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Efficacy of Ayres Sensory Integration Therapy on Gait and Balance in Patients with Downs Syndrome – An Experimental Study

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Abstract:

- ***Introduction:***
  Down syndrome (DS), caused by trisomy 21, is the leading chromosomal cause of intellectual disability and is often associated with hypotonia, joint hypermobility, and impaired gait and balance, increasing fall risk. While various therapies exist, limited evidence supports the use of Ayres Sensory Integration (ASI) for these issues in DS. This study aimed to evaluate the effectiveness of ASI therapy on gait and balance in children with DS.

- ***Aim:***
  To study the effect Ayres sensory integration therapy on gait and balance in patients with Downs Syndrome.

- **M*ethods:***
  22 children aged 5–11 years with trisomy 21 and IQ ≥50 were included. Participants underwent 18 sessions (45 minutes each, over 6 weeks) of ASI therapy. Gait and balance were assessed pre- and post-intervention using the Paediatric Balance Scale (PBS) and Dynamic Gait Index (DGI). Data were analysed using paired t-tests.

- ***Results:***
  Post-intervention, significant improvements were seen in both PBS (mean increase from 33.68 to 38.09, p=0.000) and DGI scores (mean increase from 13.77 to 15.59, p=0.000). Normality tests confirmed suitability for parametric analysis.

- ***Conclusion:***
  ASI therapy significantly enhanced gait and balance in children with DS, as shown by increased PBS and DGI scores. The structured sensory integration approach targeting tactile, vestibular, proprioceptive, and cortical inputs proved effective in improving motor coordination and reducing fall risk. These results support ASI as a valuable clinical tool for improving functional mobility in this population.

Keywords: *Downs syndrome, Paediatric Physiotherapy, Ayre's Sensory Integration Therapy.*

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I. INTRODUCTION

Downs syndrome (DS) is leading chromosomal cause of intellectual disability and the most frequently reported with birth defect. It is caused by a genetic imbalance resulting in the presence of an extra 21st chromosome or trisomy 21 in all or most of the body's cells. Ninety-five percent of Downs syndrome cases result from a failure of chromosome 21 to split completely during formation of the egg or sperm (nondisjunction) [1]. It is either nondisjunction (95%), translocation (3% to 4%), or least commonly as mosaic presentation (1%). Downs syndrome is found in equal frequency in people from different countries, social backgrounds and economic classes [2].

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An analysis was done using global burden disease data which estimated Down syndrome occurs in ~1 in 800 births worldwide [3]. A 2013 Indian study using maternal age-adjusted data estimated about 37,000 infants born annually with Down syndrome, equivalent to 1.4 per 1,000 live births [4].

The most frequently observed phenotypic characteristics in Down syndrome are epicanthic folds, brachycephaly, flat nasal bridge, upward-slanting eyes, sandal-gap toes, clinodactyly, small nose, a short broad neck, single palmar crease, increased nuchal skin fold, and fissured tongue [5].

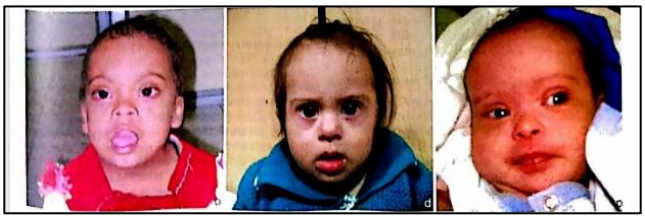

Fig 1 Children with Down Syndrome at a) 3 Months; b) 15 Months; c) 2 Years of Age, Note the Flat Facies, Upward Eye Slant and Open Mouth Appearance [6].

Children with Down syndrome frequently exhibit delayed development and impaired motor control. Neonates commonly experience feeding difficulties. About 50% children also have congenital heart defects of wall between the atria or ventricles. Dichter et al. (1993) reported that children with Down syndrome exhibited significantly lower pulmonary function and reduced physical fitness compared to age-matched controls without disabilities. Reduced cardiorespiratory endurance and weakness of the abdominal musculature have been implicated in the decline of physical fitness [1].

