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# Evaluation of Motor Performance and Dynamic Balance Control in Children with Down's Syndrome: A Cross-Sectional Study

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**Abstract:**
**Background**: Children with Down Syndrome (DS) experience significant delays in gross motor and balance functions.
**Aim:** This study aimed to explore the functionality of children with DS in these contexts and investigate the association between gross motor and balance functions.
**Methodology**: Forty children with DS, divided into two age groups (5-10 years and 11-15 years), underwent assessments using the Gross Motor Function Measure-88 (GMFM-88) and the Four-Square Step Test (FSST).
**Results:** Results showed that both groups of children with Down syndrome had lower gross motor function and balance scores compared to reference values for typically developing children of similar ages, with significant differences between groups ($p < 0.05$). Correlation analysis revealed moderate to strong negative associations between GMFM-88 and FSST scores ($r = 0.6$, $p < 0.005$; $r = 0.73$ and 0.56, $p < 0.01$). **Conclusion:** This study highlights the importance of assessing and addressing gross motor and balance functions in children with DS. The observed improvements with age emphasize the need for targeted interventions and support.

**Keywords:** Down Syndrome, Gross Motor Function Measure-88, Four Square Step Test, Motor Function, Balance Function.

## Introduction:

Down's syndrome or Down syndrome (DS) is a genetic disorder where all or part of third copy of human chromosome 21 is present, which leads to significant intellectual disability, [1,2] affecting approximately 1 in 1,000 to 1 in 1,100 live births worldwide.[3] The prevalence of DS is 1 in 830 live births according to Down syndrome Federation of India.[4] DS is characterized by intellectual disability, congenital heart defects, vision and hearing impairments, and obstructive sleep apnea syndrome.[5] As stated by Centre for Disease Control and Prevention (CDC), DS results from three types of chromosomal abnormalities: Trisomy 21 (95% of cases), Translocation DS (3%), and Mosaic Down syndrome (2%).[6] Maternal age is the primary risk factor for DS.[7, 8] Children with DS experience delays in basic gross motor skills, such as standing and walking.[9] Factors contributing to poor motor function include hypotonia,[9] cognitive impairments,[10] balance problems,[10] and sensory integration dysfunction.[11]

There are tools that can be used to test the motor skills of children with Down syndrome (DS) that are based on norms and those that are based on criteria. Norm-referenced scales, such as the Peabody Developmental Motor Scales (PDMS),[12, 13] evaluate a child's performance in relation to peers of the same age who are developing typically. This helps find differences from what is normal for people of the same age. On the other hand, criterion-referenced tools are better for kids with neurodevelopmental disorders like DS. The Gross Motor Function Measure-88 (GMFM-88)[14, 15, 16] is a criterion-referenced scale that evaluates the acquisition of specific motor skills without relying on normative standards. This allows for accurate tracking of each person's progress and direct evaluation of the outcomes of the intervention. We selected GMFM-88 for this study to ensure that the observed motor changes were associated with functional developmental milestones rather than peer performance.

Children with Down syndrome often exhibit unstable postural control, characterized by increased oscillation frequencies in both antero-posterior and medio-lateral planes, regardless of whether their eyes are open or closed.[17] These balance deficits are significantly correlated with delays in postural responses and the achievement of motor milestones during infancy.[18, 19] Testing dynamic balance is important for understanding how this group of people moves because balance is so important for motor development. Standardized tools like the Pediatric Balance Scale (PBS)[10], Reach Test (RT)[10], and Four Square Step Test (FSST)[20] were used to measure dynamic balance. These assessments provide insight into the child's ability to maintain and adjust posture during movement, which is crucial for the proficient execution of motor tasks. This study aimed to ascertain both delays in motor task performance and deficiencies in execution quality by combining GMFM-88 with dynamic balance assessments.

Previous studies demonstrate that deficits in dynamic balance considerably obstruct the development of motor skills and participation in physical activities in children with Down syndrome. To make rehabilitation plans that work for kids of all ages, it's very important to know how gross motor function and dynamic balance are related. Determining the suitable age for the initiation of balance-oriented exercises can improve intervention results.

## Methodology:

This study employed a cross-sectional observational design. The study was conducted between November 2021 to May 2022. A sample of 40 children with DS (24 Males, 16 Females; aged 5-15 years) were allocated into group A with age range 5-10 (Male -13 & Female-7) and B with age range 11-15 years (Male -11 & Female - 9) from special schools of Surat, India, participated. Stratified sampling was used to select participants. Sample size calculation was based on the formula for finite populations [Palal et al., 2023], i.e $n = 4pq/l^2$ , where p = 0.001 (prevalence rate), q = 0.999, and l = 0.1 (error estimate), yielding a required sample size of 40. Inclusion criteria are age 5-15 years, normal or corrected vision and hearing, ability to follow commands. Exclusion criteria were children with DS who could not participate reliably in the assessment procedures, critical medical conditions, recent musculoskeletal injuries and uncorrected visual impairments.

