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A Study to Determine the Effects of Sports Stacking in Improving Bimanual Coordination on Hand Dexterity in Geriatric Population

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Abstract: ***Introduction: The elderly, defined as individuals aged 65 and above, are categorized into young-old, middle-old, and old-old. A remarkable group, known as super agers, are in their 70s or 80s yet display cognitive and physical abilities of much younger people. In 2012, out of 7 billion globally, 562 million (8%) were aged 65 or older. Common age-related challenges include poor hand coordination. Engaging activities like sports stacking -such as cup stacking combined with 9- hole peg board -show great promise in improving motor function in the elderly. Aim: To examine the impact of sports stacking on hand dexterity and bimanual coordination in the elderly. Methodology: Over a period of one and a half years, 50 eligible participants aged 65 and older of both sexes were enrolled in the study. They were evenly split into two groups-Group A (received intervention) and Group B (received conventional treatment), each consisting of 25 individuals. The intervention was administered for 7 weeks, five days a week, with each session lasting a minimum of 60 minutes, totaling 35 sessions per group. Measurements for the dependent variables were taken at the beginning and at the end of the 7-week period. Result: In this the significant difference in sports stacking time was observed in Group B ($p < 0.001$) but not in Group A ($p = 0.3682$). Similarly, Group B showed significant improvements in the nine-hole peg test ($p < 0.001$), bimanual coordination ($p < 0.001$), MMSE scores ($p < 0.001$), and apathy evaluation scores ($p < 0.001$), whereas Group A's p-values remained above the significance threshold in all cases.***

Keywords: Geriatrics, Bimanual Coordination, Hand dexterity, Elderly motor function, Sports Stacking

1. Introduction

Old age is a very delicate phase- people of this age need proper comfort and care to lead a healthy life, free of worries and anxiety. In the aging process there is loss of cells in the human body leading to deterioration of organ functions.[1] These age-related factors affect the elderly population and reduce the function of their body. Commonly, "elderly" is defined as chronological age of 65 years old or older, while those from 65 through 75 years are referred to as "early elderly" and those over 75 years as "late elderly".[2]Geriatrics can also be known as synthesis of gerontology and chronic care of elderly.[3]

1.1 Bimanual Coordination and Hand Dexterity

The hand serves as an important creative tool, an extension of intellect, a means of nonverbal communication, and a major sensory tactile organ.[4] The person's ability to use their hands anatomical integrity, sensation, coordination, strength and dexterity.[5] With the declining age the hand dexterity is also affected. Psychomotor behavior and Information processing slows down most frequently during the response programming and response selection phases.[6] Functional independence may be significantly influenced by prehension, or the capacity to use our hands and upper limbs efficiently. For example, the simple task of drinking tea validates the following aspects of comprehension – visual regard, grasp, manipulation, reach and release. Prehension is the process of preparing the hand, arm, body ahead of intended movements through anticipatory or feedforward control and feedback.[7]

Table 1: Classification of Bimanual Coordination Tasks[11]

S. No.	Type of Task	
1	Open vs. Closed Tasks	An open skill is different from a closed one because of the unpredictability of the environment.
2	Discrete vs. Serial vs. Continuous	The second primary task component asks if movements have a distinct start and finish.
3	Movements Alternating in Time vs. Same Time	A third dimension pertains to whether the left and right hands move concurrently or how much the two hands' movements alternate over time. This could depend on the person's approach or control as well as the task needs. When one hand is stabilizing and the favored hand is manipulating, the two hands may switch positions over time.
4	Two Hands Same vs. Two Hands Different	Whether the tasks that the two hands must perform are the same or different. It is crucial to take into account both the movements' goals and the movements themselves. Although the objectives of the sub

		actions may differ (e.g., stabilize jar with one hand and remove lid with the other), the two hands are typically related to achieve a single environmental goal (e.g., prepare instant coffee).
5	Spatiotemporal: Symmetry vs. Asymmetry	Spatiotemporal symmetry or compatibility in bimanual tasks when the two hands' movements are rooted in time and space in multiple contexts, including with regard to the body's midline, the plane of movement, one another, and overall body orientation.
6	Symbolic vs. "Meaningless"	While the goals of "meaningless" movements are the movements themselves, symbolic movements have an objective related to object manipulation or gestural communication.

