Effect Of Multimodal Cawthorne-Cooksey Exercises on Enhancing Locomotion and Cognitive Functions in Older Adults with Mild Impairment: A Single-Blind Experimental Design

By

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I hereby declare that this dissertation/thesis entitled **“Effect of Multimodal Cawthorne-Cooksey exercises on enhancing locomotion and cognitive functions in older adults with Mild Cognitive Impairment: A single-blind experimental design”** is a bonafide and genuine research work carried out by me under the guidance of **Dr. Priyadarshini Mishra (PT), Associate Professor and Dr. Partha Ranjan Das (PT), Sr. Assistant Professor**, and there are no conflict of interest associated with this dissertation work.

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LIST OF ABBREVIATIONS USED

1. **AAN** – American Academy of Neurology
2. **a-MCI** – Amnestic Mild Cognitive Impairment
3. **CCE** – Cawthorne-Cooksey Exercises
4. **DSM** – Diagnostic and Statistical Manual of Mental Disorders
5. **EF** – Executive Function
6. **FGA**- Functional Gait Assessment
7. **ICD** – International Classification of Diseases
8. **MCI** – Mild Cognitive Impairment
9. **MMCCE** – Multimodal Cawthorne-Cooksey Exercises
10. **na-MCI** – Non-Amnestic Mild Cognitive Impairment
11. **NIA-AA** – National Institute on Aging–Alzheimer’s Association
12. **SCT**- Stroop Color Test

13. **SCWT**- Stroop Color-Word Test

14. **SLUMS-** Saint Louis University Mental Status

15. **SWT**- Stroop Word Test

16. **TMT-A & B**- Trail Making Test- A & B

17. **TUG-COG**- Timed up and go- Cognitve

18. **WHO** – World Health Organization

19. **VOR** – Vestibulo-ocular Reflex

20. **VR** – Vestibular Rehabilitation

21. **VSR** – Vestibulospinal Reflex

ABSTRACT

Title: Effect of Multimodal Cawthorne-Cooksey exercises on enhancing locomotion and cognitive functions in older adults with Mild Cognitive Impairment: A single-blind experimental design

Background: Gait and cognitive impairments are highly prevalent in older adults with Mild Cognitive Impairment (MCI), often contributing to reduced mobility and increased fall risk. Although, Vestibular rehabilitation is used in vestibular disorders, its application in older adults with MCI offers a promising approach to simultaneously improve gait and cognitive functions through multisensory stimulation.

Objective: To evaluate the effects of Multimodal Cawthorne- Cooksey Exercises (MMCE) on gait and cognitive functions in older adults with MCI

Methods: 50 older adults with MCI, screened using the Saint Louis University Mental Status (SLUMS) examination and the Timed Up and Go Cognitive (TUG-COG) test. Out of which, 20 were eligible according to inclusion and exclusion criteria. Participants were non-randomly allocated into an experimental group (n = 10), which received MMCE, and a control group (n = 10), which performed conventional exercises. Both groups underwent supervised sessions for eight weeks. Outcomes were assessed pre- and post-intervention using the Functional Gait Assessment (FGA), Trail Making Test (TMT-A and B), Stroop Word Test (SWT), Stroop Color Test (SCT), and Stroop Color–Word Test (SCWT).

Results: The experimental group showed significant improvements in FGA ($p = 0.005$) and SCWT ($p = 0.004$) following the intervention, whereas the control group did not exhibit significant changes. Between-group comparisons confirmed that improvements were greater in the experimental group.

Conclusion: MMCE effectively enhanced locomotion and inhibitory control in older adults with MCI, likely enhancing selective attention as well. These results support MMCE as a feasible, non-pharmacological intervention to improve locomotor function and specific executive abilities in this population.

Keywords: Attention; Cognitive Dysfunction; Elderly; Executive Function; Gait; Vestibular Rehabilitation

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INTRODUCTION

Aging refers to the gradual decline in the physiological functions necessary for survival and fertility. Normal aging is commonly associated with a decline in processing speed, memory, language, visuospatial abilities, and executive functions. Recent advancements in neurology have identified declines in grey and white matter volume, alterations in white matter, and declines in neurotransmitter levels that all may contribute to observed cognitive changes with aging.[1,2]

According to Petersen et al. (1997), MCI is a clinical-neuropsychological entity characterized by early signs of cognitive deterioration, i.e., an intermediate state between physiological ageing and dementia.[3]

According to the DSM-5 (2013), the American Psychiatric Association classifies MCI as a mild neurocognitive disorder (NCD), characterized by subjective and objective decline in one or more cognitive domains without loss of independence in daily functioning and not attributable to delirium or other psychiatric disorders. Similarly, the WHO's ICD-11 (2018) defines mild NCD as involving subtle cognitive decline with possible neurobehavioral symptoms, producing mild but noticeable effects on complex daily activities. The NIA-AA (2011) proposed research criteria for MCI due to Alzheimer's disease, emphasizing biomarkers such as amyloid-β deposition and neuronal injury, which, though not diagnostic, are valuable in research contexts.[4]

The 2018 AAN guideline highlights that MCI becomes more common with age affecting about 7% of adults in their early 60s and around one in four by their early 80s. Globally, prevalence ranges from 3% to 42%, with Indian studies showing 15–33%. Differences are due to variations in diagnostic criteria, study design, and population characteristics.[4,5]

In some cases, cognitive decline goes beyond typical age-related changes, though it still doesn’t amount to dementia. People with MCI have a tenfold higher risk of developing dementia and more than double the risk of all-cause mortality compared to cognitively healthy older adults. Risk for MCI tends to rise with age, especially in men and in those with fewer educational or financial resources, or who have worked mainly in manual labor. Medical conditions like diabetes, high blood pressure, and mental health issues such as anxiety and depression can add to this risk while higher education and strong social engagement appear protective.[5]

MCI can be classified according to the cognitive domains involved, which include learning and memory, language, complex attention, executive function, social cognition, and visuospatial ability. Based on the presence or absence of memory impairment, MCI is broadly categorized into amnestic (a-MCI) and non-amnestic (na-MCI) types, each of which may present as a single-domain or multiple-domain form. In a-MCI, memory deficits are the primary feature, either occurring in isolation or alongside impairments in other domains, and this subtype carries a higher risk of progression to Alzheimer’s disease. In contrast, na-MCI is characterized by preserved memory with deficits in one or more non-memory domains, is less commonly encountered, and may progress to non-Alzheimer’s dementias.[4]

According to the Neuropsychology classification system of 2009, MCI can be divided into four distinct subtypes. a-MCI is characterized by difficulties with recall and recognition, primarily affecting memory. Mixed MCI involves impairments across multiple cognitive domains rather than being limited to one. Dysexecutive MCI is marked by deficits in attention, executive functions, and visuospatial abilities. Lastly, Visuospatial MCI is identified when impairment is restricted to a single measure of visual construction. This classification highlights the diverse ways in which MCI can manifest, depending on the cognitive domains affected.[4]

MCI may progress to dementia, remain stable, or revert to normal. About 15% of adults >65 develop dementia within 2 years, with annual progression rates of 12–20%. Progression is linked to functional impairment, neuropsychiatric symptoms, hippocampal atrophy, amnestic subtype, advanced age, lower cognition, and biomarkers (reduced parietal metabolism, elevated Tau, APOE ε4). Reversion (~20%) is more common in younger males with single-domain or non-amnestic MCI, better cognition, fewer comorbidities, or reversible factors, though risk of decline remains.[4]

The clinical presentation of MCI involves dual manifestations, characterized by cognitive and gait changes. Gait regulation requires continuous engagement of central neural mechanisms, as the brain integrates multiple sensory inputs such as visual, vestibular, and somatosensory to ensure effective movement control.[6]

Individuals with MCI often experience challenges in carrying out every day functional activities. Disturbances may appear in mobility, muscular strength, balance, and gait, which together increase the likelihood of falls. Among these domains, a reduction in walking speed is frequently observed and is regarded as one of the most prominent alterations in older adults. Slower gait has also been considered a potential early sign of progression toward dementia, making it a clinically important feature. Several studies have further suggested that diminished walking speed and greater variability in walking rhythm and stability may serve as an indicator of mild cognitive impairment.[7] Thus, gait disturbances in MCI not only represent a functional limitation but also serve as potential clinical markers of cognitive decline, highlighting the need to further explore motor–cognitive interactions.