## Outcome Measures

### 1. Gross Motor Function Measure-88 (GMFM-88)[14, 15]

The GMFM-88, developed by Russell et al, is a valid and reliable criterion-referenced measure assessing gross motor function in children with motor impairments (ICC > 0.90).[16]

**2. Four Square Step Test (FSST)[19]**

The FSST, developed by Dite and Temple, assesses dynamic balance and has demonstrated high reliability (ICC = 0.95) in pediatric populations.[9]

**Procedure**

Ethical approval was obtained from the Institutional Ethical Committee (EC/SPB/044) of SPB Physiotherapy College, Surat. The purpose of the study was explained to the parent and a written informed consent, and demographic details were obtained from the parent of all the participating children. Children were primarily screened based on the inclusion and exclusion criteria. Then, children were allocated into groups based on their age. After that, one-time assessment was done on 40 children with DS. The motor function was assessed using the Gross Motor Function Measure (GMFM) scale.
The component wise assessment was taken:
GMFM-A (lying & rolling),
GMFM-B (sitting),
GMFM-C (crawling & kneeling),
GMFM-D (standing),
GMFM-E (walking, running & jumping).
Each item was measured by observation and scored on a 4-point ordinal scale. 0 point indicates that a child did not initiate the task, 1 point indicates the child performed less than 10% of a task, 2 points indicates the child partially completed an item (10% to <100%), 3 points indicates the child completed an activity (100%). Score for each dimension are expressed as a percentage of maximum score for that dimension. The total score is obtained by adding the score for each dimension and diving by 5 (the number of each dimension). So, each dimension contributes equally to the total score. The total score varies from 1 to 100. [14, 15]
The dynamic balance assessment was taken by Four Square Step Test (FSST); the children were asked to step in a pre-determined sequence over four 90 cm long sticks with flat base, placed in a cross configuration on the ground. The subject's starting position was in 1st square facing the 2nd square. The subjects were then asked to step forward, to the right, backward and to the left in each square in the clockwise direction. Then the subjects were asked to do the same in anti- clockwise direction, as the sequence of stepping. Subjects both feet must make contact in each quadrant. The children were asked to complete the test as fast as possible without touching any sticks and the time for completion of the test in both clockwise & anticlockwise directions were noted by stopwatch. All the children underwent practice trial until they become familiar with the procedure. Then, three trials of the test were given to the child with 1 min rest between trials to avoid fatigue. The test score was noted and mean of all the three trials were taken and used as the final score.[20]

**Statistical Analysis:**

Statistical analysis was performed using IBM SPSS Statistics version 20.0 for Windows. All statistical analysis was calculated using alpha level of 0.05. Normality of the data was checked by Shapiro-wilk test. Based on the distribution, appropriate parametric (t-test) or non-parametric (Spearman's Rho) statistics were used for comparisons and correlations. The descriptive analysis was done for GMFM-88; for which median and inter-quartile range was taken. The descriptive analysis was done for FSST. For that mean and standard deviation was taken. For inter-group analysis of GMFM and FSST, the independent t-test was used. The correlation was assessed between GMFM-E component & FSST, Spearman's Rho correlation analysis was done. The correlation between the percentages of full score of GMFM & FSST was assessed with Karl Pearson correlation.

**Results:**

Children with Down syndrome in both age groups demonstrated GMFM scores that reflect the characteristic motor development levels observed in this population. Both groups scored full in GMFM-A (lying & rolling) and GMFM-B (sitting). Group A scored lower in GMFM-C (crawling & kneeling) compared to Group B. GMFM-D & GMFM-E showed reduced scores in both the groups. The low scores in GMFM-D and GMFM-E were due to difficulties in performing specific activities like one-leg stands and hopping. (Table 1)

The result of intragroup assessment demonstrated higher values of FSST, which were >15 seconds, suggestive of increased fall risk and affection of balance function in children with DS of both groups. (Table 2) Older children with DS (Group B) had significantly better scores across GMFM components and FSST (fall risk assessment) compared to younger children (Group A), indicating better motor and balance functions. (table 3) The correlation was assessed between GMFM-E (walking, running & jumping) component and FSST for both groups A and B; which shows moderate correlation where 'r' value was (-0.602) and (-0.599) respectively. There is also statistically significant correlation with p-value of 0.005 between above mentioned components of both groups. (Graph 1 & 2) The correlation was assessed between percentage of full score of GMFM scale and FSST for GROUP-A & GROUP-B; which shows 'r' value of (-0.73) and (-0.56); that suggests strong and moderate correlation respectively. There is also statistically significant correlation with p-value of 0.00 and 0.01 respectively between above mentioned components of both the groups. (Graph 3 & 4). The age-group comparison was implemented to assess whether the trajectory of gross motor development in children with Down syndrome is consistent with prior observations in this population, where older children generally achieve higher GMFM scores. This approach is established in literature for profiling developmental progress in special populations.