In regard of this, Bimanual coordination, which entails combining the actions of both limbs into a single, coordinated action, is one important area impacted. This skill demonstrates how the left and right hemispheres work together, especially when the premotor and sensorimotor regions are functionally coupled. This interhemispheric synchronization is disrupted as people age due to a steady loss in both neuromuscular function and cutaneous sensibility. Bimanual coordination is also affected with the advancing age. By combining the movements of the left and right limbs into a single functional control entity, bimanual coordination is a singular example of the cooperation between two functionally distinct but linked hemispheres to achieve goal directed behaviour.[8] The precise timing and performance of bimanual movements depend on the functional coupling between the premotor and sensorimotor areas of the two hemispheres. Both cutaneous and sensation and the neuromuscular system decreases gradually with age.[9] The functional performance of hands in the elderly population is affected by these physiological changes, resulting to an increase in the duration of the time spent in the task execution, unstable grip strength and a decline in regulating and controlling capacity with fine motor control.[10]

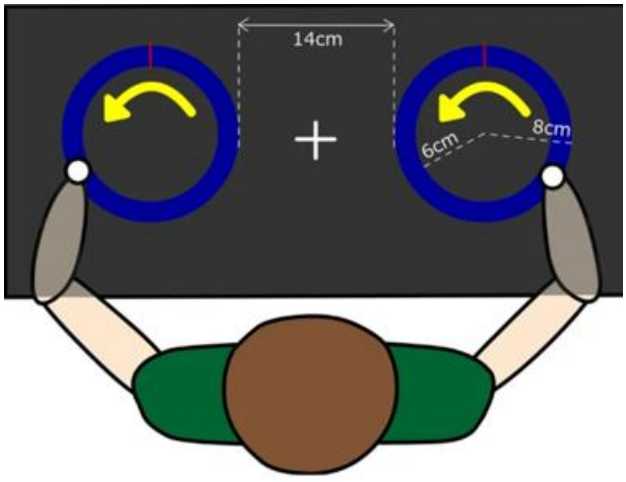

Figure 1: Bimanual coordination Board Task

1.2 Sports Stacking

Sports stacking, a cup stacking activity, started out as a recreational pursuit in 1980's.[12] Used to improve hand dexterity, cognition, memory, attention and motor skill development. In this stacking game, a tower of cups is stacked. Simple configurations (3 cups; 2 base cups with 1 on top) are first in the stacking task. These require slow, deliberate movements. More complex arrangements (3-6-3) and (6-6) use fast actions that call for highly coordinated, sequential and precise movements with both hands.[12] Sport stacking promotes equal performance on both sides of the body and bilateral proficiency. A person who improves bilateral proficiency grows a larger proportion of the right side of the brain, which is responsible for awareness, focus, creativity, and rhythm. For sports and other tasks requiring the use of both hands, including playing an instrument or using a computer, stacking helps prepare the brain. Another component of sport stacking that can improve reading and arithmetic skills is sequencing and patterning.[13]

2. Methods

Inclusion Criterion:

- Subjects with age of 65-75 years.
- Both genders were included.
- Subjects able to perform activities of daily living according to Barthel Index of ADL with score of 61-99.
- Subjects who were able to communicate.
- Subjects with intact sensory sensations as assessed on bilateral hands.
- Subjects with Medical Research Council (MRC) with a grade of 3 and 4 for bilateral hand lumbricals, flexor digitorum superficialis, flexor digitorum profundus, elbow flexors and extensors.
- Either of the hand dominance were taken.
- Subjects with no physician imposed medical exercise restriction.

Exclusion Criterion:

- Subjects with neuromuscular disorders like Myasthenia Gravis and Muscular Dystrophies.
- Subjects presenting with dystonic movements like tremors, tics.
- Subjects with musculoskeletal disorders affecting upper limb such as recent upper limb fractures, carpal tunnel syndrome, any ligament sprain or muscular strain.
- Subjects with uncontrolled hypertension.
- Subjects with history of any cardiovascular condition like angina.
- Subjects on any anti- depressant medication.
- Subjects Pre - diagnosed with hypermetropia and color blindness.
- Subjects with any type of pain in their legs, hand, back, or neck affecting the movements.

