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Relationship of Foot Length with Dynamic Balance in 9-12- Year-Old Children - Pilot Study

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ABSTRACT

Introduction: Dynamic balance as known plays a vital role in the development of the children in both gross and fine motor skills.
Purpose: To find out the relationship between the foot length and dynamic balance in children 9-12-year-old.
Methods and Materials: This pilot study was conducted among children with typical development. The age group included for the study was9-12 years. The estimated sample 24.Participants underwent initial assessment, where height, weight, and foot length were measured. To measure foot length measuring tape was used and dynamic balance was assessed using Functional Reach Test, the participants were asked to perform three successful trials of reaching forward without losing balance or taking support and mean of it were obtained.
Statistical Analysis: The collected data was summarized using the descriptive statistics such mean±S.D. (standard deviation) to find the relationship between the foot length and dynamic balance in 9-12-year-oldchildren, Pearson correlation coefficient was used, p value <0.05 was considered as significant. The data was analyzed using Microsoft Excel and SPSS 21.
Results: The mean distance reached by the children was (21.9 ± 4.9 cm) and mean foot length was (20.8 ± 1.6 cm). The obtained p value for Pearson correlation coefficient was >0.05 and hence there was no relationship found between the foot length and dynamic balance in children.
Conclusion: The foot length has no relationship with the dynamic balance score on functional reach test in children.

Key Words: Foot length, Base of Support, dynamic balance, functional reach test, children 9-12-year-old, relationship.

