Journal of Health Physiotherapy and Orthopaedics

Research Article

The effect of Bharatanatyam mudras on the quality of fine motor functions in Down syndrome children

Mudra Ramesh Mahale*, Sabah Thaver

Lokmanya Tilak Municipal General Hospital, Mumbai, Maharashtra, India

Corresponding author: Mudra Ramesh Mahale, ✉ mudramahale@gmail.com, **Orcid Id**: https://orcid.org/0000-0003-4729-3253

Received - 09-10-2025, **Revised** - 15-12-2025, **Accepted** - 25-02-2026 **(DD-MM-YYYY)**

Refer this article

Mudra Ramesh Mahale, The effect of Bharatanatyam mudras on the quality of fine motor functions in Down syndrome children. Journal of Health Physiotherapy and Orthopaedics. January-February 2026, V 3 - I 1, Pages - 11 – 15. Doi: https://doi.org/10.55522/jhpo.V3I1.0049.

ABSTRACT

One of the primary treatment objectives in children with Down syndrome is the enhancement of the fine motor skills since the motor disability has a significant impact on the normal living and self-independence. The purpose of the research was to examine the feasibility of Bharatanatyam hasta mudras as a group intervention in improving the quality of fine motor and performance of functional tasks. The protocol was given to forty 6-12 years of age children, where two mudrases were presented during the first five sessions and graded speed practice and functional integration practiced during other sessions. Pre-intervention and post-intervention tests that were set up in visual motor worksheets, coordination, pre-intervention and post-intervention tests included pre- and post-intervention tasks of pre- and post-intervention tests: pre- and post-intervention prehension and precision tasks and time-based fine motor tasks. The results showed statistically significant and stable improvement in all of the areas, which are reflected in increased repetitions, increased hand coordination, increased ability to control movement and reduced the performance of daily functional activities as measured by the number of seconds to press a button, tie shoelaces and open locks. These results imply that the multisensory, rhythmic and proprioceptive elements of Bharatanatyam mudras can be used effectively to facilitate motor learning, dexterity and perceptual-motor integration among children with down syndrome. Being a culturally-based, cost-efficient intervention, mudra-based training can be used as an addition to the existing rehabilitation strategies. Long-term follow-up of a bigger sample size should be conducted in further research.

Keywords: Down syndrome, Bharatanatyam mudras, Fine motor skills, Coordination, Functional performance.

INTRODUCTION

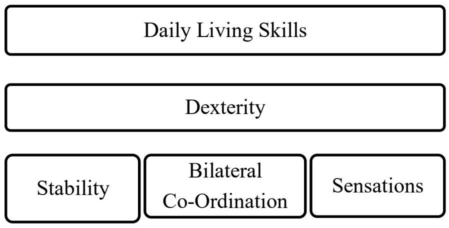
Down syndrome (DS) or trisomy 21 is a hereditary disorder caused by an abnormal segregation of chromosome 21. It is the most frequent chromosomal disorder that has been detected in children's populations and was originally described by John Langdon Down in 1862. The genetic basis of karyotyping was developed in the 1950s, and it allowed for more distinct distinctions between karyotyping and other developmental disorders. Epidemiological estimates worldwide indicate a range of 1-10 per 1000 live births, whereas estimates in India show greater variability due to ethnic/demographic heterogeneity, with localised studies revealing a prevalence of around 0.83 per 1000. The tendency pattern is schematically demonstrated in Figure 1[1-5].

Neuromuscular and sensory challenges have a great impact on the motor development of children with Down syndrome. According to developmental models, the development of fine motor skills relies on stability, bilateral interaction, and sensation, as shown in Figure 2 [6-8].