Group A

Sports Stacking Intervention[14]

Sports stacking is also known as cup stacking technique.
As per framed protocol, 2 days training was given for learning the technique.
The 3 commonly used sports stacking cycle was most used-

- 3-3-3 pattern
- 3-6-3 pattern
- 6-6 pattern

Figure 2: 3-3-3 Sport Stacking Sequence

Figure 3: 3-6-3 Sport Stacking Sequence

Figure 4: 6-6 Sport Stacking Sequence

For a period of 7 weeks, the sport stacking intervention will be carried out as follows-

Table 2: Weekly patterns of stacking

Weeks	Stacking Pattern
I	3-3-3*10
II	3-6-3*10
III	6-6*10
IV	3-3-3*10
V	3-6-3*10
VI	6-6*10
VII	3-3-3 3-6-3 } *10 6-6

Any error in stacking technique will be considered and the subject will be directed to start the pattern again.

9-Hole Peg Test Procedure[15]

A square board with 9 holes spaced 3.2 cm (1.25 inches) apart. Each hole is 1.3 cm (0.5 inches) deep. 9 wooden pegs should be 0.64 cm (0.25 inches) in diameter and 3.2 cm (1.25 inches) long. A container that is constructed from 0.7 cm (0.25 inches) of plywood, sides are attached (13 cm x 13 cm) using nails and glue.

Hand dexterity was checked by asking the subject to perform 9-hole peg test.

The pegboard was centered in front of the subject with the pegs placed in the container next to the board on the same side as the hand being tested.

The dominant hand was tested first followed by non-dominant hand. The stopwatch is started as soon as the subject touches the first peg. The stopwatch is stopped when the subject hits the last peg in the container. Then the container is placed on the opposite side of the peg board. Same procedure is done for non-dominant hand.

Two trails were performed for dominant and non-dominant hands.

An average score for both the hands was counted as the final one.

Figure 5: Assessment of Hand Dexterity

Group B Intervention[16]

Warm up Exercises-
Warm up period was carried for 10 minutes.

- Walking with long deliberate steps
- Walking with small deliberate steps
- Walking while heel raising.
- Marching on place

General Exercises
Each exercise was carried for 10 repetitions. The total duration of the exercise session was 35 minutes.

- Biceps curl
- Hammer curls
- T-rows
- Gell Ball Press
- Lumbar rotations
- Bridging
- Active range of Motion Hip Flexion
- Active range of Motion Hip Extension
- Walking between cones
- Sit to Stand
- **Cooling off activities-** General stretching exercises

3. Results

There was significant improvement in the time of sports stacking of Group A over the 7th week. On analysis using paired T-test for time of sports stacking for Group A mean and standard deviation was 38.08±4.066 at baseline and at 7th week 27.59±3.349 respectively. The time of sports stacking showed mean improvement from 38.08 to 27.59 with the mean difference of 10.49. The paired T-test value was 36.655and the p value for the group A was (<0.001).

There was significant improvement in the time of sports stacking of Group B over the 7th week. On analysis using paired T-test for time of sports stacking for Group B mean and standard deviation was 37.24±2.248 at baseline and at 7th week 35.96±2.198 respectively. the time of sports stacking showed mean improvement from 37.24 to 35.96 with the mean difference of 1.28. The paired T-test value was 38.321 and the p value for the group B was (<0.001).