While walking is largely an automatic task, cognitive processes play a key role in controlling axial musculature, balance and posture, coordinating bilateral upper and lower extremity movements and integration of visual, vestibular, proprioceptive, and other sensory feedback. Consequently, cognitive performance is a key determinant of gait in older adults, as reduced attentional capacity can directly compromise stability and elevate fall risk. Cognitive deficits can reduce allocation of attentional resources, which can compromise postural and gait stability. Executive function (EF) is the domain most commonly associated with gait dysfunction. Decline in EF and selective attention over time is associated with decline in gait speed and improvement in EF is associated with improved gait speed.[8]

Walking ceases to be fully automatic in complex situations such as negotiating uneven surfaces, performing a concurrent task, or in the presence of age- or disease-related impairments. In such contexts, additional cognitive input is required to maintain performance. The decline in gait or cognitive function observed when two tasks are performed simultaneously termed dual-task cost appears to be least pronounced when walking at a slightly reduced pace rather than at normal or very slow speeds. The nature of the secondary task influences the extent of interference, with executive functions playing a central role in regulating dual-task performance. Impairments in this capacity have been identified as predictors of negative health outcomes, including frailty, functional deterioration, and mortality among older adults.[8]

Gait and cognition share brain networks, especially those supporting EF. Neuroimaging shows that greater white matter changes are linked to slower gait and higher dual-task costs, particularly in dementia with reduced cognitive reserve. These changes can appear even in middle age. Cortical, cerebellar, and hippocampal volumes are associated with gait and EF, though many links weaken when cognitive factors are considered.[8]

Gait and cognitive impairments in older adults may arise independently or from shared pathology. Gait control relies on integrated motor, sensory, and cognitive systems, including memory, attention, and EF. Frontal–subcortical circuits mediate both gait and higher-order cognition and become increasingly vulnerable to ischemia, inflammation, and neurodegeneration with age, predisposing older adults to isolated or combined motor and cognitive deficits.[9]

Evidence shows that gait disturbances, especially under dual-task conditions, are closely linked to deficits in EF, attention, and working memory, making gait a sensitive marker of early cognitive decline. These changes may be subtle during single-task walking but become pronounced with added cognitive load, emphasizing the role of cognitive control. Assessing gait in cognitively demanding contexts helps detect early decline.[10]

Gait performance in MCI reflects the interaction between motor control and cognitive function, particularly attention, executive processes, and processing speed. Altered gait patterns in MCI highlight the influence of cognitive load on locomotor control, with deficits becoming more pronounced under challenging conditions. Even during routine walking, individuals with MCI show subtle gait changes, including reduced velocity and stride length. While slower gait correlates with adverse outcomes such as frailty, loss of independence, and mortality, velocity alone is insufficient to distinguish MCI from normal aging. These findings highlight that even habitual walking can reveal early cognitive-motor interactions.[11]

Combining walking with a cognitive task uncovers deficits not evident in single-task conditions, emphasizing the role of executive function in locomotion. Parameters such as stride time and gait variability show larger impairments under dual-task conditions, especially during demanding cognitive tasks like arithmetic. Simpler tasks, such as verbal fluency, have lower cognitive demands and produce weaker differentiation. Task complexity must therefore be tailored to maximize sensitivity for MCI detection remaining feasible for more impaired populations.[11]

Gait changes in MCI extend beyond speed, involving both temporal (stride time, variability) and spatial (stride length) parameters. Stride-time variability is particularly sensitive to cognitive load, with longer walking distances enhancing detection of subtle motor–cognitive disruptions. These multidimensional impairments indicate that gait in MCI reflects executive and attentional deficits rather than simple motor slowing.[11]

Fast-paced walking and gait initiation act as motor “stress tests,” analogous to dual-task walking as a cognitive “stress test.” These demanding conditions magnify latent gait disturbances, providing a sensitive means to detect early MCI-related impairments in motor–cognitive integration.[11] Given the impact of gait–cognition disruptions on daily functioning and fall risk, there is a need for interventions that address both motor and cognitive domains simultaneously.

The vestibular system plays a central role in navigation by detecting self-movement through linear and angular acceleration and serving as a graviceptor. It integrates and modulates information from vision and proprioception, with the vestibular labyrinths detecting head orientation relative to the gravity vector with an accuracy better than 0.5 degrees—4 to 5 times more precise than vision—thereby enabling postural adaptation to gravity and preventing imbalance and falls.[12,13]

The vestibular system, primarily recognized for its role in balance and spatial orientation, has emerging links to cognitive functions such as memory, attention, and spatial awareness. Neural pathways connecting the vestibular system to cognitive and motor centers including the vestibulo-thalamo-cortical pathway, dorsal tegmental nucleus pathway, nucleus reticularis pontis oralis pathway, and a possible cerebellar pathway—highlight its integrated role in motor-cognitive control. Vestibular rehabilitation has been shown to improve gait, and these emerging links suggest it may also enhance cognitive function by stimulating integrated neural circuits.[14]

Vestibular rehabilitation (VR) enhances balance, reduces fall risk, and alleviates symptoms of vestibular disorders by promoting central nervous system compensation and neural plasticity. The Cawthorne-Cooksey exercises (CCE), involving coordinated eye, head, and body movements, are a cornerstone of this approach, improving postural control, spatial processing, and gaze stability. Highly adaptable, safe, and cost-effective, they are effective for conditions such as BPPV, vestibular neuritis, and post-concussion syndrome. In older adults, multicomponent programs combining strength, aerobic, and balance training further counteract muscle loss, enhance walking speed, and improve overall physical function and quality of life. Clinical guidelines recommend comprehensive exercise programs integrating cardiovascular, strength, flexibility, and balance training to optimize functional outcomes.[15,16]

The Cawthorne-Cooksey program is a VR approach aimed at improving gaze stability, balance, and postural control. It includes eye and head movement exercises to strengthen the VOR and VSR, gaze stabilization tasks to reduce vertigo during dynamic activities, motion sensitivity training to decrease dizziness, and balance and coordination exercises such as tandem walking and weight shifting to enhance stability and prevent falls. Its therapeutic effects are achieved through sensory reweighting, proprioceptive enhancement, vestibular compensation, habituation, and adaptation, with the brain reorganizing to use visual, vestibular, and proprioceptive inputs for improved coordination, reduced vertigo, and better functional balance.[16]

The vestibular system plays a central role in maintaining balance, postural control, and spatial orientation, while also influencing cognitive processes such as attention, memory, and EF. Targeting the vestibular system can therefore provide a dual benefit i.e. improving both locomotion and cognitive performance.

However, in recent years, there has been increasing interest in expanding traditional vestibular exercises into multimodal approaches that also address cognitive deficits particularly in populations such as older adults. In this context, Multimodal Cawthorne-Cooksey Exercises (MMCCE) represent a contemporary adaptation of the classical CCE framework. MMCCE integrate vestibular stimulation with cognitive, functional, and sensory challenges during postural and dynamic balance activities to stimulate multiple domains simultaneously in older adults with MCI. [17]

MMCE represents a practical, low-cost, and feasible intervention that can be readily implemented in community or clinical settings for older adults. Despite their accessibility and potential to simultaneously engage motor and cognitive systems, the extent to which MMCE can improve both gait and cognitive function in individuals with MCI remains largely underexplored. Limited evidence exists on these dual-domain outcomes, leaving a critical gap in understanding how such interventions might support functional independence, reduce the risk of falls, and slow cognitive decline. Systematic investigation of MMCE in this population is therefore essential to establish their effectiveness as a holistic, non-pharmacological strategy for early intervention in MCI.

As the population ages, Mild Cognitive Impairment (MCI) presents a growing public health challenge, with individuals facing both cognitive decline and motor impairments like gait disturbances and balance issues. These impairments increase the risk of falls and further cognitive deterioration. Early interventions that target both motor and cognitive function are essential to slow MCI progression, prevent dementia, and maintain independence in older adults, improving overall quality of life. By integrating vestibular exercises (Multimodal Cawthorne-Cooksey Exercises), this research aims to offer a comprehensive, non-invasive intervention that could slow the progression of MCI, improve motor and cognitive functions, and ultimately enhance the quality of life in this vulnerable population.

AIM AND OBJECTIVES

AIM OF THE STUDY

To assess the effect of Vestibular Rehabilitation (Multimodal Cawthorne-Cooksey Exercises) on enhancing locomotion and cognition in older adults with mild cognitive impairment.

