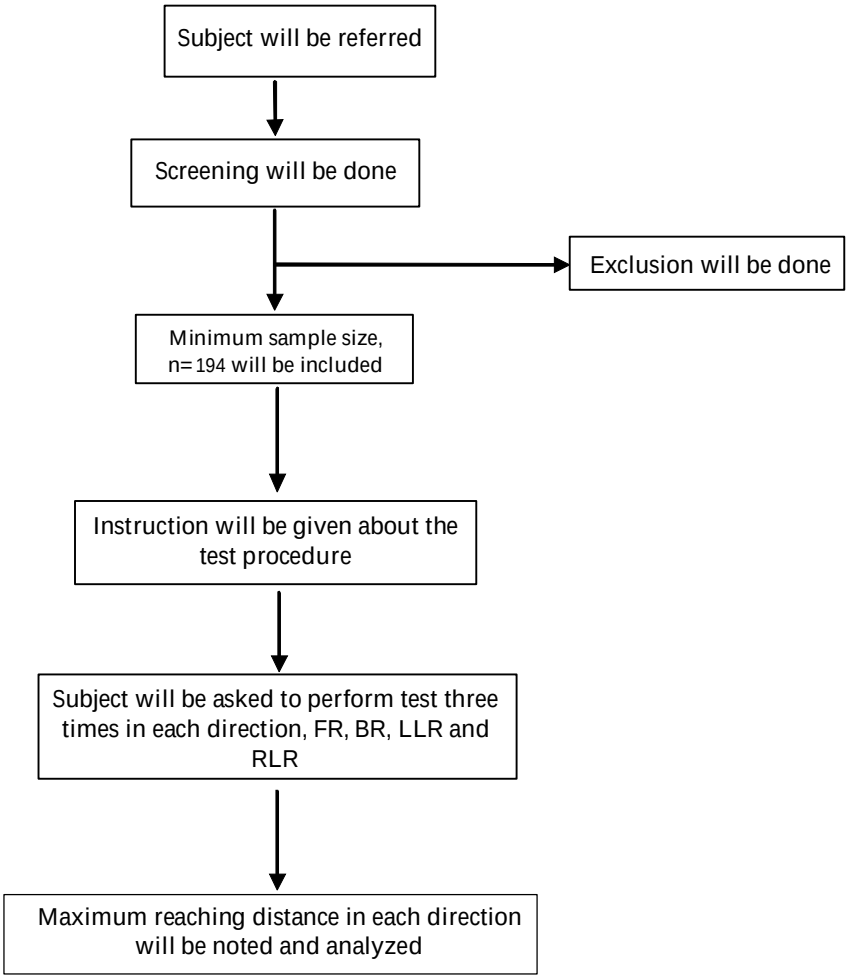
- White sheet / flex
- 3 Rulers (two with 60 cm and one with 30cm of length)

- Three adjustable wooden stand
- Measuring tape (Coman®)
- Weighing Machine (WC 150)
- Other necessary stationary (pen, paper, cardboard, scale)

Outcome measure

Maximum reaching distance measured in cm

Study protocol flow chart



Procedure

The study protocol has been approved by the university ethics committee (MMU/IEC/443). The study will be performed between October, 2014 and May, 2016. Before commencement of the study, assent from participating children and consent from their parent/guardian will be obtained. MRT consist of reaching maximum with outstretched hands in multiple directions (forward, backward, left lateral, right lateral) with feet stationary on floor without losing balance. Measurement will be taken from starting position to the point up to which participant can reach maximum in different directions. Anthropometric measurements will be taken prior to study which include estimation of height, weight, body mass index, arm length. Arm length is taken from acromion process of scapula to end of middle finger.

For performing MRT, three adjustable wooden frames with two metallic rulers each of 60cm will be used. White background will be kept behind the instrument. Subjects will be made to stand in front of the apparatus and ruler is adjusted at the level of acromion process. Subjects will be asked to reach maximum in each direction.

Subjects will be given demonstration regarding the procedure. After sufficient practice trials, they will be instructed first to raise their arm to 90° with palm facing outwards from starting position and asked to reach maximum in forward direction then come back to starting position. Followed by this the subject will be asked to reach in left lateral direction, come back to starting and then asked to reach right lateral direction without losing base of support. At the end subject will be asked to lean in backward direction as shown in figure 1 and 2. Maximum reaching ability in each direction will be recorded to tabulate the normative data of MRT.