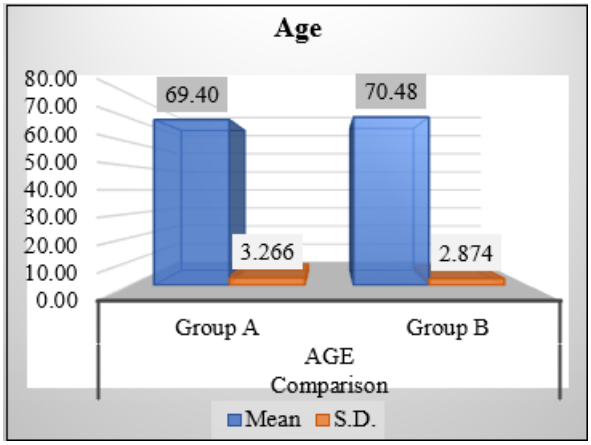

Figure 6: Shows comparison of mean of age of subjects for Group A and Group B

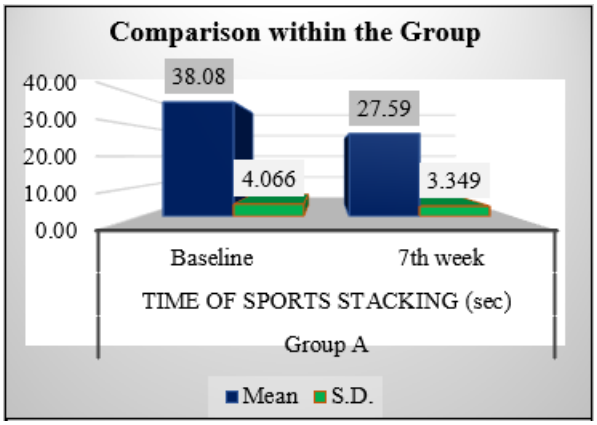

Figure 7: Shows paired T-test scores for the time of sports stacking within the group A at baseline and at 7th week.

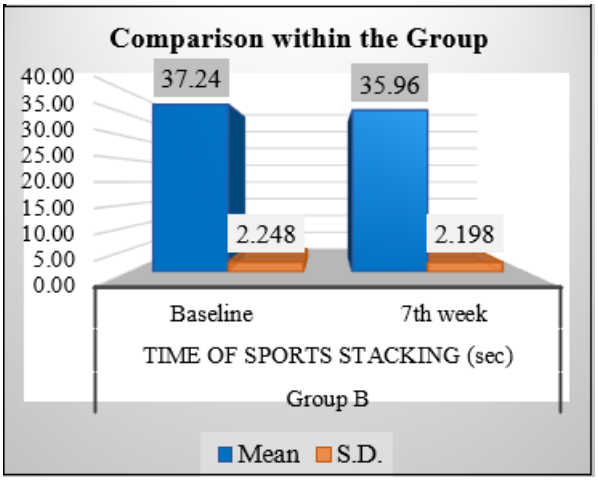

Figure 8: Shows paired T-test scores for the time of sports stacking within the group B at baseline and at 7th week.

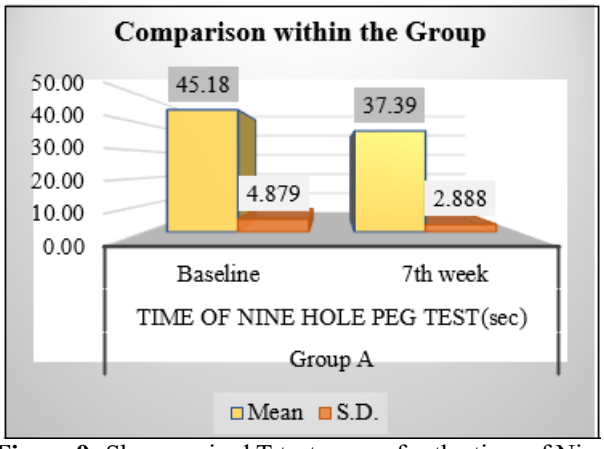

Figure 9: Shows paired T-test scores for the time of Nine Hole Peg test within the group A at baseline and at 7th week

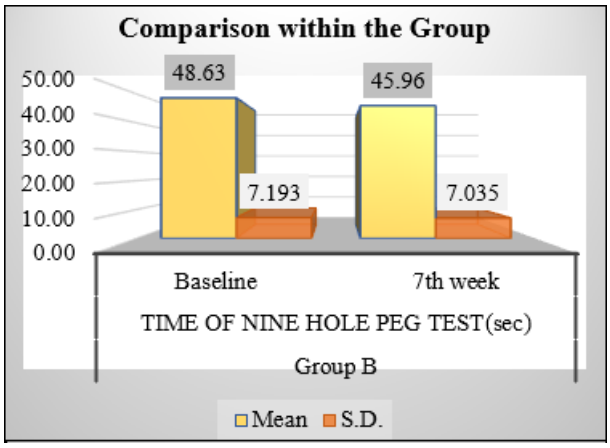

Figure 10: Shows paired T-test scores for the time of Nine Hole Peg test within the group B at baseline and at 7th week