Structural and functional neurodevelopmental abnormalities in individuals with Down syndrome manifest as reductions in overall brain volume, neuronal numbers, and delayed myelination especially within the hippocampus and neocortex. These deficits impair motor control, prompting the central nervous system to adopt atypical co-contraction mechanisms involving simultaneous activation of agonist and antagonist muscles to maintain postural stability. While this compensatory strategy enhances stability, it detracts from the speed and efficiency of voluntary movements. As a result, individuals with Down syndrome demonstrate prolonged reaction times and diminished coordination in tasks like walking, grasping, and reaching. Moreover, deficits in sensory integration and cognitive processing exacerbate these motor delays, further limiting adaptive motor responses [7]. Downs syndrome constitutes a major cause of intellectual disability, with IQ scores typically ranging from 25 to 50, the majority falling within the mild to moderate intellectual disability range. Major sensory systems in children with Down syndrome frequently exhibit impairments in both hearing and vision. Visual deficits may include myopia, cataracts, esotropia, nystagmus, and astigmatism. Mild to moderate hearing loss, whether sensorineural due to dysfunction of the eighth cranial nerve or conductive often secondary to middle-ear effusion is common. Such auditory impairments can contribute to delayed language development.

Life expectancy for individuals with Down syndrome has risen to approximately 60 years. Children with DS face a 15–20 % risk of developing leukaemia during the first three years of life. The final major health concern for this population is Alzheimer's disease.

Musculoskeletal manifestations may encompass pes planus (flatfoot), thoracolumbar scoliosis, patellar dislocation, and potential atlantoaxial instability (AAI), with the incidence of AAI estimated between 10% and 15%.

Along with the manifestations mentioned above the main characteristic features of Down syndrome are hypotonicity, joint hypermobility and ligamentous laxity. Ligamentous laxity along with resulting joint hypermobility is thought to be caused due to a collagen defect. Hypotonia is not only due to cerebellar alterations but also from dysfunctions in other central nervous system regions and processes. Due to decreased muscle tone and generalized joint laxity, these children often face challenges in achieving stable head and trunk control. As a compensatory mechanism, they rely on positional stability for instance, adopting the "W-sitting" posture in order to maintain trunk stability while seated. Furthermore, children with Down syndrome frequently avoid engaging trunk musculature for rotational movements and tend to transition from prone to sitting with legs held widely abducted [1].

Children with Down syndrome demonstrate significantly reduced balance and gait abilities compared to their typically developing peers. Their static and dynamic balance remains low throughout growth, even after achieving independent walking, whereas typically developing children show continued improvement with age. These limitations are primarily due to intrinsic characteristics of Down syndrome namely, muscle hypotonia, excessive ligamentous laxity, and postural instability which collectively disrupt the development of effective gait patterns. Gait deviations commonly include slower walking speed, shorter step length, wider base of support, pronounced postural sway in both anterior–posterior and mediolateral directions [8]. The gait pattern is poorly coordinated gait with legs spaced widely; knees are bent with their feet turned out like pigeon toed manner [9].

Following are the physiotherapy interventions given in DS- For early stimulation we can perform NDT that is neuro development therapy with massage therapy. Therapeutic exercises like aerobic training, in aerobic training walking or jogging, exercises with an ergometer. Resistance training in which we give progressive resistance training, weight bearing exercises conditioning and jumping training with circuit training. In balance training, we can perform exercises using rehabilitation ball with core stability exercises. We can also advise them orthosis such as supra malleolar orthosis [10].

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Ayres sensory integration (ASI) is also called as "SI (sensory integration) therapy" and "classical sensory integration" [11]. The theory of ASI approach was originated in 1960s by Anna Jean Ayres, an American occupational therapist and psychologist for patients with sensory processing disorders [12]. ASI is frequently confused with other types of therapy such as "sensory-based intervention" which is based on same principles and target similar clinical features of sensory processing disorders (SPD) but the intervention differs from that of Ayres. ASI primarily focuses on the tactile, vestibular and proprioceptive system and considering the persons involvement [10]. Tactile system stimulation depends on exteroceptors stimulation which has protective and discrimination functions. Tactile system activities such as using different structures and heat surfaces (rough, rubbery, smooth, slippery, crude and cool). Proprioceptive stimulation which receives the stimulations from muscles and joints. Proprioceptive system activities include static proprioceptive training by weight bearing and positioning. Vestibular stimulation activities include swinging therapy, balance board, medical ball etc. Cortical Sense Training activities include using of different material weight, and texture with closed eyes for identifications and stereognosis skill training using one foot then the other [7].