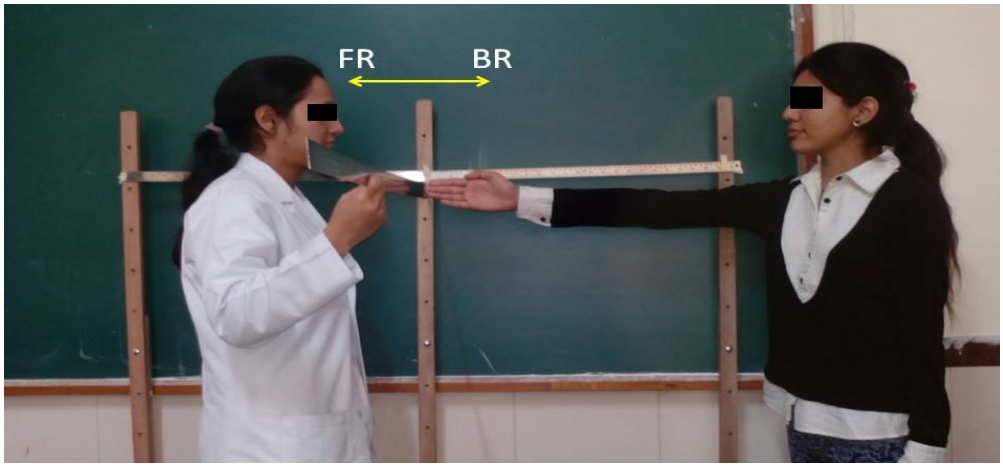


Fig. 1: Children with typical development (TD) performing forward and backward reach test (FR and BR), a subdivision of multi-directional reach test (MRT)

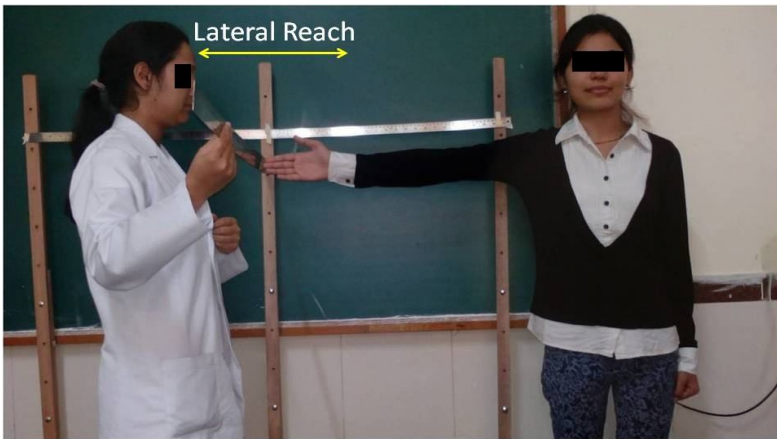


Fig. 2: Children with typical development (TD) performing left lateral and right lateral reach test (LLR and RLR), a subdivision of multi-directional reach test (MRT)

Data analysis

Data will be analyzed using software SPSS Version 16.0 (SPSS Inc. Chicago, IL, USA). Normality of collected data will be established using kolmogorov-Smirnov test of normality, which is used in case of sample size >50. If data follows normal distribution average MRT value will be expressed in terms of mean ± SD. If not, expressed in median and inter quartile range (IQR) or mean and 95% confidence interval (CI) or geometric mean and range. Independent t-test (parametric) or Mann Whitney u test (non-parametric) will be used for establishing significant difference in values based on normality. Alpha value will be analyzed if significance will be < 0.05 to minimize type 1 error.

Discussion

In this study, children will be made to perform the MRT in a free standing environment without support, which will be more challenging. Measurement of reach in one direction cannot predict value of other. Therefore it will be necessary to find value in each direction because falls occur in all directions. Hence, reach as a measure of the limits of stability needs to

be assessed in all directions. In a nutshell, the MRT will be a feasible clinical measure for limits of stability. On the basis of such assessments, effective preventative and rehabilitative measures could be developed.

Conclusion

The normative data of MRT will be estimated at the end of the study will be helpful in documenting the prognosis of dynamic balance after rehabilitation. This data will be first available normative report of MRT among the children aged 5 to 12 years.

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