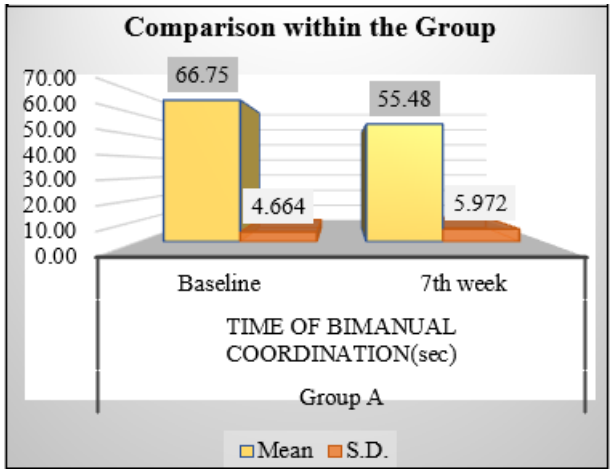

Figure 11: Shows paired T-test scores for the time of Bimanual Coordination within the group A at baseline and at 7th week

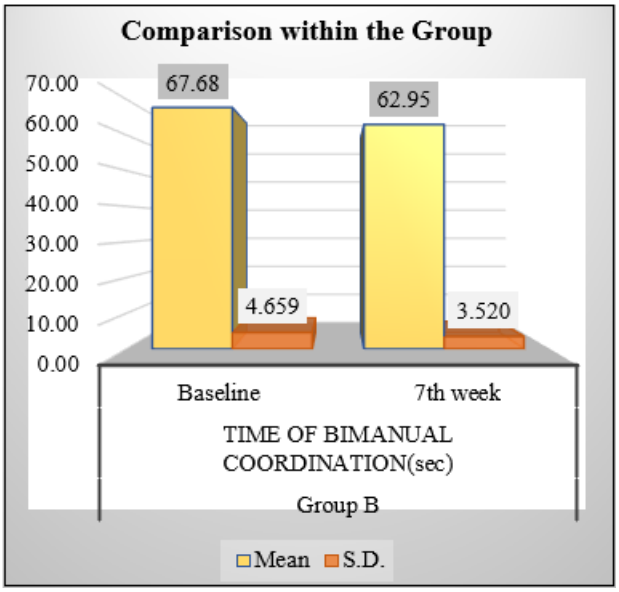

Figure 12: Shows paired T-test scores for the time of Bimanual Coordination within the group B at baseline and at 7th week

4. Discussion

This study aimed to assess effect of sport stacking on hand dexterity and bimanual coordination in 50 geriatric participants over a seven-week period. The parameters measured included performance in sports stacking, the Nine Hole Peg test and bimanual coordination. Group A was administered Sports Stacking Intervention and Group B received conventional physiotherapy.

Each group was evaluated at baseline and again at the end of the seventh week using paired and unpaired t-tests to determine within-group and between-group changes. The results revealed significant within-group improvements for both groups across all domains. However, between-group comparisons indicated that Group A consistently exhibited more robust and statistically significant improvements than Group B.

Sports Stacking: In older adults, sports stacking can serve as a low-impact, engaging intervention that simultaneously

targets motor, cognitive, and psychosocial health domains. Sports stacking helps in rapid, precise movements and enhance hand-eye coordination and strengthen the neural pathways that integrate visual information with motor control. Switching seamlessly between right- and left-hand maneuvers promotes bilateral integration, while memorizing and executing stacking sequences sharpens focus and mental processing speed. The rhythmic pacing and requirement to recover gracefully from errors also foster stress resilience and improve reaction time, which are critical for safe mobility in daily life.[17] In this study, both groups improved in their sports stacking times over the seven-week period. Group A showed a marked reduction in completion time, indicating a better hand-eye coordination and speed. Similarly, Group B demonstrated improved performance. However, the comparative analysis between the two groups revealed that the differences were statistically significant, suggesting that while both groups benefited, sports stacking intervention clearly outperformed the other in this task.