OBJECTIVES OF THE STUDY

To evaluate the effect of Multimodal Cawthorne-Cooksey Exercises on locomotion and cognitive functions in older adults with mild cognitive impairment (MCI) using FGA, TMT-A & B, Stroop Test (SWT, SCT, SCWT).

HYPOTHESES

NULL HYPOTHESIS: Multimodal Cawthorne-Cooksey Exercises will not significantly improve locomotion and cognitive functions in older adults with MCI.

ALTERNATE HYPOTHESIS: Multimodal Cawthorne-Cooksey Exercises will significantly improve locomotion and cognitive functions in older adults with MCI.

REVIEW OF LITERATURE

1. **Cosentino et al. (2020)** conducted a study at IRCCS San Camillo Hospital, Venice, Italy, including 43 participants with MCI and 43 age-matched healthy controls. Participants underwent detailed neuropsychological testing, gait assessment using the BTS FREEMG 300 system, and structural brain imaging with 3D T1-weighted MRI on a 1.5 T Philips Achieva scanner. In the MCI group, gait speed showed a significant positive correlation with memory performance ($p < 0.05$), whereas in controls, gait parameters such as speed, cadence, and stride length were correlated with executive function ($p < 0.01$). Neuroimaging revealed that gait in MCI was associated with temporal and limbic regions, including the superior temporal gyrus, thalamus, and parahippocampal gyrus. In contrast, gait in healthy controls was linked to frontal regions, particularly the middle and superior frontal gyri, as well as the cerebellum. These findings indicate that gait is supported by different neural networks in MCI versus healthy aging, emphasizing the link between motor function and cognitive processes in early cognitive decline.

2. **Takakusaki (2017)** highlights the neuroanatomy of posture and gait control, emphasizing the integration of multisensory inputs—somatosensory, visual, and vestibular—for adaptable locomotion. Automatic gait is primarily mediated by brainstem-spinal pathways, whereas navigating unfamiliar environments requires cognitive contributions from the temporoparietal cortex for posture control and motor planning. The motor cortex supports anticipatory adjustments necessary for goal-directed movements. Interventions such as exergaming and vestibular training have been shown to improve gaze stability, balance, and gait in older adults. Impairments in cortical, basal ganglia, or cerebellar regions can

disrupt posture-gait control, increasing fall risk and highlighting the importance of targeted therapeutic strategies for cognitively impaired older adults.

3. **Montero-Odasso (2018)** reviewed the relationship between cognition and fall risk in community-dwelling older adults aged 65 and above. The review highlighted the interplay between gait, cognitive function, and brain motor control deficits in aging, emphasizing dual-task gait assessments as sensitive markers for fall risk. Impairments in attention and executive function were associated with gait slowing, instability, and increased likelihood of falls. Interventions such as cognitive-enhancing drugs in Parkinson's disease, as well as cognitive, dual-task, and virtual reality training, were shown to improve mobility and reduce fall risk in older adults, including those with cognitive impairment.

4. **Klotzbier and Schott et.al (2017)** examined cognitive-motor interference during walking in young adults, healthy older adults, and older adults with probable mild cognitive impairment (pMCI) using the Trail-Walking Test (TWT). The study demonstrated excellent reliability of the TWT (ICC = 0.83–0.97) and found that older adults with pMCI exhibited significantly longer durations and greater dual-task costs, especially under high cognitive load conditions. Receiver operating characteristic analysis showed that only complex dual-task conditions reliably distinguished pMCI from healthy controls (AUC > 0.7). The findings suggest that dual-task gait assessments, particularly those with higher cognitive demand, may serve as sensitive screening tools for early detection of pMCI.

5. **Bukhari et al. (2022)** conducted a single-blind randomized controlled trial at Doctor Raza Clinic, Swabi, Pakistan, including adults aged 60–75 years. Participants were randomized into two groups: one received exergaming and the other vestibular training, three times per week for six weeks. Outcome measures included the Dynamic Gait Index, Timed Up-and-Go test, and Dynamic Visual Acuity test. Of 24 participants (12 per group, mean age 66.3 ± 4.36 years), both groups demonstrated significant intra-group improvements ($p < 0.05$), while inter-group differences were not statistically significant ($p > 0.05$). The study indicates that both exergaming and vestibular training can enhance gait, balance, and gaze stability in older adults, although neither intervention was superior.

6. **Gökçe et al. (2024)** investigated the effects of repetitive home-based galvanic vestibular stimulation (GVS) on cognitive function in 21 healthy older adults (mean age 64.66 ± 2.97 years; 12 females). Participants were randomly assigned to either a GVS group or an active control group. The GVS intervention consisted of 20-minute sessions, five times per week for two weeks. Cognitive performance was assessed using the Stroop Test, Trail Making Test A & B, and a Dual-Task paradigm. A significant group-by-time effect was observed for tracking accuracy ($F(1,18) = 7.713$, $p = 0.012$), with improvements seen only in the GVS group ($t = -2.544$, $p = 0.029$). The study suggests that home-based GVS may enhance visuospatial abilities in healthy older adults.

7. **Ricci et al. (2016)** conducted a randomized clinical trial with a three-month follow-up involving 82 older adults with chronic dizziness due to vestibular disorders. Participants were assigned to either a control group following the conventional Cawthorne & Cooksey protocol (n = 40) or an experimental group receiving the Multimodal Cawthorne & Cooksey protocol (n = 42). Outcomes included the Dynamic Gait Index, fall history, grip strength, Timed Up-and-Go, sit-to-stand, multidirectional reach, and static balance tests. Except for fall history, all outcomes improved post-intervention and were maintained at follow-up. Significant between-group differences were observed in the Sensory Romberg Eyes Closed and Unipedal Left Leg Eyes Open tests, favoring the Multimodal protocol. While both protocols enhanced balance, the Multimodal Cawthorne & Cooksey protocol demonstrated superior performance on specific static balance measures.

8. **Ribeiro et al. (2022)** carried out a longitudinal quasi-experimental study to examine cognitive and psychological outcomes of vestibular rehabilitation in older adults with confirmed vestibular dysfunction. Fifty participants aged 60–86 years underwent eight sessions of customized Cawthorne–Cooksey exercises. Cognitive performance was assessed with the Brief Neuropsychological Battery (Neupsilin), and psychological distress was measured using the Geriatric Depression Scale (GDS-15). Post-intervention results showed significant improvements in overall cognition as well as in specific domains including orientation, attention, memory, arithmetic skills, oral and written language, praxis, and executive functions, alongside a reduction in psychological distress. These findings provide evidence that vestibular

rehabilitation not only enhances physical balance but also promotes broad cognitive gains and emotional well-being in elderly individuals with vestibular dysfunction.

9. **Ebenezer et al. (2023)** conducted a randomized controlled trial to evaluate the effects of vestibular rehabilitation therapy (VRT) on cognition and quality of life in individuals with chronic dizziness or vertigo. Sixty participants were randomized into a medication-only group receiving betahistine and a VRT + medication group. Outcomes included the Dizziness Handicap Inventory (DHI) for quality of life, and digit span, task-switching, and P300 measures for cognition. While both groups demonstrated improvement in DHI scores, the VRT + medication group showed significantly greater reductions, along with marked cognitive benefits—enhanced digit span and task-switching performance, reduced P300 latency, and increased P300 amplitude—compared to medication alone. These findings indicate that VRT not only alleviates physical symptoms but also improves cognitive function, highlighting its potential as a comprehensive therapeutic approach for patients with chronic dizziness or vertigo.

10. **Micarelli et al. (2023)** conducted a randomized study to examine the effects of a head-mounted display (HMD)–based vestibular rehabilitation protocol in older adults with unilateral vestibular hypofunction (UVH), both with and without mild cognitive impairment (MCI). A total of 47 participants were assigned either to conventional vestibular rehabilitation or to vestibular rehabilitation combined with a home-based virtual reality protocol using an

HMD. Significant within-group improvements were observed across all groups in posturography parameters, dizziness-related outcomes, and quality of life, although no changes were noted in vestibulo-ocular reflex (VOR) gain with conventional rehabilitation alone. In contrast, the HMD intervention group showed significantly greater post-treatment improvements in VOR gain, postural control, and quality of life compared to conventional therapy. Moreover, positive correlations were found between Mini-Mental State Examination scores and improvements in low-frequency power spectra ($r = 0.72$) and Dynamic Gait Index scores ($r = 0.76$), suggesting that cognitive status influenced rehabilitation outcomes. The findings indicate that integrating virtual reality into vestibular rehabilitation is safe and may enhance postural and functional gains even in older adults with MCI, thereby supporting the feasibility of technology-assisted vestibular rehabilitation in cognitively vulnerable populations.