**Discussion:**

Our study demonstrated that children with DS experience delays in motor function and balance. Palisano et al. [15] have assessed motor functions of children with DS using GMFM which showed positive correlation between age & motor function, with older children exhibiting better scores and reduced individual variability. It supports our findings that motor performance in children with GROUP-B showed better scores & lesser individual variability with smaller standard deviation compared to GROUP-A. Also, their result favours our findings that none of the children with DS less than 6 years were able to complete all the tasks of GMFM. Preyal et al. [21] justified the probable reason for motor delay stating that it is due to structural differences in the brain like reduction in volume of grey & white matter of the frontal lobes, parietal lobes, cerebellum, corpus callosum and hippocampus.

Wang et al. [22] have assessed motor functions with GMFM & 4 subtests of the Bruininks Oseretsky Test of Motor Proficiency; they found that not all the children with DS aged between 8 to 19 years, were able to achieve full scores in walk/ run/ jump dimensions. We also found the similar result that the children with DS have difficulty in performing one leg standing, hopping, stair walking, tandem walking etc. The probable reason for this is explained by Malak et al. [15] that is improper muscle contraction because of muscle weakness, laxity in tendons, hypoplasia of cartilage, impaired bone density and dysfunction in sensory integration processes. It has been observed that walking is difficult because it requires good balance. Another justification was the children with DS shows higher muscle co-contraction during walking than Typically Developing (TD). This was due to internal low stiffness (tone) and that results inimpaired control in reciprocal movements, as needed to perform above mentioned activities. [14,23] Connolly et al[24] have taken Bruininks Oseretsky Test of Motor Proficiency in children with DS & Mentally Retarded (MR); which shows low scores for gross & fine motor skills, visual motor skills, running speed and strength in children with DS compared to children with MR. It supports our findings of motor delay in children with DS. As Down syndrome is the commonest reason for intellectual dysfunction; the lower Intelligence Quotient (IQ) level can hamper the motor performance of children with DS. Alesi et al. [25,26] have noticed gross motor function delay which is because of impaired cognitive processes like perceptual ability and visual-motor integration. They have also told that the gross motor delay relates to the affected IQ.

Malak et al. [27] have found that some of the children with DS aged more than 6 years were able to perform all the task of GMFM scale; whereas in our study we couldn't find any child with DS who have completed all the task of GMFM. Christina et al. [21] have assessed functional balance by PBS & Functional Reach Test (FRT) in children with DS aged between 8 to 12 years; which was suggestive of affection in balance control with reduced scores in few components of PBS (one leg standing, tandem standing, placing alternate foot on step and reaching forward with outstretched arm). They've also found reduced functional mobility in FRT. It has been observed in our study that the children with DS have difficulty in performing the activities which requires good balance in single limb stance; like hopping, stair walking on alternate foot, tandem walking etc. Also, considerably increased sway was noticed when limits of stability was challenged in some specific activities. We observed impaired way of execution of some tasks in children with DS. Other researchers also observed increased postural sway in antero-posterior & medio-lateral direction for compensation, while performing activities which requires a good dynamic balance. Other compensatory techniques for maintaining balance are increasing posterior displacement and trunk stiffening due to poor postural control. [22,24] Kaya et al. [28] have taken PBS, Timed Up and Go Test (TUG) test in children with DS & TD aged between 9 to 11 years, which shows reduced scores in PBS and increased time in TUG test. Mehta et al. [29] have found affection of FSST & FRT scores in children with DS aged between 5 to 16 years in their pre-assessment of interventional study; which was supporting our findings in FSST outcome. These both studies favour our findings which was increased performance time in FSST (>15 s) of children with both the age groups. The related justification was given by Chen et al. [30] for this was increased reaction time while maintaining balance is due to delayed myelination in children with DS compared to TD. Jung et al. [31] have found balance affection in children with DS (aged between 4 to 12) compare to TD; as they have low scores in Romberg's test, Sharpened Romberg test & FRT. They have also found age wise good scores in children with DS & TD. It was also observed in our study that the children with increased age of DS have better scores in FSST compared to younger children with DS. The probable reason for affection in dynamic balance control was that the children with DS have affected flexor and extensor co-contraction that makes difficulty in maintaining an equilibrium while standing or walking. They have also found that limited movements can lead to difficulty in maintaining equilibrium. [17] Another predictable justification was that poor balance control can be because of slower decision making, declined information processing, reduced skill to integrate multimodal sensory stimuli, longer