Figure 1: Prevalence Of Down Syndrome

Africa	Australia: 0.6-0.9/1000
1- West Nigeria: 1.15/1000 (Year 1982) 2- South Africa: 2/1000 (1974-1993)	**Europe:** 1-3/1000 1- Belgium: 0.62/1000 2- Croatia: 1.4/1000 3- Czech Republic: 1.07/1000 4- Denmark: 1.14/1000 (in 1979) increased to 3.2/1000 (in 1994) 5- England and Wales: 1.08/1000 6- Ireland (EUROCAT): 1.83/1000 7- Scotland: 1.29/1000 8- Estonia: 1.17/1000 9- France: 2.17/1000 10- Hungary: 1.5/1000 11- Netherlands: 1.46/1000 12- Norway: 2/1000 13- Russia: was 0.93-2.2/1000 14- Spain: 1.3-2.91/1000
Arab world: 1- Emeritus: 3.12/1000 2- Oman: 2/1000 3- Libya: 1.94/1000 4- Qatar: 1.83/1000 5- Arabs in Israel: 1.83/1000 6- Saudi Arabia: 1.8/1000 7- Kuwait: 1.72/1000 8- Egypt: 1.42/1000	**North America:** 1- Canada: 1.24-1.7/1000 2- Mexico: 1.53/1000 3- USA: 0.9-1.18/1000
Asia China: 2/1000 Taiwan: 0.8/1000 India: 0.83/1000 Timor Leste: 1.24/1000 Indonesia:1.24/1000 Laos: 1.25/1000 Malaysia: 1.25/1000 Philippine: 1.25/1000 Singapore: 1.25/1000 Thailand: 1.25/1000 Vietnam: 1.25/1000 Japan: 2.55/1000 Pakistan: 0.9-1.24/1000 Iran: 1.22/1000 Turkey: 0. 9-0.99/1000	**South America:** 1- Brazil: 1.25/1000 2- Chile: 2.47/1000 3- Colombia: 1.25/1000 4- Paraguay: 1.25/1000 5- Peru: 1.25/1000 6- Venezuela: 1.25/1000

Figure 2: House Model For Fine Motor Development

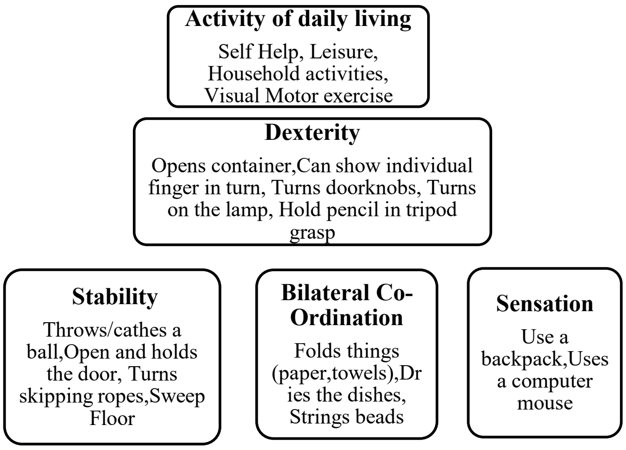


Stability is defined as the proximal control at the trunk and shoulder girdle to facilitate efficient distal hand function; bilateral coordination to facilitate effective bimanual activities; and the support provided by the sensory structures of the tactile, vestibular, and proprioceptive systems to maintain a constant amount of feedback that is required to perform precise motor planning and accurate activities. Table 1 describes these sensory mechanisms and their relevance in functions [9-11].

Table 1: Sensory System

The tactile system	The vestibular system	The proprioception system
Protective touch: The tactile system helps us discriminate between threatening and nonthreatening touch sensations. Furthermore, the tactile system provides information about the objects	Coordination: The vestibular system helps us coordinate the movement of our eyes, head and body. In addition, the vestibular system controls our body's relation to gravity.	Motor Skills: The proprioception system consists of components of muscles, joints and tendons that provide us with a subconscious awareness of our body.
Characteristics of a child with hypo or hyper-reactive tactile system: Withdraws from being touched Dislikes certain textures Prefers to wear loose clothing Complaints about or resistance to efforts at washing hair, brushing teeth or washing face Often is unable to determine where something is touching their body	Characteristics of a child with a hypo- or hyper-reactive vestibular system: Displays spinning and rocking behaviour Frequent falls and trips Exhibits poor eye control and concentration Shows increased emotional sensitivity	Characteristics of a child with hypo- or hyper-reactive proprioception system: Is often clumsy May display hand flapping May hold objects tightly or loosely Hugs tightly Walks very heavily Seeks deep pressure by wearing heavy clothes or placing heavy objects upon themselves

Figure 3: Fine motor in early age



DS children are also known to have hypotonia, ligamentous laxity, reduced kinesthetic awareness, changed palmar creases, short fingers and curved digit patterns that include clinodactyly, which limits grasping, dexterity and fine motor coordination. Figure 3 further shows these developmental factors.