The gait can be assessed by Dynamic Gait Index (DGI) and was developed by Shumway-Cook and Woolacott which is a performance-based tool which evaluate ability of individual to modify gait in response to changing functions or obstacles during walking. DGI is a sensitive and efficient assessment tool for adults thus can be useful in children too [13,14]. DGI measures dynamic balance in walking, stair climbing and mobility function. Time to administer is less than 10 minutes [15]. Test-retest (ICC = 0.970 CI (0.915-0.990)) and inter-rater (ICC = 0.983 CI [0.882- 0.998]) [13]. And balance can be assessed by the Paediatric Balance Scale (PBS) which was developed to assess balance measure for school-age children with mild to moderate motor impairments and it is a modification of Berg's Balance Scale [16]. This scale includes Sitting to standing, standing to sitting, Transfers, standing unsupported, sitting unsupported, standing with eyes closed, standing with feet together, standing with one foot in front, standing on one foot, turning 360 degrees, turning to look behind, retrieving object from floor, placing alternate foot on stool, reaching forward with outstretched arm. Each item should be scored utilizing the 0 to 4 scale and the maximum score is 56. PBS for total test score (ICC 3,1 = 0.997) [17].

II. METHOD

This study was designed as a pre-post experimental investigation (uncontrolled trial). It was carried out at the Physiotherapy Department of RJS College of Physiotherapy, Kokamthan. The sample comprised 22 children diagnosed with Down syndrome, including both male and female subjects, selected through a convenience sampling method. The sample size was determined using OpenEpi at a 95% confidence interval. Prior to participation, all individuals were screened for eligibility based on specific inclusion and exclusion criteria.

➢ *Inclusion Criteria:*

- Age 5 to 11 years.[18]
- Both male and female gender.
- Diagnosis- Children who are diagnosed as trisomy 21.
- Intelligence quotient (IQ) equal to or above 50 [2] [mild mental retardation (IQ between 50-55 and 70), moderate mental retardation (IQ between 35-40 and 50-55)][19]

- *Exclusion Criteria:*

- Children with severe neurological disorder (cerebral palsy and epilepsy)
- Orthopaedic problems
- Surgical interference in upper and lower limbs
- Visual or hearing problems
- Receiving medical drugs that affect behaviour and attention.[2]

➢ *Procedure*

All the parents of subjects who fulfilled the criteria and were willing to participate in the study were given the informed consent form and patient information sheet. The participants and their parents or guardians were informed that they have a right to withdraw from this study at any time and if they decide so their decision will be respected and their participation will cease immediately. Baseline data was collected at 0 week of gait and balance by using Dynamic Gait Index for children and Paediatric Balance Scale respectively.

Post intervention at the end data was collected at 6 weeks. Participants received 18 sessions, 45 min each for 6 weeks.[20]

➢ *Intervention*

- *Tactile Stimulation:*

✓ Using different textures such as rubbery and rough participants will be asked to touch by feet and walk on the textured surface.
✓ Pressuring and brushing the skin tactile receptors.
✓ Placing feet in sand and rice for discrimination.
✓ Visual and hearing stimulation.

- *Vestibular Stimulation:*

✓ Disturbance of the child from different developmental positions with changing of the base of support and centre of gravity with eye opened then closed and with shifting weight on the two legs then on one leg to achieve gradual postural control ability.
✓ Gait training on one line then side walking then bypass walking.

- *Proprioceptive Training:*

✓ Weighted clothes were used for proprioceptive stimulation.

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- ✓ Weighted ball for pulling and pushing was used for stimulation.
- ✓ Dynamic proprioceptive training via walking and manual approximation in whole joint angles to stimulate whole proprioceptors of lower limb joints and pelvic girdles.

- *Cortical Sense Training:*

- ✓ Using of different material weight, and texture with closed eyes for identifications and stereognosis skill training using one foot then the other [7].

III. OUTCOME MEASURE

➢ *Dynamic Gait Index (DGI) for children –*

There are 8 items on the DGI. The 8 items include : 1. Gait Level Surface, 2. Change in gait speed, 3. Gait with horizontal head turns, 4. Gait with vertical head turns, 5. Gait and pivot turn, 6. Step over obstacle, 7. Step around obstacles, 8. Stairs and each item is scored on a 4-point scale [(3) Normal; (2) Mild impairment; (1) Moderate impairment; (0) Severe impairment] with a maximal score of 24.[14] A score below 19 is indicative of increased fall risk [15].