INTRODUCTION

Postural control is the ability to position the COM (Centre of Mass) of the body within the BOS (Base of Support) of the body so that it is able to perform certain tasks. [1] It includes integration of various sensory information through visual, vestibular, and somatosensory feedback and execution of postural responses. [1] Within BOS if the vertical line of COM passes then, stability can be maintained. Lower the COM over larger BOS and or within same BOS more central the COM stability improves. An unstable posture is observed because of high COM over relatively small BOS. Therefore, dynamic postural stability control system is needed as for the naturally occurring spontaneous sway. [1] The phases of development of child include: Phase 1: The age group involved here was 3-6 years, it said to have less difficulty in equilibrium on flat ground as the child walks, they use the space strategy of head stabilization. But in the children of age 6 tends to show head and trunk stiffness as they face an increase in difficulty in level of equilibrium. Phase 2: The age group involved here was 7- 8 years, now the child is able walk easily even when the level of equilibrium difficulty increases, in space strategy the child got used to the head stabilization. The level of equilibrium difficulty increases as the child walks in a path that is way too narrow. In the last phase in adulthood they use space strategy quite often, as the child tends to roll. A complex task is to maintain balance while in locomotion, as there is a need to have equal compromise between the body to have lateral stability maintained and the body being propelled forward. [2] The postural control is said to be increasing/ improving when there is decrease in the postural sway. Centre of Mass and its position gives us an idea regarding postural control of a child while assessing it. It's said that the COP (Centre Of Pressure) of the GRF (Ground Reaction Force) below the BOS controls the COM, always the COP moves quickly to catch the COM, as COM moves quite slowly. Usually the information regarding control strategy and stability is given by COP and COM. But it may also be considered that while in standing the COP is not completely aligned with the COM hence, we may consider that COP also provides us the information regarding stability. Under the circumstances where the COM moves away from the body, to get it back to normal COP has to move. When the COM moves away from the body child may induce ballistic strategy and do large corrections of COP to get the COM back to where it was at first (within BOS). As the child ages they may induce the usage of open and closed loop mode of control it may be seen at the age of 8-9 years. [3] Its development occurs in a stage like progression based on the system involved in the postural control. [4] Visual, vestibular, somatosensory, and musculoskeletal systems, through these systems balance is maintained. With age, varies the development of these systems. First system to develop is somatosensory and last is the vestibular. As each system reaches attains a certain threshold which now has ability to support associated behavior in turn develops postural control. [4] Dynamic balance is operationally defined as the ability to maintain postural control during movement, such as reaching or walking. [4] In typical development, the direction of postural stability growth occurs cephalocaudally. Hence an infant at first achieves head control, trunk control and then postural stability. [5] Postural stability maintained or controlled over BOS is balance. [5] In activities like walking, running, and playing balance plays a vital role. Either at home, school, and community. Both balance components are influencing these activities. [5] Balance mainly depends on visual-vestibular systems during early childhood and the dependence than changes to somatosensory-vestibular system. [5] It requires more than 6 years to develop adult like balance. Balance improves as children ages, which allows them to participate in daily activities independently. Adequacy of the postural stability influences the reaching activity quality. [5] Sensory impairment (visual, vestibular, and somatosensory deficit) and children with developmental disabilities such as CP, results in postural and balance issues. These results in various functional impairment like frequent falls leading to reduction in mobility which further leads to disability then morbidity. The dependency on caregiver increases with the postural stability issues and the impairment leads to community participation restriction as the child ages. [5] Systems mature around the age range of 8-12 years of the balance and posture. One of the anthropometric factors i.e. feet that does has its effect on postural control. In the sole of feet there is presence of mechanoreceptors and proprioceptors which conveys information regarding the pressure changes. As the child is on his feet stationary or moving the information regarding the surface gravity orientation, position, external environment, speed and force of the body is conveyed to the CNS (Central Nervous System) through somatosensory system of the feet. [6] There is an interconnection between the development of motor behavior and postural control. Direction specific activation of postural control muscles is seen when there is a sway in the body, like dorsal muscle activation occurs when there is a forward sway of the body, just so that balance is attained. An active body sway can be seen while performing a reaching activity which is task specific. [7] The skills of walking improve as they age and repeated walking makes them more skilled in that task. If observed closely the walking of the children who just began walking, the absence of push off and heel strike phases can be noted. These phases will be present as when compared to adults. A wide BOS support is the preferred walking pattern seen in children which disappears as they grow. They will later be able to manage on manipulating the supporting leg with their body weight as they have obtained an improvement in balance and co-ordination. Up to the age of 3 and a half an increase in the pelvic / ankle spread ratio is seen as the child initiates walking, later on it tends to be consistent. A reduced postural sway and improved postural control can only