Motor outcomes are also influenced by the sensory profile of children with DS. Most of them have high visual learning styles, respond well to demonstration-based learning and greatly depend on visual tools to plan motor movements. Proprioception and motor unit recruitment deficits also might be additional factors that cause slow or ineffective fine motor responses. These factors combined make children with DS have a certain problem in doing their daily functional activities, like opening buttons, tying shoelaces, manipulating fasteners, holding writing tools, or completing school tasks that demand precision. Academic readiness is therefore not the only aspect of fine motor skill development that is necessary, but also self-care, independence, and self-esteem.

Movement-based therapies are not new since they have been studied to have a possible effect on the neuromotor outcomes in neurodevelopmental conditions. The Indian classical dance Bharatanatyam, which is based on expressive movement, rhythm and organised hand movements (hasta mudras), offers a sensory-motor experience. Bharatanatyam mudras involve graded finger isolation, wrist movement, scapular stability, bilaterality of hands and coordination of timing, which are important aspects of fine motor development. The dance encourages multisensory involvement in activating the visual, auditory, tactile and proprioceptive channels at the same time, thus aiding perceptual-motor integration. Visual feedback by mirrors and rhythmic entrainment can additionally be used to increase learning in motor and neuromuscular responsiveness. Although dancing and movement-based interventions have shown the potential positive effect on motor coordination, perception-motor skills, and reaction times in children with DS, specific research evaluating the influence of Bharatanatyam mudras on fine motor functions in this group has not been conducted yet. Given that children with DS have high visual learning abilities, and that mudras are organised, repetitive, and culture-specific, the given form of therapy can provide a special way of promoting fine motor precision, dexterity, and functional tasks. The present study aimed to:

Assess functional activity measures to evaluate the baseline fine motor performance of the children with Down syndrome.

Identify how a structured Bharatanatyam mudra-based intervention may influence fine motor precision, coordination and dexterity [12-15].

Measuring the variation of time efficiency in carrying out daily functional activities after training in mudra.

METHODS

Study design

The interventional study was carried out to determine the influence of the Bharatanatyam hasta mudras on the fine motor skills in children with Down syndrome. The research used a systematic treatment where all participants were subjected to progressive mudra training, and functional clinical outcome measurement was taken at the start and end of the therapeutic intervention of fine motor performance. The design allowed direct comparison of the changes during pre-intervention and post-intervention in one group.

Participants

The sample size was 40 children with Down syndrome, and convenience sampling was done to recruit participants aged between 6 and 12 years. Inclusion criteria were the presence of Down syndrome and the ability to follow basic instructions, whereas exclusion criteria excluded children with musculoskeletal injuries to the upper limb or hand and neurological disorders other than Down syndrome.

Ethical approval

The Institutional Ethics Board of the Nanavati Super Speciality Hospital provided the ethical approval of the study. The parents or legal guardians were informed of the purpose of the study, procedures, and potential benefits before which informed consent was given in written form to make sure that the study complied with ethical research requirements of conducting a study with paediatrics.

Intervention protocol

The intervention had 10 sessions aimed at gradual teaching and strengthening Bharatanatyam hasta mudras. The initial five sessions involved the introduction of two distinct mudras as per session, with ten repetitions of each mudra being performed in the presence of the therapist. The next five lessons focused on practising all the already learned mudras at graded slow, medium, and fast speeds in order to increase motor control and timing. Functional training was added in order to make the children practice the mudra movements in everyday activities that need fine motor control. Further, a home practice program was used where parents were taught instructional videos, and parents were requested to make sure that children practised the mudras three times a day in front of the mirror; the parents were required to send the videos of such practices so that compliance could be monitored.

Description of mudras

The therapeutic protocol incorporated ten Bharatanatyam mudras, with each being chosen based on its ability to produce fine motor attributes like finger isolation, grip modulation, wrist extension and bilateral coordination. Table 3 provides detailed descriptions of the position of the hands, joint implication, biomechanical and functional applications of each mudra. The mudras selected was to focus on stability, coordination, proprioception, and dexterity, which correlate with the key elements of fine motor development.