11. **Goswami et al. (2024)** conducted a three-armed randomized controlled trial to investigate whether vestibular therapy could enhance the effects of cognitive training in elderly individuals with mild cognitive impairment (MCI). Thirty-six participants were randomized into vestibular therapy combined with computerized cognitive training, cognitive training alone, and a control group. Over an 8-week intervention period, the vestibular-cognitive group demonstrated significantly greater improvements in ERP-P300 latency and amplitude, Digit Symbol Substitution Test, and Trail Making Test-B compared to the other groups, indicating superior gains in processing speed and executive function. These findings highlight that incorporating vestibular rehabilitation

into cognitive interventions may yield greater cognitive benefits in MCI than cognitive training alone, supporting the role of vestibular-cognitive interactions in non-pharmacological management strategies.

12. **Wrisley et al. (2010)** conducted a prospective cohort study with 35 community-dwelling older adults aged 60–90 years to evaluate the validity of the Functional Gait Assessment (FGA). Participants completed the Activities-specific Balance Confidence Scale (ABC), Berg Balance Scale (BBS), Dynamic Gait Index (DGI), Timed Up and Go (TUG), and FGA in a single session, and falls were tracked prospectively over six months. The FGA showed strong concurrent validity, correlating with the ABC ($r = 0.53$, $p < 0.001$), BBS ($r = 0.84$, $p < 0.001$), and TUG ($r = -0.84$, $p < 0.001$). An FGA cutoff score of $\leq 22/30$ demonstrated both discriminative and predictive validity for fall risk, with 100% sensitivity, 72% specificity, a positive likelihood ratio of 3.6, and a negative likelihood ratio of 0.

13. **Tombaugh (2004)** examined normative data for the Trail Making Test (TMT) A and B in a large sample of 911 community-dwelling adults aged 18–89 years (mean age = 58.5). Participants were screened with the Mini-Mental State Examination (MMSE) and Geriatric Depression Scale (GDS) to exclude cognitive or psychiatric impairments. The TMT was used to assess processing speed (Part A) and cognitive flexibility (Part B). Results showed that age had a strong influence, accounting for 34% of the variance in TMT-A and 38% in TMT-B performance, while education had minimal effect. Normative data

stratified by age and education were established, with percentile scores generated for clinical application.

14. **Faria et al. (2024)** evaluated the construct validity, short-term test–retest reliability, and sensitivity to mental fatigue of the Stroop task in older adults across two studies. In Study 1, forty participants completed the Stroop task twice with a 30-minute interval, demonstrating strong concurrent validity, significant differences between congruent and incongruent conditions ($p < 0.001$), and excellent response time reliability ($ICC = 0.926$). However, cognitive inhibition showed significant variability across repeated trials ($p < 0.001$). In Study 2, fifteen participants performed a Flanker task to induce mental fatigue, which led to significantly poorer Stroop performance on the subsequent trial ($p = 0.045$). These findings suggest that the Stroop task is valid and reliable overall but sensitive to mental fatigue, with cognitive inhibition proving less stable over short retest intervals.

METHODOLOGY AND PROCEDURE

- **STUDY DESIGN:** Experimental (Pretest- Posttest Control)
- **STUDY POPULATION:** Older adults aged 60–80 years with Mild Cognitive Impairment (MCI)
- **SAMPLE SIZE:** The sample size was estimated using G*Power software (version 3.1.9.7) for a two-tailed test with an effect size of 0.5, significance level (α) of 0.05, and power of 80%. The calculation indicated a required sample size of 44 participants. A total of 50 older adults were screened using the SLUMS and TUG-COG, of which 30 were excluded based on the eligibility criteria. Finally, 20 participants were recruited and completed the study.
- **SAMPLING TECHNIQUE:** Purposive Sampling
- **STUDY SETTING:** Local study setting
- **STUDY DURATION:** 1 year
- **MATERIALS REQUIRED:** Stopwatch, Chair without armrests, Measuring Tape, Marker, Small and large size ball of medium weight, Tumbler, Wrist and ankle weights (0.5,1 and 1.5 kg), Foam balance pad, Pencil & Paper,
- **INCLUSION CRITERIA:**

- Aged 60–80 years
- Both genders (male & female)
- MCI screened by SLUMS
- TUG cognitive > 15 s indicating balance impairment
- Able to read and understand basic English instructions

➢ EXCLUSION CRITERIA:

- History of psychiatric, neuromuscular, orthopaedic, neurological, or rheumatologic disorders
- Illiteracy or inability to follow study instructions
- Unwillingness to continue in the study
- Onset of new conditions such as stroke during the study
- Discontinuation or dropout from the intervention for any reason

OUTCOME MEASURES:

Functional Gait Assessment: The Functional Gait Assessment (FGA) is a 10-item test of postural stability and motor performance during walking, adapted from the 8-item Dynamic Gait Index to reduce ceiling effects. The 10 components include gait on a level surface, change in gait speed, gait with horizontal and vertical head turns, gait with pivot turn, stepping over an obstacle, gait with a narrow base of support, gait with eyes closed, ambulating backwards, and using steps. Each item is scored on a 0–3 scale (0 = severe impairment, 3 = normal), with a maximum score of 30. The test may be administered with or without an assistive device, but no physical assistance is allowed. Equipment required includes a stopwatch, a 20-foot walkway, a 9-inch obstacle, and steps with rails. Administration typically takes 5–20 minutes, and a 4-point change is considered clinically meaningful. Cut-off scores of ≤22/30 indicate fall risk, while ≤20/30 predict unexplained falls within 6 months

Trail making test form A & B:

The Trail Making Test (TMT) assesses visual attention, processing speed, sequencing, mental flexibility, and executive functioning. Part A requires participants to connect 25 numbered circles in order as quickly as possible, while Part B requires alternating between numbers and letters in sequence (1-A-2-B…). Both parts are timed, with errors corrected while timing continues, and testing is stopped at 300 seconds if incomplete. Scoring is based on completion time, and derived measures such as B–A or B/A may reflect executive functioning.

Stroop Test:

The Stroop Color-Word Test evaluates selective attention, processing speed, cognitive flexibility, and inhibitory control. It includes three conditions: reading color words printed in black ink (Word), naming the colors of solid patches (Color), and naming the ink color of incongruent color words (Color-Word), which requires inhibiting the automatic reading response. Performance is measured by completion time, number of errors, and interference effects. Standard instructions are given before each condition, and practice trials may be provided if necessary.

PROCEDURE

The research proposal was submitted to the Institutional Ethical Committee for ethical clearance, and permission was also obtained from the Head of the Institution. A pre-post experimental study was conducted in which participants (n = 50) were screened in the community using the SLUMS Questionnaire and the TUG–COG Task Test. Of these, 20 participants who met the inclusion criteria were identified. The study procedure was explained in detail to eligible individuals, and written informed consent was obtained from all willing participants.

Demographic and baseline data, including age, sex, education level, and relevant medical history, were documented through proper assessment. Participants were blinded and allocated into two groups, with 10 participants each: Group A (experimental group) received Multimodal Cawthorne-Cooksey Exercises, while Group B (control group) received a Conventional Exercise Program targeting strength, flexibility, and balance components, matched for duration and frequency. The intervention frequency was two sessions per week, conducted for eight weeks, with each session lasting 50 minutes.

PROTOCOL

The experimental group performed Multi-Modal Cawthorne-Cooksey Exercises (MMCCE) in progressive stages. Stage A (lying position, 28 minutes) involved eye and head movements. Stage B (sitting position, 32 minutes) included eye, head, and trunk movements with object handling. Stage C (standing position, 38 minutes) incorporated eye, head, and trunk exercises along with dynamic movements such as sit-to-stand, ball passing, and turning. Stage D (moving, 24 minutes) focused on walking tasks (across the room, up/down slope, and steps), ball games (throwing and kicking), and functional tasks combined with balance challenges. Across sessions, exercises were progressed by modifying speed, surface stability, object size, and adding resistance (weights), along with simultaneous cognitive tasks such as counting backward or verbal fluency.