be obtained through practice. [8] Due to imbalance it results in traumatic injuries and influence the developmental pattern (proximal and distal). Increased frequency of falls in children leads to functional disability and state of distress. These in turn has its influence on several development like social, psychological, and biological. [9] Hence the requirement of the standardized norms is essential for the estimation of the fall risks. And necessary precautions can be planned for the children with less balance as compared with the norms as prescribed. For the examination of the static and dynamic balance there are many tests for certain age group and children with and without disabilities. The balance examination through these tests helps us to understand about the current balance status of the child so that if the examination results show reduced balance compared to the prescribed norm, early detection of its cause and the particular intervention can be initiated. The tests involved in the examination of balance does not only assess balance some also assesses the gross motor skills. [9] The static and dynamic balance can be examined in 2 ways either in a laboratory or through standardized scales or tests. The instruments in laboratory used to examine balance are stabilography, motion analysis, posturography and accelerometer these are highly cost effective and functions are complex. Scales or tests used to assess static balance one of them is Romberg test. FRT is a test used to assess dynamic balance in forward direction in children which was given by Ducan et al**.** [9] In relation to environment with feet stationary on the floor during forward, backward, side bending and reaching activities, balance is essential. [9] The development of balance is interconnected to the development of the other skills, like motor skills, activity participation, physical development. [10] In dynamic balance control there is involvement of the environment, task, and biomechanical constraint as well, hence these factors must also be looked upon while assessing. During reaching activity there is a certain pattern for the muscle activation, which also includes shoulder blades protraction and trunk rotation these end up altering the distance reached scores. These are not only the factors that influence reach distances but there are other factors like characteristics of the participants and procedure used for the testing. In the context of the psychometric properties of FRT it has been proposed as discriminative and diagnostic tool of postural control- feed forward mechanism. [11] There is requirement of the feedforward control during dynamic conditions to maintain balance, anticipatory postural adjustments (APAs) can be done if there were postural disturbances on the basis of feedforward control. For a stable posture, at the central level from various body parts the proprioceptive information has to be integrated and co-processed. Perturbations from either vestibular or proprioceptive system through equilibrium control proper muscular response can be initiated; hence nature of the equilibrium control is reflexive. [12] In functional context of reaching, measures dynamic balance on FRT. While controlling the moving COM at a self-induced velocity forward displacement occurs. Test of balance control is FRT, hence biomechanical constraints and environment; tasks must be taken into consideration. [11] Within BOS the ability to keep COG with limited amount of sway is equilibrium. Hence essential for activities and postural control. Controlling equilibrium is an ability that is crucial for children. Daily living activities have been influenced by postural control in standing and sitting. As balance and gait can be influenced by interior or exterior factors, it plays a critical role in daily activities**.** [13] 10-29% of prevalence is of postural balance disturbances**.** [14] A significant component of physical therapy examination is balance examination. Balance can be assessed in either clinical or laboratory test. But downside of laboratory test is it requires special equipment and cost effective, such as force platform and are of complex functioning. These may hinder the clinical application held routinely. Thus, the use of balance assessment tools is highly recommended**.** [15] Those are FRT (Functional Reach Test) and MRT (Multidirectional Reach Test) as it is commonly used for dynamic balance. The advantages of using tests are its cost effective, easy administer and time saving without usage of special equipment. In FRT the participant is supposed to reach beyond the arm's length while feet should be kept fixed position, participant should perform the task without losing balance, taking a step, or touching wall for support or taking assistance of examiner. FRT has a test retest reliability of 0.75, inter rater value of 0.83 and intra rater value of 0.98. [15] Movement pattern and muscle strategies are involved in postural strategies. There are three strategies like hip, knee, and ankle strategies**.** [16] Ability to move voluntarily, react to perturbation and to maintain a position is balance. It can be either static or dynamic. In an antigravity, weight-bearing posture ability to maintain steady position is static balance. In altering position or change in position ability to move while maintaining balance is dynamic balance**.** [17] If there is occurrence of perturbation of the system, sensorimotor information will be integrated through CNS and manages to attain stability. While quite standing 3 of the options can be utilized in the lower body in case of perturbation on the basis of magnitude and direction in order to control posture. Example: 1) An approach involving hip/ ankle/ combination strategies can be utilized if there was anterior/posterior plane of perturbation along with fixed BOS approach. 