Table 2: Outcome measures

Test	Objectives
Co-ordinations Tests	To assess the coordination of the wrist and forearm
Time-Based Functional Activities	To assess reaction time
Prehension and precision activities	To assess the grips
Visual Motor Worksheets	To assess the perceptual motor function

Table 3: Mudras and Uses

Mudra		Description	Uses
Kapota		Both hands in cupped position hold against each other with the wrist slightly extended and elbow flexed, with the shoulder slightly in horizontal flexion	It helps in improving the curvature of the hands, as this would stretch the hand's dorsal surface. - Can be used in the play activity of hiding things.
Karkata		- Fingers of both the hands intertwined in each other with the wrist slightly extended and elbow flexed and should in horizontal flexion	- Helps in improving the spaces between the fingers to create more room for the movement of the fingers.
Keelaka		- Little finger DIP 90-degree flexion and hold against each other and rest of the fingers flexed with the wrist in maximum extension.	- In children with down's syndrome, it is known that the little finger is short and curved; this mudra will help in stretching the curved PIP. - Improve the proprioceptive input of the hand.
Matsya		- One hand is kept on the other with interossei together, except for the thumb and ulnar deviation of the wrist. - Resemblance to fish	- Helps in improving the movement of the thumb alone. With the help of practising in three speeds, it would help improve the control of thumb movement.
Varaha		- Thumb in neutral with hands on each other and interossei adducted and MCP flexion with ulnar deviation of the wrist.	- With the movement of the wrist in flexion and extension, this mudra will help improve the static posture and improve the force production in maintaining the posture of the finger.
Garuda		- Interossei adducted and thumb abducted and held next to each other - Resemblance to a bird/butterfly	- Improves the MCP flexion with PIP and DIP in neutral. - When modified to use individual fingers- Improvement in alternate use of fingers. - Improves overall mobility of fingers.
Bherunda		- Thumb adducted and flexed and fixed under first PIP and DIP Flexion with rest of the finger touching the palm with the wrist slightly extended.	- Helps in improving the Tip-to-pad grip.

Katkavardhana		- Thumb flexion and first and second finger MCP flexion with PIP and DIP in neutral; Ring finger in slight flexion and little finger in neutral with the wrist slightly extended. - Resemblance to the tripod grip	- Improve the pad to pad grip. - Improves the holding of an object in the first three fingers which can help in activities like; holding the pens and writing, Typing the shoelace, Buttoning the shirt etc
Kartariswastika		- First finger flexed and middle finger slight MCP flexion and rest of the finger touching the palm with the wrist slightly extended	- Helps in the individual movement of the fingers front and back It helps in increasing the mobility of the finger.
Pushpaputa		- Both the hands are cupped and are held next to each other with maximal wrist extension.	Since the dorsal surface has been stretched, the positions provide input to improve the curvature's depth so that child can hold the things in hand. E.g. Holding flowers/ taking water in hand for washing face etc.

Outcome measures

The four categories of outcome measures were used to evaluate fine motor performance, which are coordination tests, time-based functional tasks, pre-comprehension and precision activities, and visual motor worksheets. Tests of coordination assessed the skill of the child in repetitive movements of the forearm and the wrist during a time frame. Efficiency and speed needed in carrying out duties like buttoning, tying shoelaces and unlocking a lock were measured using time-based functional activities. Prehension and precision tasks evaluated grip patterns, grasp modulation and fine manipulative control and visual motor worksheets evaluated perceptual motor integration and precision when tracing or in patterned activities. Table 2 presents a detailed description of each of the measures and their objectives.

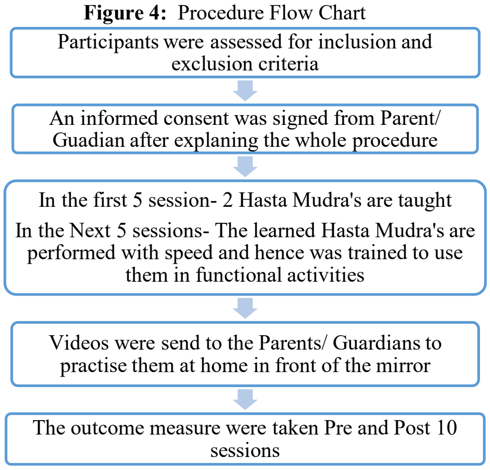
Procedure flow

The procedural sequence for participant recruitment, baseline assessment, intervention delivery, home program monitoring, and post-intervention evaluation is summarised in Figure 4. This flow chart illustrates the stepwise progression of the study and the standardised process followed for all participants.