The control group performed a multicomponent exercise program comprising warm-up exercises (limb movements with breathing), aerobic exercises (stick displacement and walking with hand-to-knee touch), resistance training for the upper limb (diagonal limb movement) and lower limb (sit-to-stand), balance and coordination activities (straight line, obstacle, and heel-to-toe walking), followed by stretching exercises (toe-touch, trunk rotation, and arm elevation).[18]

Pre- and post-intervention assessments were conducted using the Functional Gait Assessment (FGA), Stroop Test, and Trail Making Test A & B (TMT-A and TMT-B).

All collected data were systematically recorded. Statistical analysis was performed to interpret the findings, and results were derived based on comparisons between pre- and post-intervention outcomes.

Fig.1.1

MULTI-MODAL CAWTHORNE COOKSEY EXERCISES

Stage A- Lying Position- 28 minutes (1 session)

1. Eye movements a) up and down. b) from side to side. c) focusing on finger moving from near to far away from face.	**1.** a-b-c: 2 min slow, 2 min quick. Simultaneous counting backwards from a randomized number between 20 and 99.
2. Head movements a) bending forward and backward. b) turning from side to side.	**2.** a-b: 30 sec (2 series): neck stretching (flexor, extensor, rotator right, rotator left muscles). 1 min slow, 2 min quick EO. 1 min slow, 2 min quick EC.

Stage B- Sitting Position- 32 minutes (2 sessions)

1. Eye movements Repeat a-b-c.	**1.** a-b-c: 2 min slow, 2 min quick. Simultaneous fruit verbal fluency.
2. Head movements Repeat a-b.	**2.** a-b: 30 sec (2 series): neck stretching. 1 min slow, 2 min quick EO. 1 min slow, 2 min quick EC.
3. Trunk movements a) shoulder shrugging and circling.	**3.** a: 2 min: switching shoulder circling direction (counterclockwise- clockwise) every 30 sec. **Session 1:** no wrist weight. **Session 2:** 0.5 Kg wrist weight.
b) bending forward and picking up an object (medium ball) from the ground.	**3.** b: 30 sec (2 series) back stretching (sitting position- bending forward- holding). 1 min: switching the object every 30 sec. **Session 1:** pencil/ medium ball. **Session 2:** pencil/ heavy ball (2.0 kg).

Stage C- Standing Position- 38 minutes (6 sessions)

1. Eye movements Repeat a-b-c.	**1.** a-b-c: 4 min: switching feet position (2 min apart, 1 min feet together, 1 min tandem position). **Sessions 1, 2:** stable surface. **Sessions 3, 4:** unstable surface. **Sessions 5, 6:** switching surface (stable- unstable) every 30 sec. Simultaneous counting backwards from number 20.
2. Head movements Repeat a-b.	**2.** a-b: 4 min EO, 4 min EC: switching feet position (apart- together) at 2 min. **Sessions 1, 2:** stable surface. **Sessions 3, 4:** unstable surface. **Sessions 5, 6:** switching surface (stable- unstable) every 30 sec. Simultaneous animal verbal fluency.
3. Trunk movements Repeat a.	**3.** a: 2 min: switching shoulder circling direction (counterclockwise- clockwise) every 30 sec. Switching feet position/ surface (apart/ stable- together/stable- apart/unstable- together/ unstable) every 30 sec. **Sessions 1, 2:** 0.5 Kg wrist weight. **Sessions 3, 4:** 1.0 Kg wrist weight. **Sessions 5, 6:** 1.5 Kg wrist weight.
4. Dynamic movements a) sitting to standing position.	**4.** a: 1 min regular seat height (43 cm), 30 sec higher seat height, 30 sec lower seat height. **Session 1, 2:** higher (46 cm), lower (40 cm). **Session 3, 4:** higher (49 cm), lower (37 cm). **Session 5, 6:** higher (52 cm), lower (34 cm).
b) throwing a (small) ball from hand to hand above eye level.	**4.** b: 2 min: switching ball size (little, small, medium, large) every 30 sec.
c) throwing a (medium) ball from hand to hand under knees lifting foot.	**4.** c: 2 min: switching ball size (little, small, medium, heavy- 2.0 Kg) every 30 sec.
d) sitting to standing position, and turning around oneself.	**4.** d: 1 min EO, 1 min EC.

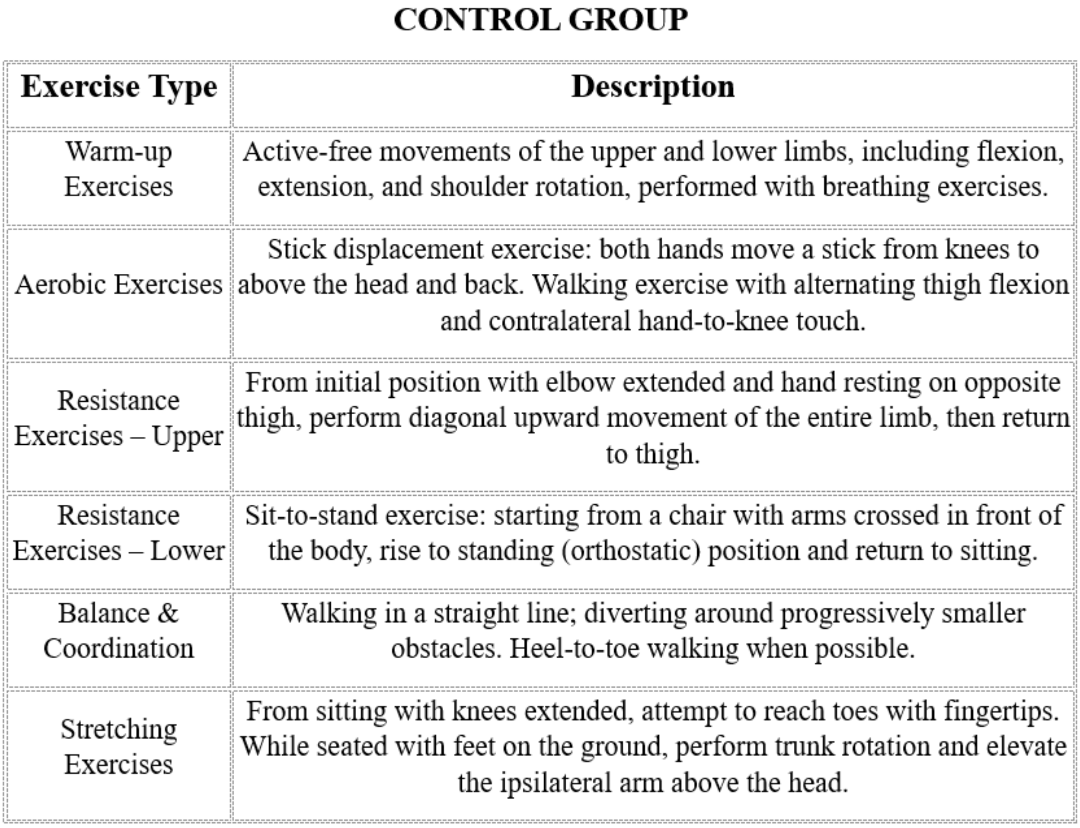
Stage D- Moving- 24 minutes (6 sessions)

1. Circling around the therapist who will throw a (medium) ball to you, and throwing it back.	**1.** 6 min: switching ball size every 2 min. **Sessions 1, 2:** little, medium, large balls. **Sessions 3, 4:** small, medium, large balls. **Sessions 5, 6:** small, large, heavy (2.0 Kg) balls. Simultaneous color verbal fluency.
2. Walking across the room.	**2.** 2 min EO, 2 min EC: switching walking direction (forward, backward, right, left) every 30 sec. **Session 1:** no ankle weight. **Session 2:** 0.5 Kg ankle weight. **Sessions 3, 4:** 1.0 Kg ankle weight. **Sessions 5, 6:** 1.5 Kg ankle weight.
3. Walking up and down the slope.	**3**: 2 min EO: 1 min (holding a glass of water), 1 min (holding a ball). **Session 1:** no ankle weight/ small ball. **Session 2:** 0.5 Kg ankle weight/ medium ball. **Sessions 3, 4:** 1.0 Kg ankle weight/ large ball. **Sessions 5, 6:** 1.5 Kg ankle weight/ heavy (2.0 Kg) ball. 2 min EC **Sessions:** Same ankle weight protocol (as above).
4. Walking up and down the steps.	**4.** 2 min EO: 1 min regular step height (13 cm), 30 sec higher step height, 30 sec lower step height (6 cm). **Session 1:** higher (16 cm)/ no ankle weight. **Session 2:** higher (16 cm)/ 0.5 Kg ankle weight. **Sessions 3, 4:** higher (19 cm)/ 1.0 Kg ankle weight. **Sessions 5, 6:** higher (22 cm)/ 1.5 Kg ankle weight. 2 min EC: regular step height. **Sessions:** Same ankle weight protocol (as above).
5. Ball game a) Throwing a (medium) ball. b) Kicking a (large) ball.	**5.** a: 3 min: throwing a ball towards targets attached to a wall according to the therapist's instruction (2 min), and according to the patient's own preference (1 min).