2) An approach of hip/ stepping strategy can be utilized, if the plane of perturbation is in medial/lateral or its larger. [18] On the strategies used will always depend on the demand of degree of attention during perturbation. Primarily torque begins at ankle joint in the case were ankle strategy is used. In this strategy within the BOS, the COM is maintained by CNS through COP, often referring this strategy as cone/ flexible inverted pendulum. The COP is maintained by ankle strategy through slight sways in anterior/posterior directions while in quite stance. Hip strategy may be used in circumstances wherein there is narrower BOS or high intensity perturbation and maintain balance of system, in these circumstances the utilization of ankle strategy would be of no use. The recovery from imbalance while utilizing the hip strategy there is quick and large movements and at ankle there is rotation in antiphase. In the situation where the perturbation occurs in medial/lateral plane then the hip strategy used causes hip lateral movement which induces both abduction and adduction of either of the legs. If the intensity of the perturbation is way higher then, in order to prevent oneself from falling one must take a step ahead. The sequence of postural muscle organization in children who has just begun to walk independently as they develop is in an ascending manner from distal to proximal, also its response is way slower in children when compared to adults. [18] The perturbation with higher intensity can only be withstood if the child has enough of locomotive experience and by not using the stepping strategy. Anticipatory postural control adjustments (APAs) is the one through which an individual is able to recognize and prevent oneself from postural stability getting disturbed even before the perturbation appear. The equilibrium system getting disturbed can only be adjusted through joint torques induced by priorly determined postural strategies although feed forward control has its form which is APAs. They function in 2 forms: 1) for the purpose of movement preparing the posture 2) lending assistance on the basis of velocity or force. Some studies reveal that on the basis of magnitude regarding the perturbation which may lead to instability the anticipatory adjustments take place. Some studies indicate that the perturbations that are predictable, humans are capable of getting used them and maintain stability. Postural synergies are utilized for the faster application of mechanism of postural control through CNS. A certain group of muscles are forced to work up on, when there is CNS level motor control simplification, although single neural command is conveyed to one group of muscles. [18] There is equal amount of activation of every muscle through CNS. Task oriented goals are performed with reduced influence of CNS under the control of functional coupling of muscle groups in comparison to if activation took place one by one. There is no requirement of multiple joints spanning through separate muscles, as desired task level function is required to be mentioned only, this is performed through the central-set based mechanism postural strategies. Within a synergy if one is able to regulate the timing of the muscular activation then task can be performed optimally. Through perturbation studies the typical understandings of the muscle synergies come. The coactivation of the limb and trunk muscles are initiated by the synergies and also COM has some relation regarding the synergy recruitment in the muscle. An activation of one or more synergies can take place during perturbations, even in different individuals as seen in muscle activation differs from trial-to-trial. For a task to be conducted there should be combination of synergies in different proportions. Parallel changes can be seen in every muscle as a result, when in-accordance to the varying task the control signals conveyed by the synergies will also vary. For the co-ordination of motor outputs, the muscle synergies act as central mechanism, therefore it refers the muscle synergies are not reflexive in nature. Muscle activation of both voluntary movements and automatic postural adjustments occurs in a quicker way and the degree of freedom being reduced for the system is due to postural synergies utilization. In a descending influence, like prior experience, anticipation and sensory feedback, modulation occurs from the muscle synergies contribution. [18] Adults are likely to rely on hip strategy, while children are more likely to rely on the ankle strategy. [19] With age static balance improves, but the reliance on vision continues. During external perturbation there is requirement of whole-body reaction which should be rapid and must include counter rotation of segments about the COM, lower extremity joint movements, stepping, reaching for a stabilizing object, while in dynamic reaction**.** [19] From vestibular, proprioceptive, and visual systems the information from these must be (re)weighed and integrated by the CNS which induces muscular responses which are well coordinated which in-turn allows an individual to stand upright. [20] Ankle joint torque controls the whole body by moving it as a single segment inverted pendulum, ankle strategy is used under conditions like slow and small amplitude perturbation (i.e. quite bipedal standing). The body moved as double segment inverted pendulum, along with the presence of counterphase motion at ankle and hip is known to be the hip strategy it can be used in conditions like fast or large amplitude perturbation. Although, postural control is said to be multivariate in nature. [19] FRT is defined as maximal distance an individual can reach forward beyond arm's length in a standing position without loss of balance, taking a step, or touching the wall. [21] There are various studies indicating factors like gender, weight, age, height, arm length and length of lower extremity influences balance **,** ErtugrulYuksel et al (2017) found high correlation of height, upper and lower extremity length, and arm span with FRT and exhibit good correlation with age and weight, [15] Aman Khasawneh et al (2015) found that in the case of dynamic balance it was calf circumference and ankle width were the significant contributor, [22] Sara M. Butz et al (2015) strongest relationship was between age and arm length with balance scores on TUG (Timed Up and Go), PBS (Pediatric Balance Scale). [4] Few studies investigated the influence of foot length or BOSon dynamic balance. One of them was Volkman et al (2006) found that BOS, age, height significantly influences on FRT. [23] The recent studies regarding the influence of foot length / BOS were limited hence the need for the investigation of the influence of the foot length/ BOS on dynamic balance in children of age range 9-12 years.