simple motor reaction times, delays in the onset of postural control and loss of anticipatory postural control.[29]
Malak et al. [14] have checked correlation between GMFM & PBS in children with DS aged between 2 to 10 years. They have found strong positive correlation between full score of GMFM & PBS with 'r' value of 0.7 and strong positive correlation between GMFM-E & PBS with 'r' value of 0.64 that supports our findings of correlation between GMFM full score & FSST, GMFM-E & FSST; that is negative strong to negative moderate correlation. It has been noted that the children with DS have hypoplasia of cerebellum; hence they have affection in cerebellar functions. The cerebellum is not only responsible for balance control but it has important function in limb co-ordination & locomotion. It plays a crucial role in each level of learning abilities in motor functions. This could be the probable reason for correlation of motor and balance functions of children with DS.[17] It has been observed that the children with DS were facing difficulty in following the task explained verbally; rather they tried to copy the task/ position assumed by therapist. This study demonstrates that advancing age is associated with improved motor and balance function in children with DS, consistent with previous findings. Our findings reinforce the need for age-adapted interventions.

**Limitation**:
1. Limitations include restriction to ages 5 to 15 years and absence of IQ testing, which may affect generalizability
2. Weight was not taken into consideration.

**Future Recommendation**:
1. Future research should include broader age ranges and incorporate cognitive assessments such as IQ to better understand their influence on motor and balance function in children with DS
2. Other correlation can be tried such as Body Mass Index(BMI) & physical function, cognitive and physical function etc.

**Conclusion:**
The results of this study emphasize the necessity of incorporating dynamic balance training into initial physiotherapy interventions for children with Down syndrome. Motor function and balance are closely related, so a comprehensive approach that works on both can improve physical performance and help people become more independent. These findings bolster the formulation of age-specific rehabilitation strategies that emphasize balance control as a fundamental element for motor skill acquisition. Adding these kinds of targeted interventions could help kids with DS take part in more daily activities and improve their overall quality of life.

**Availability of data and materials:**
Data will be shared on specific request to the author depending upon the nature and purpose of the requirement.
***Declaration of interest statement***
The authors report there are no competing interests to declare.

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**Table 1: Median scores and IQR of GMFM components in both the groups.**

| GMFM Component (Full Score) | Group A | Group B |
|---|---|---|
| | Median (IQR) | Median (IQR) |
| GMFM A (51) | 51(0) | 51(0) |
| GMFM-B (60) | 60(0) | 60(0) |
| GMFM-C (42) | 41.5 (2) | 42 (0) |
| GMFM-D (39) | 35(7) | 35(2) |
| GMFM-E (72) | 57(10) | 61(7) |

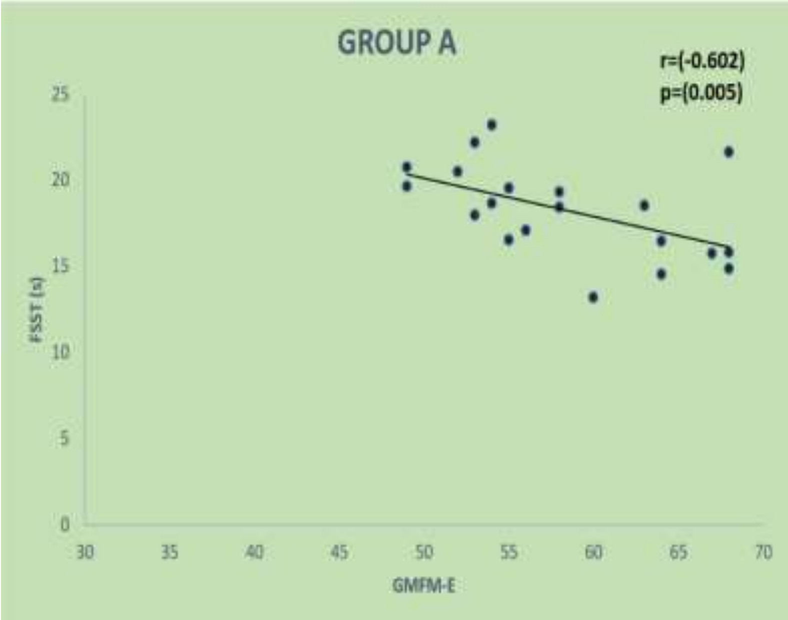
**Table 2: Mean and Standard deviation of FSST of both the groups**

| | Group A<br>Mean ± SD | Group B<br>Mean ± SD |
|---|---|---|
| FSST (s) | 18.2 ± 2.69 | 16.8 ± 1.46 |