	Sessions 1-2: small ball/ 0.5 Kg wrist weight. **Sessions 3-4:** medium ball/ 1.0 Kg wrist weight. **Sessions 5-6:** large ball/ 1.5 Kg wrist weight. **5.** b: 3 min: kicking a ball towards targets attached to a wall according to therapist's instruction (2 min), and according to the patient's own preference (1 min). **Sessions 1-2:** small ball/ 0.5 Kg ankle weight. **Sessions 3-4:** medium ball/ 1.0 Kg ankle weight. **Sessions 5-6:** large ball/ 1.5 Kg ankle weight.

min= minutes, **sec**= seconds, **cm**= centimeter, **EO**= Eyes Open, **EC**= Eyes Closed

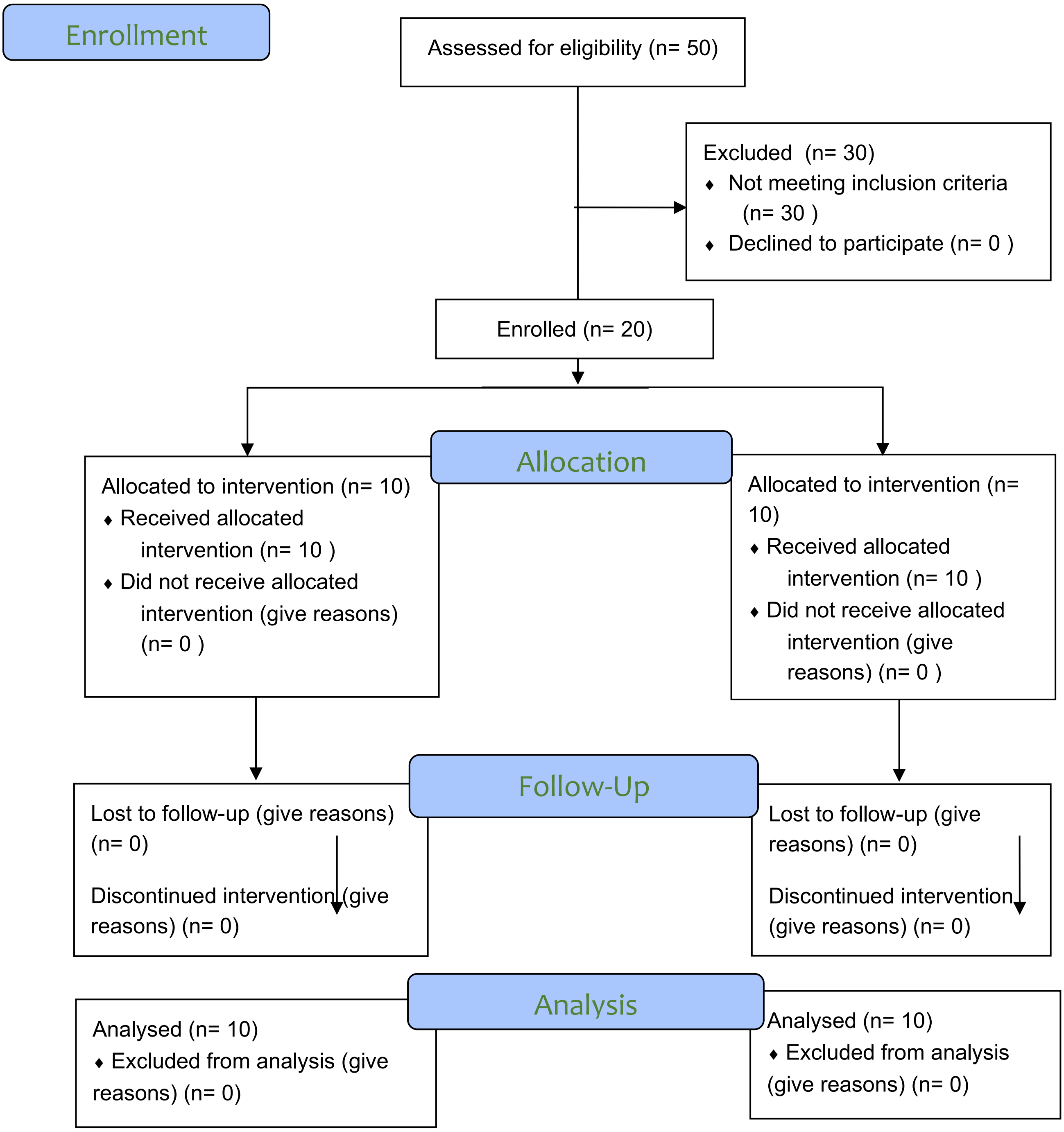
Fig.1.11



CONTROL GROUP

Exercise Type	Description
Warm-up Exercises	Active-free movements of the upper and lower limbs, including flexion, extension, and shoulder rotation, performed with breathing exercises.
Aerobic Exercises	Stick displacement exercise: both hands move a stick from knees to above the head and back. Walking exercise with alternating thigh flexion and contralateral hand-to-knee touch.
Resistance Exercises – Upper	From initial position with elbow extended and hand resting on opposite thigh, perform diagonal upward movement of the entire limb, then return to thigh.
Resistance Exercises – Lower	Sit-to-stand exercise: starting from a chair with arms crossed in front of the body, rise to standing (orthostatic) position and return to sitting.
Balance & Coordination	Walking in a straight line; diverting around progressively smaller obstacles. Heel-to-toe walking when possible.
Stretching Exercises	From sitting with knees extended, attempt to reach toes with fingertips. While seated with feet on the ground, perform trunk rotation and elevate the ipsilateral arm above the head.

CONSORT 2010 Flow Diagram



EXPERIMENTAL GROUP

Fig. 1.12: Head movement in lying position- Eyes open

Fig. 1.13: Head movement in lying position- Eyes closed

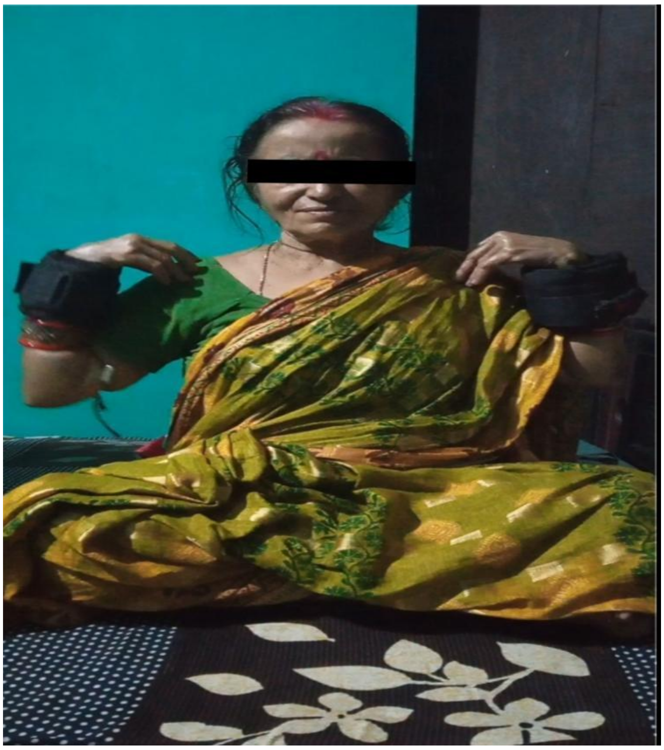


Fig. 1.14: Shoulder circles with wrist weights in sitting position

Fig.1.15: Forward bending in sitting position

Fig.1.16: Eye movement in tandem stance on a stable surface

[redacted]

Fig. 1.17: Standing with feet together on an unstable surface

Fig.1.18: Throwing a ball with wrist weight

Fig.1.19: Kicking a ball with ankle weight

CONTROL GROUP


[redacted]

Fig.1.20: Active-free movement


[redacted]

Fig. 1.21: Stick displacement exercise

Fig.1.22: Sit-to-stand exercise

Fig.1.23: Diagonal movement of the upper limb

Fig.1.24: Heel-to-toe touch in sitting with knee fully extended

Fig. 1.25: Trunk rotation with ipsilateral arm elevation

STATISTICAL ANALYSIS

Data were analyzed using SPSS version 27.0, with the level of significance set at $p < 0.05$. The Shapiro–Wilk test was applied to assess normality. Baseline demographic variables (such as age) and screening outcomes followed a normal distribution ($p > 0.05$) and were presented as mean ± standard deviation (SD). The main outcome measures did not follow a normal distribution ($p < 0.05$) and results were presented as median and interquartile range (IQR). Within-group comparisons were performed using the Wilcoxon Signed-Rank test, and between-group comparisons were analyzed using the Mann–Whitney U test. A p-value < 0.05 was considered statistically significant.