MATERIALS AND METHODS

Ethical clearance was obtained from the ethics committee of A.J. Institute of Medical Sciences, Mangalore. The study was commenced after obtaining approval ethical clearance. This Pilot Study was carried out in a period of 6 months from October 2019 to March 2020. Children of age 9-12 years were included from schools of Mangaluru in Dakshina Kannada, who were screened for inclusion and exclusion criteria, after seeking permission from the Deans of the respected schools, the subjects falling within the inclusion criteria were recruited for the study. Convenient sampling technique was used to include the participants in the study. A sample size of twenty-four was estimated. The parents of the subjects participating in the study were given information sheet containing the study details and, also the Child Assent consent form was obtained from the subject's parents priorly to the commencement of the study. Inclusion criteria for the study were 1) 9-12 years of age group, 2) both genders were included with typical development. Exclusion criteria were 1) neurologic or orthopedic diagnoses, 2) history of developmental delay or balance impairments, 3) history orthopedic surgeries within the past 6 months, 4) all diagnostic conditions and surgical histories were identified through parent report.

Materials: Pen, paper, measuring tape, yardstick, adjustable stand.

Procedure: At first a signed informed consent was obtained from the parents of the participants. A detailed procedure was explained about the test to all participants. After the recruitment an initial examination included the following: demographic data, height, weight. The foot length and dynamic balance was then measured.

Outcome measure: To measure the foot length: Measuring tape**.** To assess dynamic balance: Functional Reach Test (FRT)

Measuring the foot length with measuring tape: It was measured from the end of the heel to the tip of the big (greater) toe in centimeters. [4]

Functional Reach Test (FRT): The participants were asked to remove their footwear and to stand along the wall, there is adjustable stand with yardstick. Participant's right acromion process was palpated, and the yardstick was adjusted to the level of it. The participants stood parallel to the yardstick with their right arm raised up to 90^0. Initial marking was made with reference to the tip of the right middle finger against the yardstick this marking was the initial reach point without the attempt of reaching forward. While performing reaching activity the opposite arm should be kept relaxed on the side. They were then asked to reach forward as far as possible without losing balance or taking a step forward or taking wall support or assistance of the examiner. Once they reach a point beyond their arm's length, they were asked to maintain that position for 3 seconds and terminal reach point was recorded. They were asked to reach forward 3 times between each trial a 5 second rest time was provided. [5]

STATISTICAL METHODS: The collected data was summarized using the descriptive statistics such mean +S.D. (standard deviation) to find the relationship of foot length with dynamic balance in 9-12 years old children. Pearson correlation coefficient was used, p value <0.05 was considered as significant. The data was analyzed using Microsoft Excel and SPSS 21. The obtained p value for Pearson correlation coefficient is >0.05 hence there is no relationship between the foot length and dynamic balance in children.

RESULTS

The frequency of the sample population according to gender included in the study and the percentage of it included is shown in the table 1.