➢ *Paediatric Balance Scale (PBS) –*

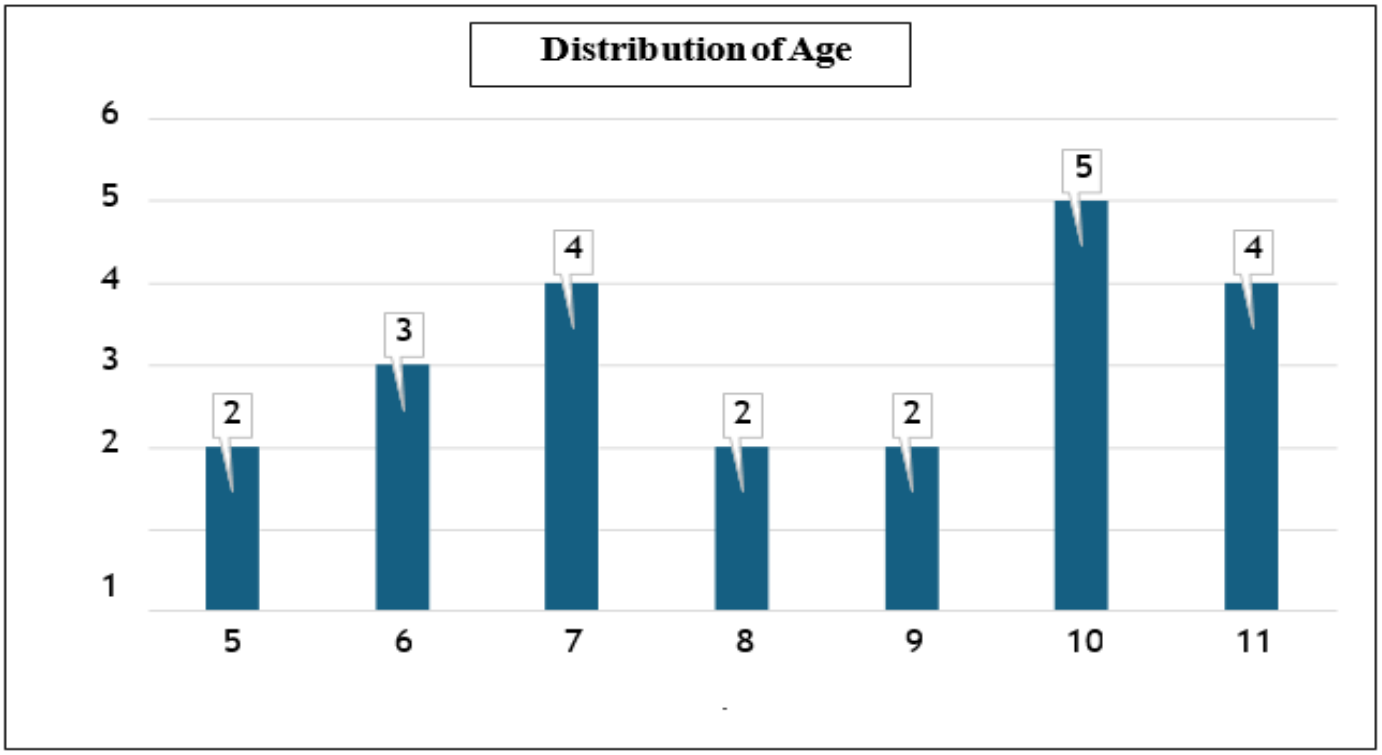
It is a simple and easily clinically applicable scale and consist of 14 items which are relevant for everyday tasks. Items related to sitting, standing (with eyes open and closed), turning, reaching, etc. are involved [17].

➢ *Data Analysis*

The data analysis was done using Microsoft Excel, and all statistical analyses were conducted using the latest version of IBM SPSS Statistics software. Descriptive statistics were used to summarize demographic data (age and gender) and clinical outcome measures: Paediatric Balance Scale (PBS) and Dynamic Gait Index (DGI), both pre- and post-intervention. Measures such as mean, median, standard deviation, range, and confidence intervals were reported. Normality of the data was assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests, which indicated that all outcome variables followed a normal distribution ($p > 0.05$). Based on this, parametric tests were deemed appropriate. A paired samples t-test was used to compare pre- and post-intervention scores for both PBS and DGI to evaluate the effectiveness of the intervention.