The Nine Hole Peg Test offers a rapid, sensitive snapshot of hand–finger dexterity in older adults, making it an invaluable tool for both screening and intervention. By timing how quickly an individual can place and remove pegs, clinicians establish a clear baseline of fine motor function and can detect subtle declines that often precede difficulties with daily tasks like buttoning clothing or handling small objects. Regular retesting not only tracks the impact of targeted therapies such as strength training or coordination drills but also helps identify those at greater risk for falls and loss of independence, since slowed peg placement often parallels broader sensorimotor and balance impairments. Moreover, because the test taps into cognitive–motor integration requiring planning, attention, and visuospatial processing, prolonged completion times can signal emerging cognitive concerns, prompting further evaluation.[18] In this current study, improvements were evident in the Nine Hole Peg test for both groups. Participants in Group A showed faster task completion times by the seventh week. Group B, however, also showed improvements. When comparing the two groups, the analysis indicated that Sports stacking intervention and Brain Gym exercises were statistically significant, highlighting a more effective response to the intervention in this group. The superior gains seen in Group A's Nine-Hole Peg Test performance likely reflect a combination of motor learning, exercise-induced neuroplasticity, and enhanced cognitive–motor integration. Repeated fine-finger tasks drive use-dependent changes in the sensorimotor cortex strengthening the very neural circuits that control dexterity and over time these adaptations translate into faster, smoother peg placement and removal.[19] **Hübner L et al[20] (2018)** studied that acute bouts of exercise have been shown to increase cortical activation in motor areas and facilitate motor memory consolidation, giving participants an immediate boost in fine-motor control that compounds with practice. Several prior investigations have reported comparable improvements in Nine-Hole Peg Test times following related interventions. For instance, **Dhote et al[21] (2017)** conducted a pilot study of hand-grip strength exercises in a geriatric sample demonstrated significant reductions in pegboard completion times after a structured training period.

Bimanual coordination is critical for everyday tasks in older adult activities like dressing, meal preparation, and personal care often demand fluid, simultaneous use of both hands making it a cornerstone of functional independence. With advancing age, however, individuals exhibit declines in movement accuracy, greater variability, and slower execution times during bimanual tasks, reflecting age-related neuromuscular changes and reduced interhemispheric communication.[22] These impairments are closely linked to diminished ability to perform activities of daily living, higher fall risk, and overall loss of autonomy, which is why clinicians increasingly use bimanual coordination measures to screen for frailty and functional decline. Importantly, research shows that structured bimanual coordination training through targeted movement drills and cross-lateral exercises can not only restore dexterity but also promote neuroplasticity and yield transferable gains in both motor and cognitive domains for the geriatric population.

Assessment of bimanual coordination showed progress in both groups. Group A participants performed the task more efficiently by the end of the trial period in this study. However, Group B also exhibited improvement. The comparative results indicated that the improvement in Group A was statistically more significant than in Group B. This suggests enhanced neural integration and bilateral motor control in Group A, possibly due to more effective or targeted intervention**. Torre MM et al[23] (2023)** showed that older participants who completed structured bimanual coordination training not only improved on the practiced tasks but also transferred benefits to untrained motor and cognitive tests, with mediation analyses implicating enhanced inhibitory control as the key driver. Moreover, **Eiichi Naito et al[24] (2021)** demonstrated that bimanual digit exercises which specifically target interhemispheric communication restored declined hand-finger dexterity in geriatric subjects, further supporting the role of cross-lateral training in promoting bilateral motor control.

5. Conclusion

The goal of the current study was to assess how sports stacking activities affected the older population's hand dexterity, bimanual coordination, and neuropsychological performance-more especially, cognition and apathy. 50 individuals who were 65 years of age or older were recruited and split into two groups at random: Group A was the intervention group, and Group B was the conventional group. Sessions were held five days a week for at least sixty minutes each, for the seven-week duration of the intervention. Changes in the dependent variables before and after the intervention were assessed using standardized assessment instruments, including Bimanual Coordination Test and Nine Hole Peg Test. The study's findings showed that the interventional group (Group A) significantly outperformed the conventional group (Group B) in every parameter that was measured. With a notable improvement in hand dexterity and bimanual coordination. These results provide credence to the idea that involving senior citizens in organized, brain-stimulating, and coordination-based activities, like sports stacking, might result in significant gains in physical functioning. This study emphasizes how crucial it is to incorporate accessible, affordable, and non-pharmacological

therapies into geriatric care and rehabilitation. To build on the encouraging findings of this study, future research with bigger sample sizes, longer intervention times, and more diverse populations is advised.

6. Limitations and Future Scope

The sample size of the study was small (n=50) limited. No long-term follow-up were taken to access the sustainability of improvements, whereas Cognitive assessment was limited to MMSE and the external factors were not controlled.

Large sample studies with diverse geriatric population can be conducted in the future. Long term follow-up can be implemented. Further, it can explore the effect of these interventions in population with specific neurological or cognitive impairments and can incorporate more comprehensive neuropsychological assessment.

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Conflict of interest: None declared

Ethical approval: Approval was taken by the ethical committee of DAV institute of Physiotherapy and rehabilitation, Jalandhar (PUNJAB) in December,2023.

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