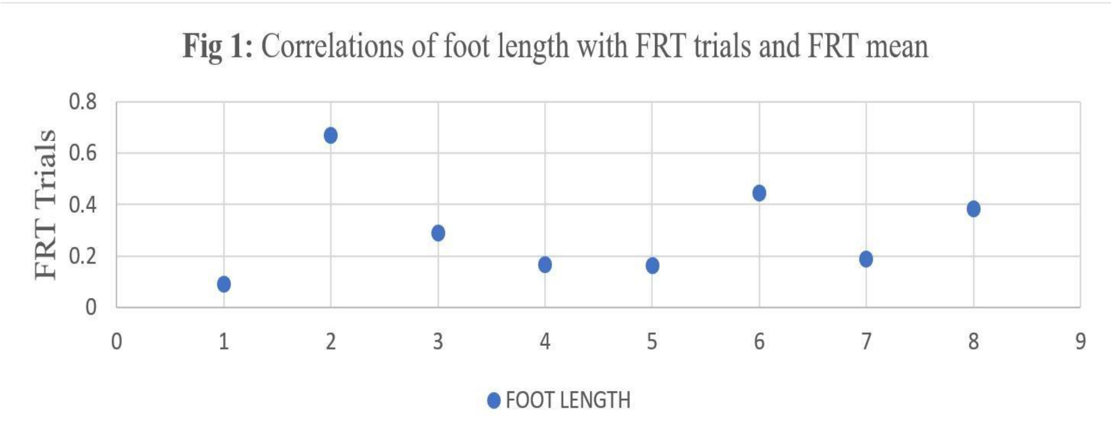
Table 1: Gender wise distribution of subjects

	FREQUENCY	PERCENT
FEMALE	12	50.0
MALE	12	50.0
TOTAL	24	100.0

Mean and standard deviation of the age, height, weight, foot length, FRT trial 1, trial 2, trial 3, FRT mean is shown in the table 2.

Table 2: Distribution of foot length and FRT Mean $\pm$ S.D. (Standard Deviation)

	MEAN	S.D.
AGE	10.50	1.14
HEIGHT	133.3	10.74
WEIGHT	26.62	6.38
FOOT LENGTH	20.89	1.62
TRIAL 1	21.25	5.95
TRIAL 2	21.55	4.99
TRIAL 3	23.04	4.83
FRT MEAN	21.92	4.97



**. Correlation is significant at the 0.01level (2-tailed).

A significant negative relation was found between the foot length and dynamic balance in children. The r (Pearson correlation) and p (significance 2-tailed) values of foot length, FRT trial 1, trial 2, trial 3, and FRT mean were shown in graph Fig 1.