Statistical analysis

All the statistical procedures were carried out with the help of IBM SPSS Statistics Version 23. The paired t-tests were used to compare pre- and post-intervention scores to identify whether the changes in fine motor performance were significant. Means and standard deviation (SD) were used to Analyse results and statistically significant results were determined at $p < 0.05$ [16-19].

Figure 4: Procedure Flow Chart



RESULTS

Participant characteristics

A total of 40 children with Down syndrome voluntarily participated in the study. The sample consisted of 18 males (45%) and 22 females (55%), indicating a slightly higher proportion of female participants. The gender distribution is visually represented in Graph 1. Demographic characteristics, including mean age (7.75 ± 2.2 years) and gender breakdown, are summarised in Table 4. The heterogeneous distribution of participants provides a representative profile of children within this age group living with Down syndrome and exhibiting typical variations in fine motor functioning.

Graph 1: Gender distribution

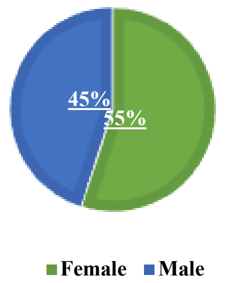


Table 4: Baseline Data for Subjects

Baseline data	Subjects
Age	7.7 5± 2.2
Gender M/F	18/22

Visual motor performance

There were significant differences in the visual motor worksheet tasks in four out of the four worksheets post Bharatanatyam mudra intervention. The children showed superior skills in visual tracking of patterns, co-ordinating and reproducing them, which translated into the fact that they were able to repeat more patterns in a one-minute period of time. These improvements indicate an increased perceptual-motor integration and they indicate that integration of visual feedback, motor action repetitions and hand positioning organization helped to produce more skilled motor performance. Graph 2 displays the changes in the pre and post-results. Table 5 displays numerical values that show a steady improvement in all visual motor activities, which indicates a statistical improvement as well as a clinical improvement as reported in the original analysis.

Graph 2: (Mean) Pre and Post values of visual motor sheets completed within a minute

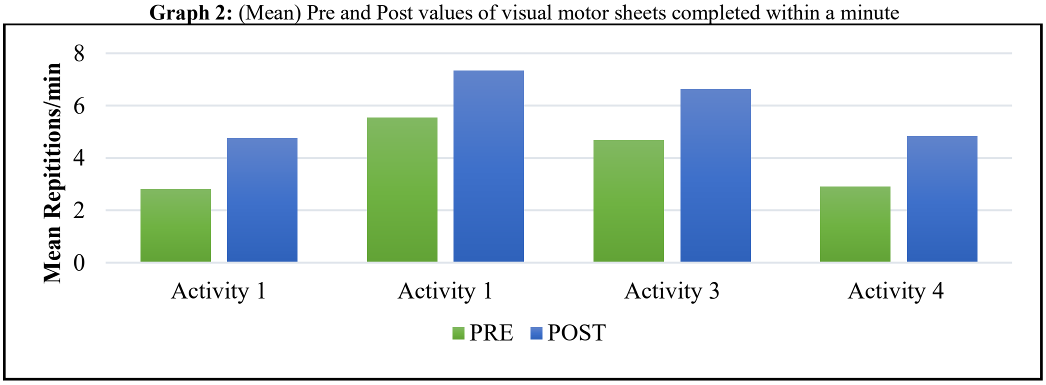


Table 5: Visual motor activities: pre–post comparison

Activity	Outcome	Pre (Mean ± SD)	Post (Mean ± SD)
Visual Motor Activity 1	Repetitions within 1 minute	2.80 ± 2.87	4.75 ± 2.31
Visual Motor Activity 2	Repetitions within 1 minute	5.52 ± 5.07	7.33 ± 5.56
Visual Motor Activity 3	Repetitions within 1 minute	4.68 ± 4.56	6.63 ± 5.44
Visual Motor Activity 4	Repetitions within 1 minute	2.90 ± 3.68	4.82 ± 4.19

Coordination performance

There was a clear improvement in upper limb coordination tasks of the participants, and they included tapping and pronation-supination. It is also a positive indication that repetitions per minute increase, which implies more control over the movements of the wrists and forearms and better rhythm and time. The enhancements are consistent with the systematic use of mudra that requires accurate and repetitive stimulation of the distal muscles. Better coordination is also an indication of better kinaesthetic awareness and perceptual correspondence of movement patterns. The results are presented in Graph 3, and the numerical results are given in Table 6. The increase in coordinated repetitions reminds us of the positive effect of the neuromuscular responsiveness and motor sequencing by mudra training.