Table 1 Age-Wise Frequency Distribution

Age	Frequency	Percent
5	2	9.1
6	3	13.6
7	4	18.2
8	2	9.1
9	2	9.1
10	5	22.7
11	4	18.2
Total	22	100.0



Graph 1 Graphical Representation of Age-Wise Distribution of Subjects

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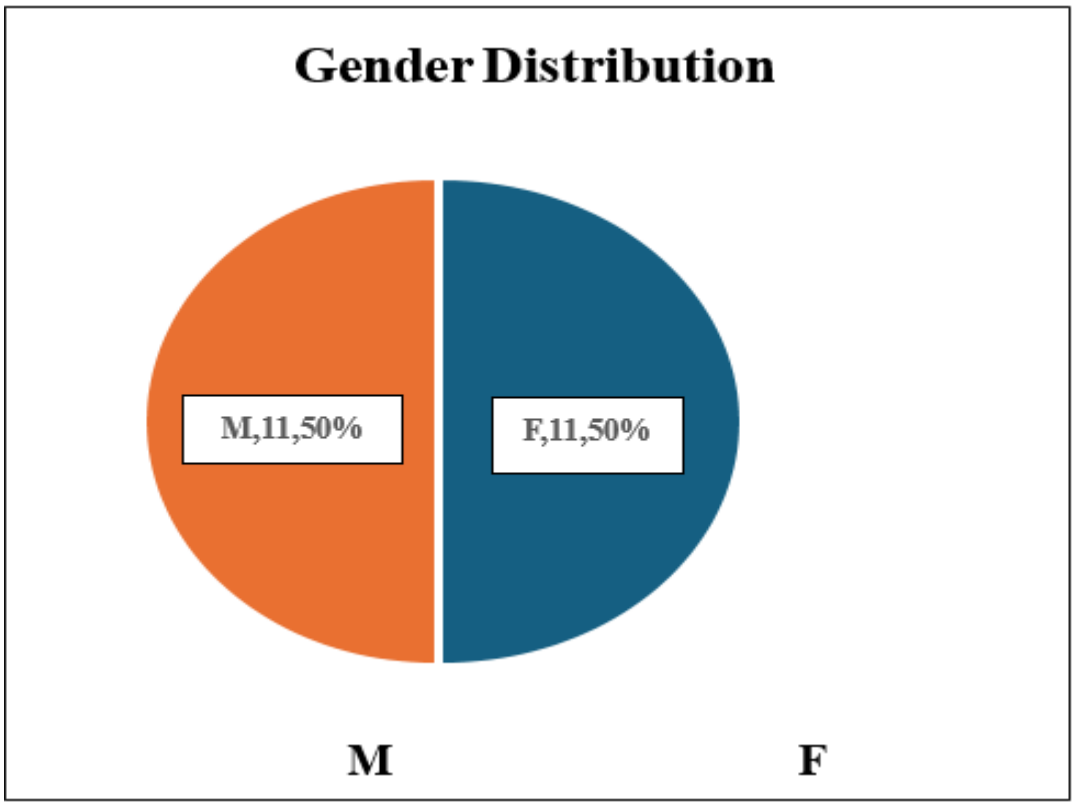
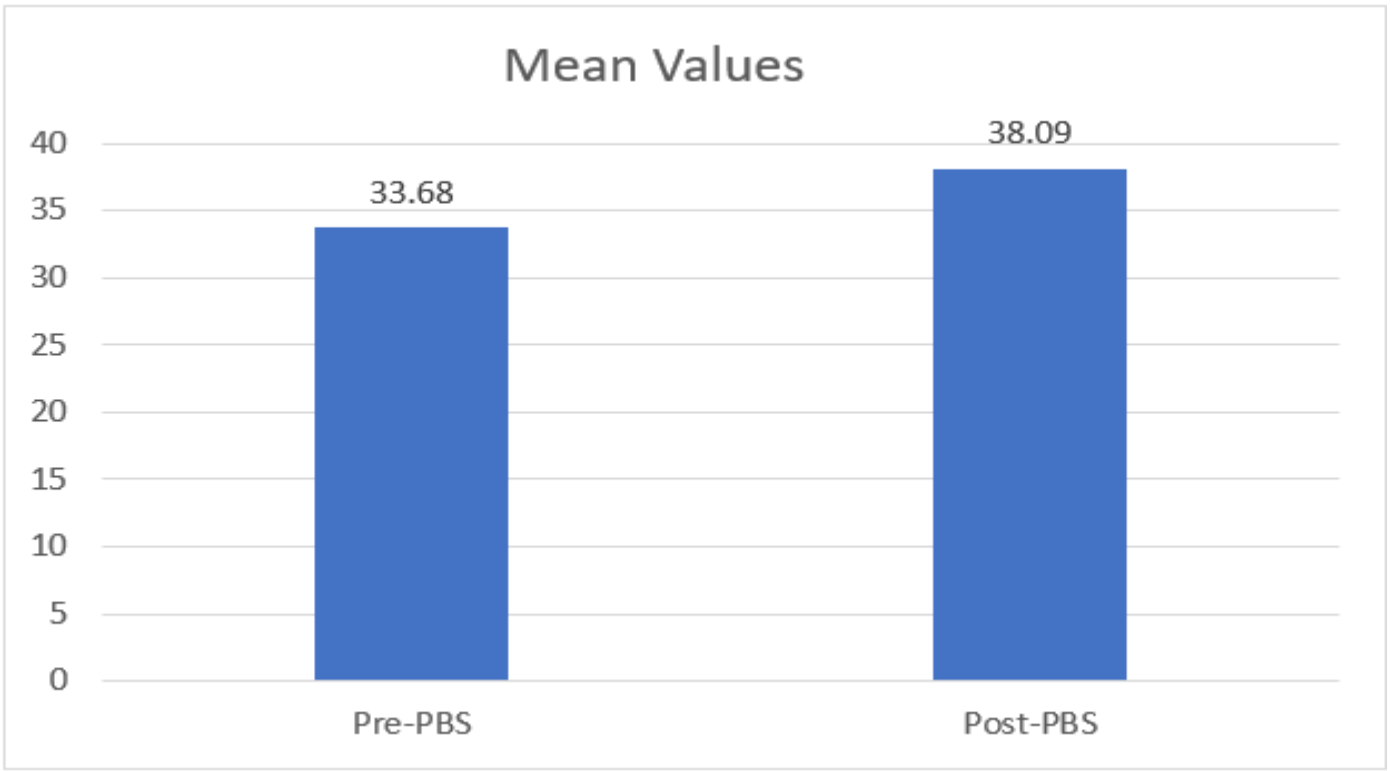
Table 2 Gender-Wise Distribution