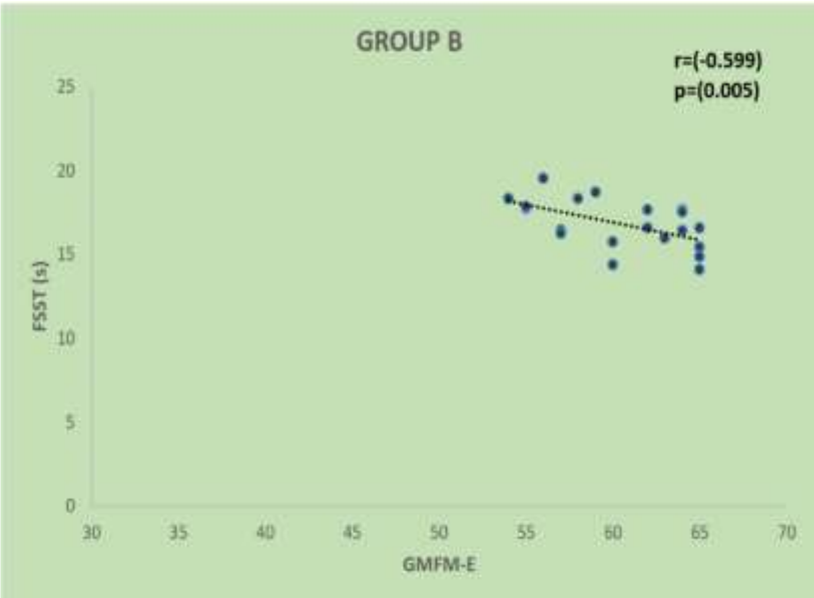
**Table 3: Inter-group analysis of GMFM scale and FSST**

| | | Mean ± SD | M.D | p-value |
|---|---|---|---|---|
| GMFM | GROUP A | 92.8 ± 2.48 | 1.7 | **0.013*** |
| | GROUP B | 94.5 ± 1.25 | | |
| FSST | GROUP A | 18.2 ± 2.69 | 1.4 | **0.044*** |
| | GROUP B | 16.8 ± 1.46 | | |
| ***Significance p<0.05** | | | | |

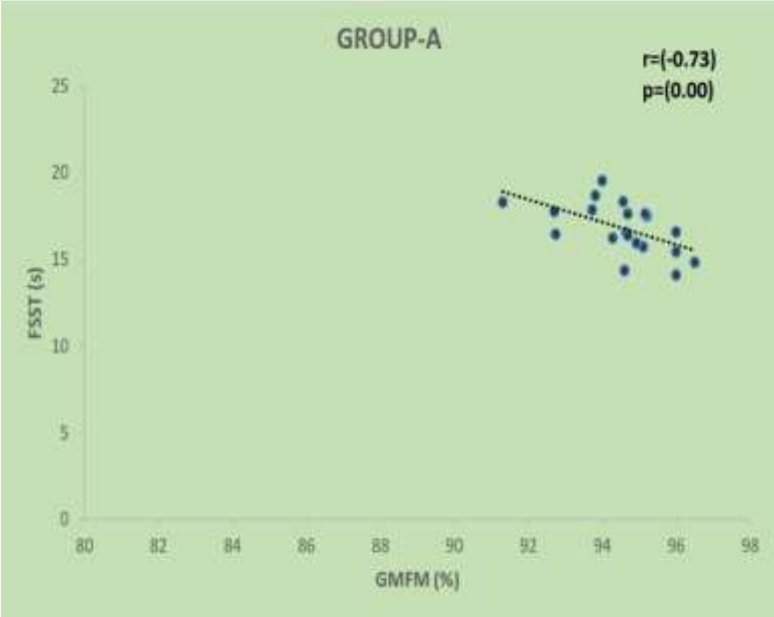
**Graph 1: Correlation between GMFM-E & FSST for GROUP-A**




**Graph 2: Correlation between GMFM-E & FSST for GROUP-B**



**Graph 3: Correlation between GMFM & FSST for GROUP-A**




**Graph 4: Correlation between GMFM & FSST for GROUP-B**