Time-Based prehension and precision tasks

The massive decreases were found during the time taken to perform effective activities that needed prior knowledge and precision, which involved putting on a shirt button, shoelace tying and lock opening. These slices exhibit a less rugged motor organisation, quicker grasp release activity and greater grip modulation capacity. Improvements imply enhanced use of feedback in task performance, especially in the last level of accuracy movement, where children with the down syndrome feature delays. These are graphically represented in Graph 4, and the values were tabulated in Table 7. The reduced task duration is one consequence of the fine motor control, which is the greater control ability over the small intrinsic muscles and an increase in visual-proprioceptive coordination.

Fine motor activities per minute

Children had shown more repetitions in all fine motor tasks that were done in a one-minute session. Activities such as folding paper, knot tying and manipulation of small objects showed improvements which were measurable, meaning a higher level of dexterity, speed of action and continuality of action. These advantages may be likened to the concepts of motor learning integrated in the scenario of the mudra training in which the independent movement of the fingers repeated and sustained to sustain the intrinsic and extrinsic muscles of the hand. Finger mobility and coordination was also increased and specifically showed in activities that involved bilateral and two-hand manipulation and hand stability in precision. The findings are given in Graph 5 and the figures tabulated in Table 8. These repeat benefits are in support of the hypothesis that the mudra practice positively influences both the proximal stability and distal control

Graph 3: (Mean) Pre and Post values of co-ordination test performed within a minute

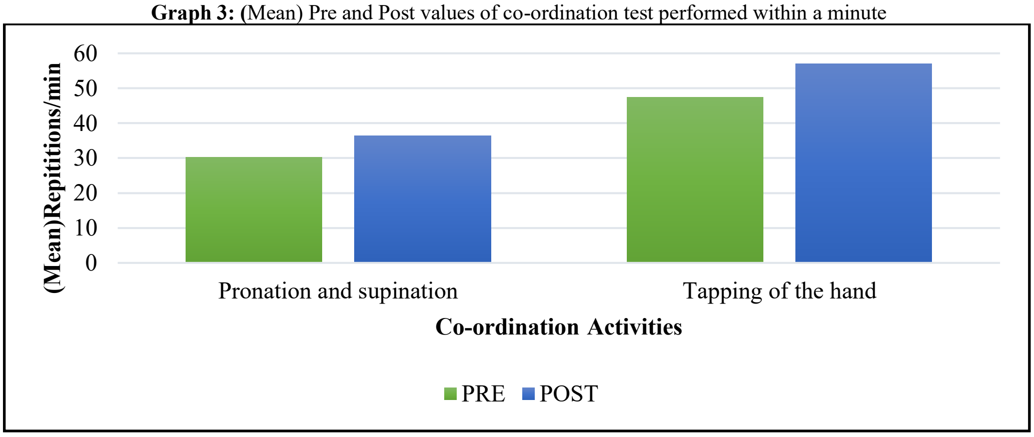


Table 6: Coordination activities: Pre–Post comparison

Activity	Outcome	Pre (Mean ± SD)	Post (Mean ± SD)
Tapping the Hand	Repetitions within 1 minute	47.42 ± 32.25	57.02 ± 31.93
Pronation–Supination	Repetitions within 1 minute	30.23 ± 17.21	36.38 ± 16.57
Tying Knots	Repetitions within 1 minute	1.9 ± 2.2	4.03 ± 1.93
Folding Paper	Repetitions within 1 minute	3.25 ± 2.83	5.13 ± 3.09

Graph 4: (Mean) Pre and Post values of time-based prehension and precision activities