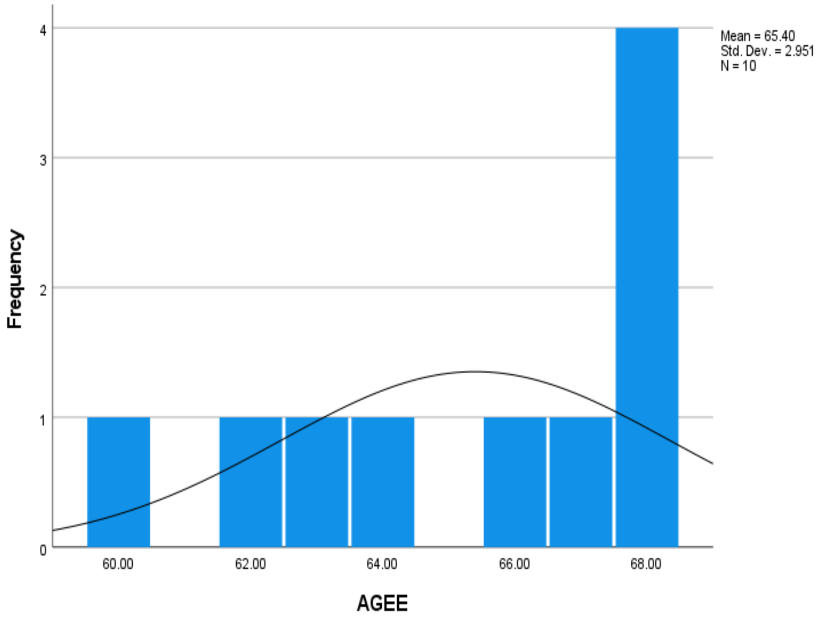
RESULTS

Within-group analysis revealed that Group 1 demonstrated statistically significant improvements in FGA (p = 0.008), SWT (p = 0.020), and SCWT (p = 0.004), whereas changes in TMT-A (p = 0.105), TMT-B (p = 0.16), and SCT (p = 0.375) were not statistically significant. In contrast, Group 2 showed a statistically significant improvement only in SCT (p = 1), while no significant changes were observed in FGA (p = 1.000), TMT-A (p = 0.557), TMT-B (p = 0.432), SWT (p = 0.492), or SCWT (p = 0.77).

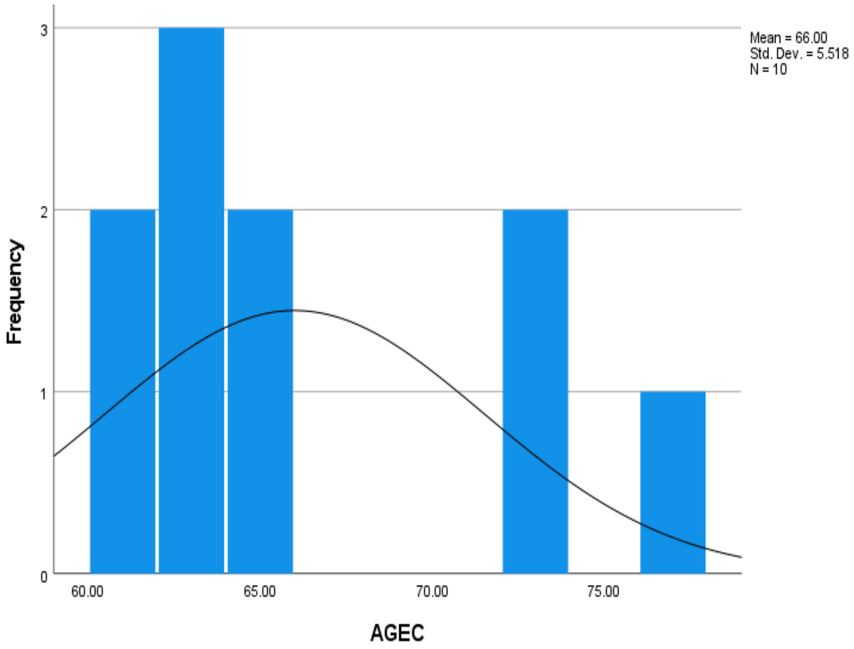
Between-group analysis demonstrated that post-intervention, there were statistically significant differences between Group 1 and Group 2 in FGA (p = 0.005) and SCWT (p = 0.004). However, no significant differences were observed between the groups for TMT-A (p = 0.179), TMT-B (p = 0.143), SWT (p = 0.052), or SCT (p = 0.579).

Table 1.1: Baseline Demographic, Screening, and Outcome Measures of Participants

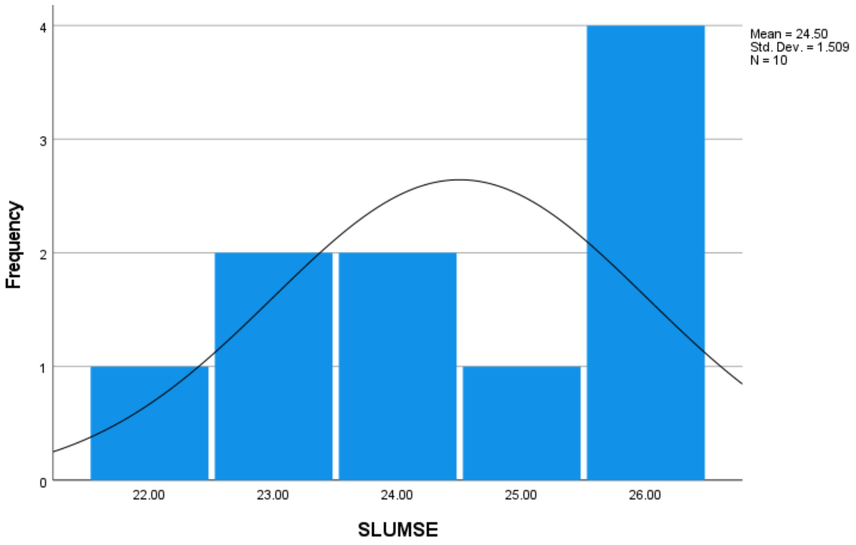
Variable	Group – 1	p-value	Group – 2	p- value
	(n = 10)		(n = 10)	
Demographics				
Age (in years) [Mean ± SD]	65.4 ± 2.95	0.059	66.4 ± 5.58	0.065
Gender (male/female)	04:06		06:04	
Screening Measures				
SLUMS [Mean ± SD]	24.50 ± 1.50	0.087	23.70 ± 1.63	0.627
TUG-COG [Mean ± SD]	20.87 ±1.50	0.306	21.91± 21.02	0.54
Outcome Measures				
FGA [Median (IQR)]	24.5 (3.0)	0.093	25.0 (2.50)	0.048
TMT-A [Median (IQR)]	35.83 (16.22)	0.254	32.95 (14.61)	<.001
TMT-B [Median (IQR)]	64.62 (43.46)	.001	64.27 (29.33)	<.001
SWT [Median (IQR)]	37.99 (9.37)	<.001	35.57 (12.69)	0.667
SCT [Median (IQR)]	63.73 (23.68)	0.247	52.68 (42.95)	0.003
SCWT [Median (IQR)]	92.95 (51.87)	0.078	89.49 (85.74)	0.019