Category	Frequency	Percent
F	11	50.0
M	11	50.0
Total	22	100.0



Graph 2 Graphical Representation of Gender-Wise Distribution of Subjects



Graph 3 Graphical Representations of Mean Value Distribution of Paediatric Balance Scale.

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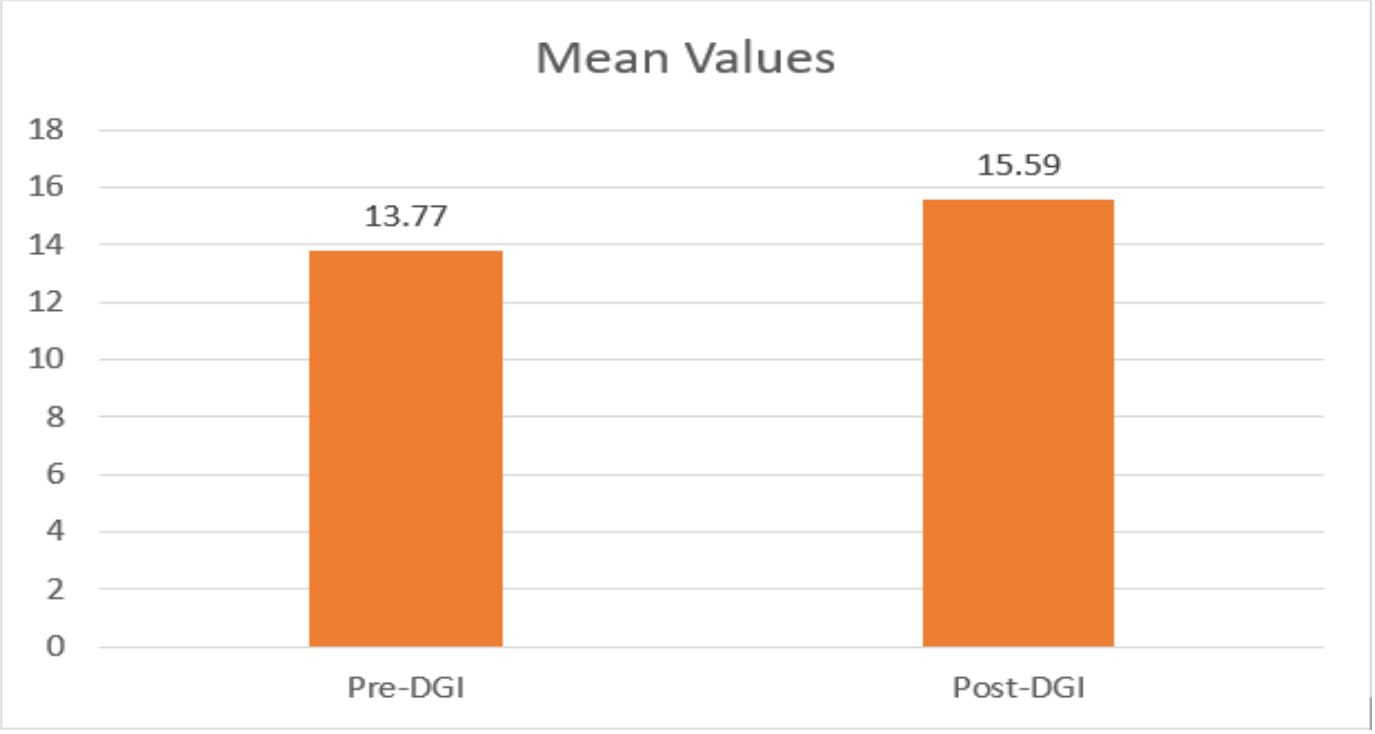

Graph 4 Graphical Representations of Mean Value Distribution of Dynamic Gait Index

Table 3 Paired Sample Statistics for Paediatric Balance Scale (PBS) [Pre and Post]

Paired Samples Statistics						
		Mean and std. deviation	t-value	p-value	Std. Error Mean	Sig. (2- tailed)
Pair 1	Pre-PBS	33.68 ± 7.779	-11.726	0.749	1.658	0
	Post-PBS	38.09 ± 9.38		0.76	2	

Table 4 Paired Sample Statistics for Dynamic Gait Index (DGI) [Pre and Post]

Paired Samples Statistics						
		Mean and std. deviation	t-value	p-value	Std. Error Mean	Sig. (2- tailed)
Pair 1	Pre-PBS	13.77 ± 3.366	- 12.834	0.432	.718	0
	Post-PBS	15.59 ± 3.825		0.248	.816	

IV. RESULT

A total of 22 children, aged between 5 and 11 years, participated in the study. The age distribution varied, with the highest proportion being 10-year-olds (22.7%), followed by those aged 7 and 11 years (each 18.2%). The least represented age groups were 5, 8, and 9 years, each comprising 9.1% of the sample. Gender was evenly represented, with 11 males (50.0%) and 11 females (50.0%). Descriptive statistics for the Paediatric Balance Scale (PBS) showed a mean pre-intervention score of M = 33.68 (SD = 7.78), which increased post-intervention to M = 38.09 (SD = 9.38). For the Dynamic Gait Index (DGI), the pre-intervention mean was M = 13.77 (SD = 3.37), rising to M = 15.59 (SD = 3.83) after the intervention. Before inferential testing, the assumption of normality was evaluated using Shapiro–Wilk tests. Results indicated that both PBS and DGI scores, at pre- and post-intervention stages, did not significantly depart from normality (Pre-PBS: W (22) = 0.972, p = .749; Post-PBS: W (22) = 0.972, p = .760; Pre-DGI: W (22) = 0.957, p = .432; Post-DGI: W (22) = 0.945, p = .248). As all p-values exceeded .05, the normality assumption was upheld, justifying the use of paired-samples t-tests. Paired-samples t-tests revealed statistically significant improvements in both outcome measures. For PBS, there was a significant increase from pre- to post-intervention scores ($t(21) = -11.73$, $p < .001$; mean difference ≈ 4.41 points). Similarly, for DGI, the score significantly improved ($t(21) = -12.83$, $p < .001$; mean difference ≈ 1.82 points).