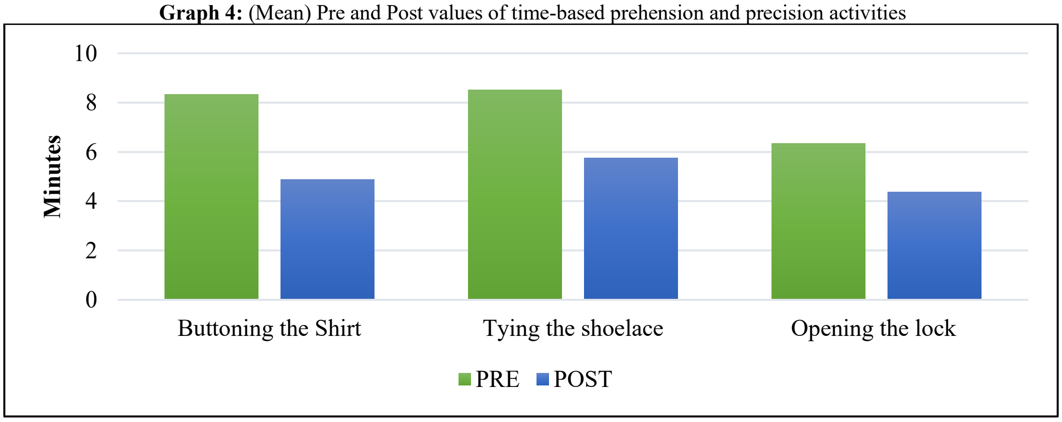


Table 7: Fine motor activities per minute: Pre–Post comparison

Activity	Outcome	Post (Mean ± SD)
Tying Knots	Repetitions within 1 minute	4.03 ± 1.93
Folding Paper	Repetitions within 1 minute	5.13 ± 3.09

Graph 5: (Mean) Pre and Post values of fine motor activities performed within a minute

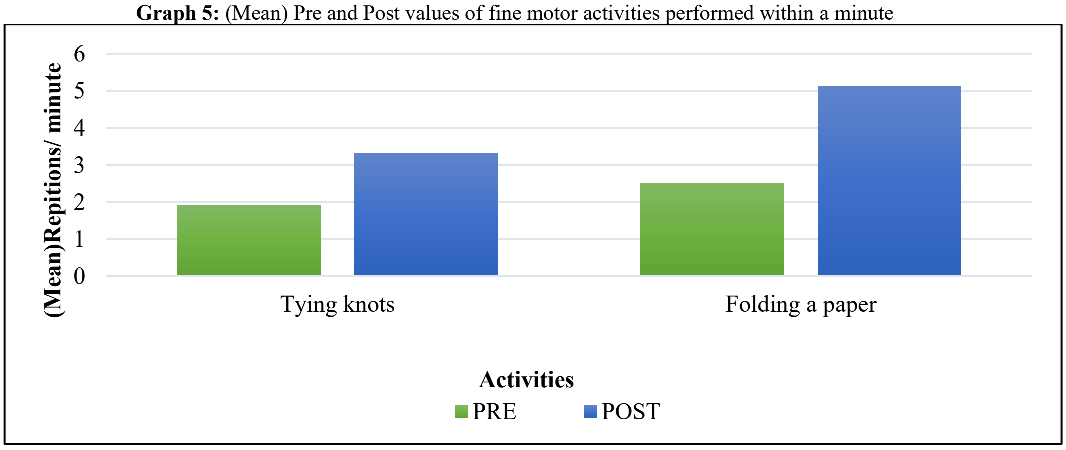


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Table 8: Time-based prehension and precision activities

Activity	Time Taken (Pre)	Time Taken (Post)
Buttoning the Shirt	8.34 ± 4.66	4.89 ± 2.80
Tying the Shoelace	8.51 ± 2.22	5.75 ± 1.76
Opening the Lock	6.34 ± 4.66	4.38 ± 3.02

DISCUSSION

The results of this study have shown that Bharatanatyam hasta mudra training had significant effects in improving all the outcomes in fine motor in children with Down syndrome. Respondents demonstrated greater accuracy on visual-motor worksheets, repetitions in coordination tasks, efficiency in pre-and precision activities, and faster completion of functional fine motor activities of buttoning, tying shoelaces, and opening locks. These findings reveal international improvements in skills of dexterity, hand coordination, control of movements and speed of performing tasks which directly affect independence of daily living tasks. It was consistently seen that there were improvements in every domain, which is indicative of the fact that progressive mudra practice affected positively the neuromotor processes with respect to the fine motor performance.