DISCUSSION

The purpose of this study was to investigate that whether foot length relates with dynamic balance in children of age range 9-12 year. As known that dynamic balance plays a critical role in the development of the child. It influences the development of gross motor skills (such as running walking, stepping etc.), physical development and activity participation. The lesser the postural control the more severely the motor skills, physical development and participation in functional activities gets affected, leading to disability. As states priorly the postural control maintenance can be attained and perfection can only be attained if the child has more and more of the experience with perturbation be it predicted or unpredicted. If there is lack of experience the child has with maintenance of postural control the higher the frequency of fall. The fall frequency increases with the reduced dynamic balance as well, which in-turn will lead to physical impairment, which in later stages becomes disability, this causes the dependence level of child on the caregiver to increase. Impairment can also be seen as a result of instability due to lack of activation of various muscle synergies required for the proper postural stability. As mention priorly in this study that there are various muscle synergies involved in maintenance of the postural stability, not all the synergies have a nature as reflexive. Muscle synergies must be identified and initiated accordingly as in the circumstances of predicted or unpredicted perturbation or instability for attaining stability, if the synergies do not act upon in proper timing along the perturbation the individual may experience fall. Hence due to these consequences the examination of balance at earliest becomes very essential for the prevention of the severity of the consequences if any. Early detection of the balance impairment and detecting the underlying causes can lead to better goal specific intervention which will lead to faster recovery as possible. While examining the balance of a child the examiner must keep in mind that the balance can get affected due to several factors which should also be taken into consideration. Factors include internal, external environment, anthropometric characteristics like age, height, weight, gender, arm length, calf width, ankle width, lower extremity length and foot length. This is a pilot study which was conducted in the schools of Mangalore, Dakshina Kannada. After obtaining the approval from the ethical committee, the study was initiated in children of 9-12 years age, who underwent initial assessment which included the recording of the name, age, gender, height, weight, foot length and dynamic balance. Height was assessed using stadiometer, weight through weighing scale and dynamic balance was assessed using FRT were the participants were asked to stand barefoot against the yardstick on the adjustable stand with their arm raised forwards at $90^0$and were instructed to perform reaching activity as far as possible. In each trial the participants were asked to maintain the end position for few seconds. There were 3 trials conducted and mean was also recorded. Rest between the trials were allowed, but no more than few seconds. From several anthropometric factors, the factor included in this study was foot length, which was not found to be influencing dynamic balance. There are several studies resulting in positive relation of anthropometric factors with dynamic balance. But the result of this study showed a negative relation between the anthropometric characteristic (foot length) with dynamic balance. The studies opposing the result of this study include Habib and Westcott (1998) examined FRT scores in Pakistani children 8- to 10-year-olds, base of support (foot length) was a significant predictor of mean FRT scores. [24] Nirav PV et al conducted a study in which they stated that when balance was assessed on PBS it was found that anthropometric characteristics like arm length, foot length, age and height influence the balance scores. [25] Some studies that support various other factors other than in this study, Mathew W. Hill (2019) et al in their study mention that the arms do influence the reaching activity in children. [20] Duncan et al (1990)reported the presence of correlation between arm length and functional reach, [26] Norris et al (2008) examined 3- to 5-year-old children and determined weight to be the only anthropometric factor to predict FRT scores for 3- and 4-year-old children, but no factors predicted FRT scores for the 5-year-old group. [21] Volkman et al (2009) in their study mentions that when assessed for dynamic balance in children with typical development the results showed that the reach scores were affected by age, height and BOS. [11] Limitation of this is the sample size and the procedure used to measure the reach score in FRT. Not only the method used for the measurement of reaching activity but also the methods of reach like 1 arm finger to finger, 2 arm fingers to finger can affect the reach scores. In this study participants were selected on the basis of the inclusion criteria, there were equal number of males and female participants included in this study. In the results of this study it was seen that the mean±S.D. of the distance reached by children in each FRT trials increased. There were few seconds of rest provided to participants between each FRT trials performed. The statistical method used in this study for analysis was Pearson correlation. If p value found to be <0.05 then it was considered to be significant. But if p value found to be >0.05 then it was considered to be not significant. In this study the p value was found to be >0.05. Conclusion of this study states that anthropometric factor (foot length) doesn't influence the dynamic balance within the age range considered in this study. Even though this study concludes that the anthropometric factor specifically foot length doesn't affect the reaching scores on FRT, directly in children with typical development when assessed for dynamic balance, we cannot completely rely on this information as this study was conducted in a small population, which cannot be considered as the representation of the whole population. Hence the suggestion is that there should be further studies on the same factor (foot length) influencing the balance in children with typical development. Future investigations should include large sample size, various ways of measuring reach and various ways of reaching, biomechanical constraints and while assessing reach one should also pay attention while considering dominant or non-dominant arm for assessing the dynamic balance on FRT as the test measure. For the high reliance on the results of this study. While assessing for the dynamic balance using FRT as the test measure, as it is easy, reliable and non-time-consuming method to assess the dynamic balance in children without disability. There are various limitations in this study, first about the sample size, which included only a small population which hinders the reliability of the results. Second, only one standardized scale used in this study for the assessment or investigation of the dynamic balance which was FRT, the limitation is not the scale itself, but it is the method used for measuring the distance reached by the participants. In recent studied it mentions that while using the FRT for the dynamic balance examination in which there is reaching activity it involves various methods to measure initial and the end point reached by the participants. For example, one hand or two-handed reach, (unilateral or bilateral reach), tip of middle finger to tip of the toe distance, open or clasped handed reach. Due to these limitations the results of this study require further investigation to be conducted for the higher reliability of the correlations found in this study.

CONCLUSION

The foot length was found to have no influence on dynamic balance in children of age range 9-12 years.

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