V. DISCUSSION

The study involved 22 participants, aged between 5 years to 11 years. They underwent a structured Ayres sensory integration (ASI) intervention involving tactile, vestibular, proprioceptive, and cortical training, designed to improve gait and balance in children with Down syndrome. All participants had comparable pre-intervention PBS (33.68 ± 7.78) and DGI

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(13.77 ± 3.37) scores, indicating similar levels of balance and gait function at study entry. Normality tests confirmed parametric analysis suitability. Physiotherapy plays a pivotal role in managing children with Down syndrome, one of the primary aim of physiotherapy for children with Down syndrome is to enhance gait and balance.

The results of this study showed that PBS scores significantly improved by approximately 4.41 points post-intervention ($t = -11.73$, $p < .001$). DGI scores increased by roughly 1.82 points ($t = -12.83$, $p < .001$). These outcomes indicate meaningful gains in balance and gait following ASI therapy. A recent similar, randomized controlled trial by Metehan Yana , Erdoğan Kavlak , Musa Güneş (2022) reported that adding sensory integration therapy (SIT) to neurodevelopmental therapy (NT) in 21 children with Down syndrome led to significantly greater improvements in motor skills (measured by BOT-2 SF) and attention (Stroop TBAG) over six weeks, compared to NT alone ($p < .01$). Although that study didn't measure gait directly, the superior motor gains support the idea that multisensory stimulation enhances motor functions including gait stability consistent with our PBS and DGI findings.

To the best of our knowledge this is the first study to investigate efficacy of Ayres sensory integration therapy on gait and balance in patients with downs syndrome. However, Azzam (2019) conducted a randomized trial with 30 children with Down syndrome, randomized into a group receiving sensory integration therapy plus specific physiotherapy and a control group receiving physiotherapy alone. After 12 weeks, the experimental group showed highly significant improvements in gross motor coordination (e.g., backward balancing, hopping, jumping) and proprioception (grip control, kinaesthetic awareness) compared to controls ($p = .0001$). These motor coordination gains closely parallel our PBS and DGI improvements, underscoring the effectiveness of adding sensory integration to physiotherapy in DS.

Similarly, Sensory integration is also used in other paediatric conditions such as CP. In 2023 Raipure et al. studied 40 children with spastic diplegic cerebral palsy, divided into two groups: one receiving Neurodevelopmental Technique (NDT) plus conventional physiotherapy and the other receiving Sensory Integration Technique (SIT) plus conventional therapy. After 4 weeks of treatment, the SIT group exhibited significantly greater gains in gross motor function (GMFM-88), Paediatric Balance Scale (PBS difference ≈ 1.85 points), and gait metrics compared to the NDT group, all at $p = .0001$. Although the population differs, the PBS and gait improvements mirror our DGI and PBS gains, highlighting sensory integration's robust impact on motor outcomes.

Other independent investigations further support sensory integration benefits; A systematic review by Vaishnavi B Warutkar , Rakesh K Kovela , Snehal Samal (2023) in children with cerebral palsy, including spastic diplegia, consistently report that SIT combined with conventional therapies improves balance, gait, and gross motor function significantly more than conventional therapy alone ($p < .0001$).

Together, these studies demonstrate that sensory integration interventions yield substantial improvements in motor coordination, balance, and gait, both in Down syndrome and in cerebral palsy populations. Our findings PBS increase of ~4.41 points and DGI gain of ~1.82 points are directly supported by similar effect magnitudes observed in these studies. In conclusion, ASI is an effective rehabilitation modality in neurodevelopmental conditions.

VI. CONCLUSION

In conclusion, this pioneering study demonstrates that Ayres Sensory Integration (ASI) therapy is effective in improving both balance and gait performance among children with Down syndrome. Participants exhibited significant increases in Paediatric Balance Scale (PBS) and Dynamic Gait Index (DGI) scores, reflecting enhanced postural control, motor coordination, and functional walking ability. The structured ASI intervention combining tactile, vestibular, proprioceptive, and cortical sensory training proved to be a powerful therapeutic modality. These findings support the incorporation of ASI protocols into therapeutic regimens for Down syndrome children to promote mobility gains and reduce fall risk. The improvements in multisensory processing appear to translate directly into measurable motor function benefits. Overall, the results affirm that ASI constitutes a valuable addition to clinical practice, offering meaningful functional outcomes in this population.

ABBREVIATIONS

DS – Down Syndrome
DGI – Dynamic Gait Index
PBS – Paediatric Balance Scale

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