These improvements could be attributed to a number of factors. This semi-iterative nature of the mudra training probably contributed to the motor learning process by repeatedly stimulating cortical motor circuits and increasing the neuro-muscular control of the motor activity. Proprioceptive receptors as a result of joint positioning, tactile receptors as a result of finger postures, and visual receptors as a result of mirror-based home practice could be possible contributors to the strengthening of perceptual-motor integration. The systematic sequencing of mudras and especially when trained at slow, medium and fast speeds was associated with the entrainment of the rhythms to facilitate timing, coordination and anticipatory regulation. The mirror neuron system could have been activated too since children visually compensated and replicated hand gestures with the help of external visual monitoring which suffices internal motor mapping and enables more effective movement generation. The combination of these mechanisms is consistent with the key elements of fine motor development that have been identified through the foundational models, stability, bilateral coordination, and sensation and explain the extensive improvements that occur following the intervention.

The current findings are supported by comparison to past studies. Previous studies have indicated that grip and pinch-like strengths are generally lower in children with Down syndrome, and this directly affects their manipulative skills, which reported the necessity of remedies that enhance fine motor skills. The inabilities in prehension and anticipatory grasping with delayed closure of a grip and erroneous reach paths have been also reported, and the increased precision timings in the current study indicate that mudra training can be used to offset such shortcomings. Understand pattern anomalies like abnormal posture of the fingers and loss of control, and the systematic molding of the fingers when performing mudra was probably a factor that led to proper motor alignment. Ethnic issues such as fine motor impairments of the daily functioning are also prevalent in the population discovered that dexterity-oriented tasks were worse in children with Down syndrome than in their age-matched peers, and the opposite is observed in the current study with specific repetitions. Task-specific fine motor training has been already revealed to positively improve precision and finger control, whose results indicate the benefit of the structured, repetitive, and skill-related manipulation. In addition, explained the importance of practice and neural adaptation to enhance motor control in the Down syndrome, which supports the theoretical premise of mudra gains in therapy.

Taken together, these findings suggest that Bharatanatyam mudras is a low-cost, culturally relevant, and interesting form of therapy, which can be incorporated into the practice of physiotherapy and occupational therapy. The intervention also works in parallel to improve several aspects of strength, control, precision, timing, and perceptual-motor coordination of the fine motor functioning which makes it appropriate in improving real-world functional performance in children with Down syndrome. The well-structured but artistic quality of mudras also encourages motivation and continued involvement, which are such essential factors of treatment success. This research has weaknesses, however. The sample size is fairly small and restricts the ability to generalize the results and it was not done using long-term follow-up, which would have made it possible to investigate the maintenance of the improvements over time. Also, no direct method was used to test grip strength through a handheld dynamometer, which would have been an excellent quantitative measure of proximal and distal hand muscles. The future studies need to include objective measures of strength, application of standardised fine motor scales like BOT-2 or PDMS-2, and investigation of motor gains maintenance after mudra-based training in the long term [20-24].

CONCLUSION

This interventional research study proves that the effect of Bharatanatyam hasta mudras is significant and can be quantified to influence the fine motor skills of children with Down syndrome. In all the evaluated areas, visual-motor performance, coordination tasks, pre-comprehension and precision activities and one-minute fine motor tasks, the participants had shown great improvement after the organised mudra-based training program. The improvements were considered in the form of repetitions, movement control, better coordination, and shorter time to perform functional activities of daily living like buttoning, shoelace tying, and handling small objects. The findings demonstrated that the serial repetitive activity of mudras, alongside controlled changes in speed and functions of the technique, was a good workout that reinforced motor planning, dexterity, bilateral hand activity, and neuromuscular ability. The combined nature of the mudras that mandates the isolation of fingers, modulation of the wrist, proprioceptive awareness and visual-motor coordination seems to have helped in enhancing both the distal and proximal motor performance. In addition, the systematic practice routines such as the one involving home-based mirror feedback were likely involved in improving sensory integration, improved motor mapping, and task precision. Bharatanatyam mudras is a culturally-based, low-cost, and interactive form of therapy and as such, provides a viable alternative or supplement to the traditional fine motor rehabilitation approach to children with Down syndrome. On the whole, this research paper presents positive findings to the therapeutic importance of Bharatanatyam mudras in improving fine motor skills and functional activities. Although additional studies are required using bigger samples and prolonged follow-ups, the current results indicate that one of the possible solutions to incorporating traditional art into modern pediatric rehabilitation practices is to ensure fine motor development and consequential enhancement of daily living skills among children with Down syndrome.

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