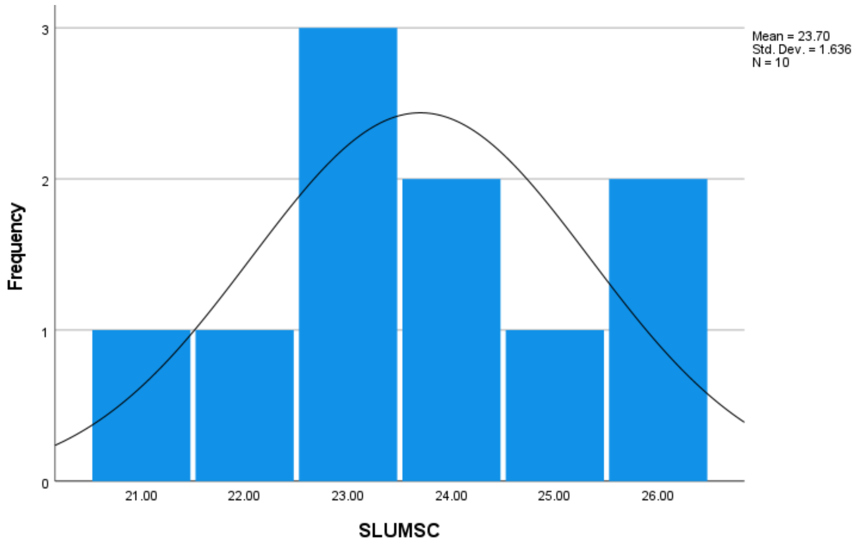
Graph 1.1: Normality plot of age in EG (Shapiro-wilk test, p= 0.059)



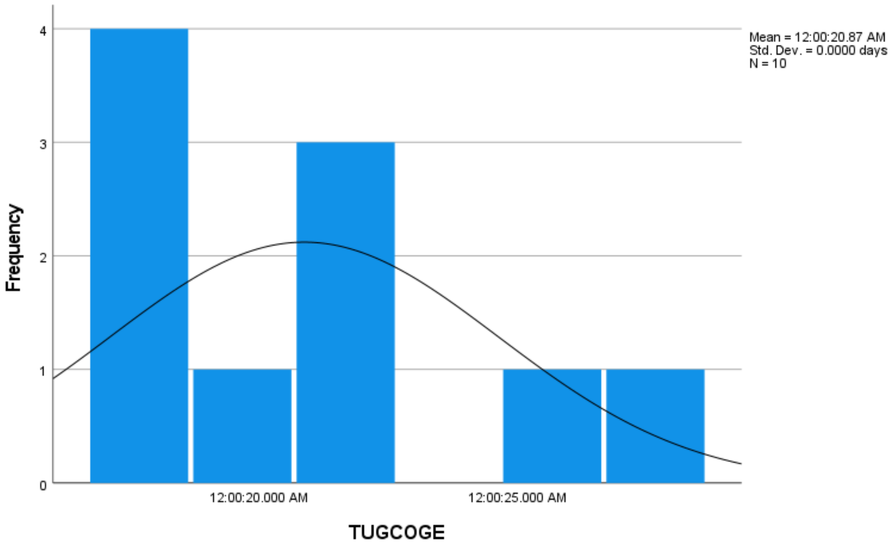
Graph 1.11: Normality plot of age in CG (Shapiro-wilk test, p= 0.065)



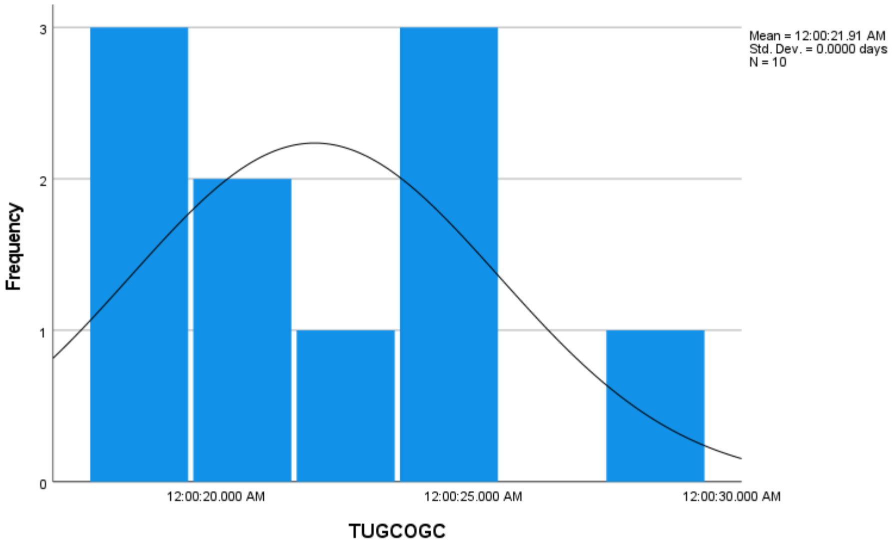
Graph 1.12: Normality plot of SLUMS in EG (Shapiro-wilk test, p= 0.087)



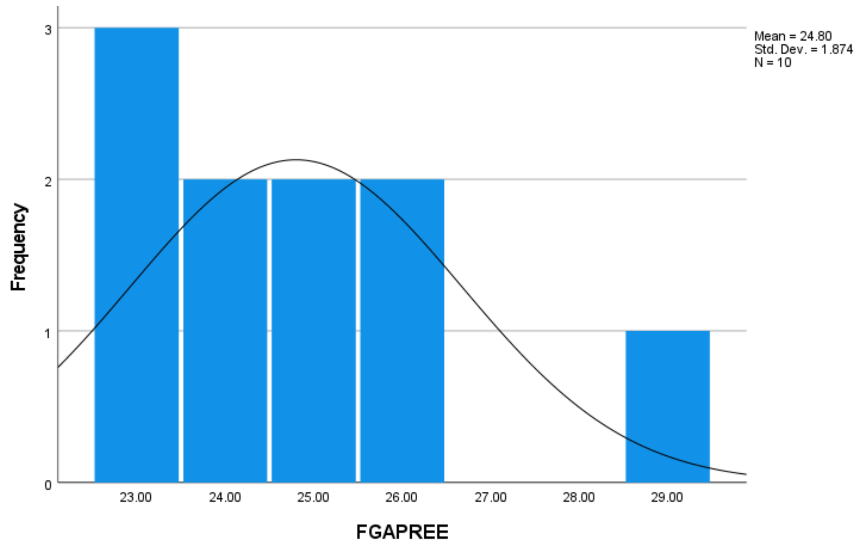
Graph 1.13: Normality plot of SLUMS in CG (Shapiro-wilk test, p= 0.627)



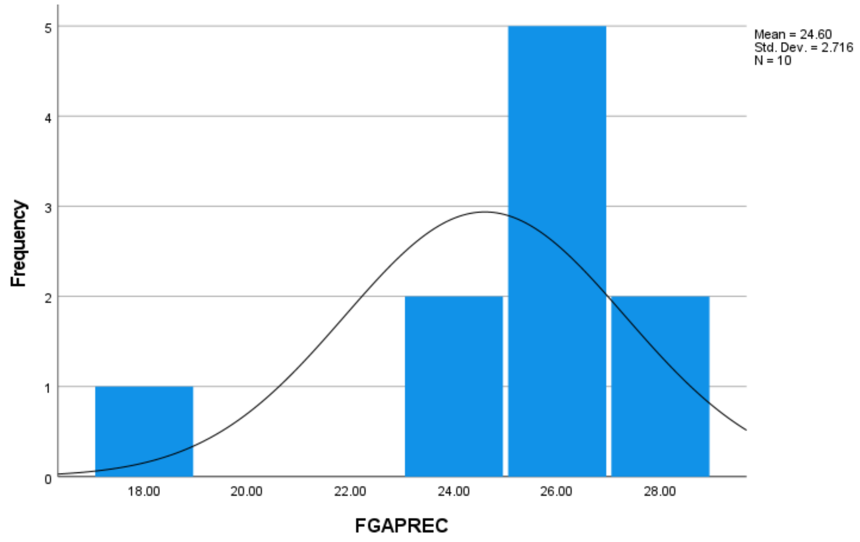
Graph 1.14: Normality plot of TUG-COG in EG (Shapiro-wilk test, p= 0.306)



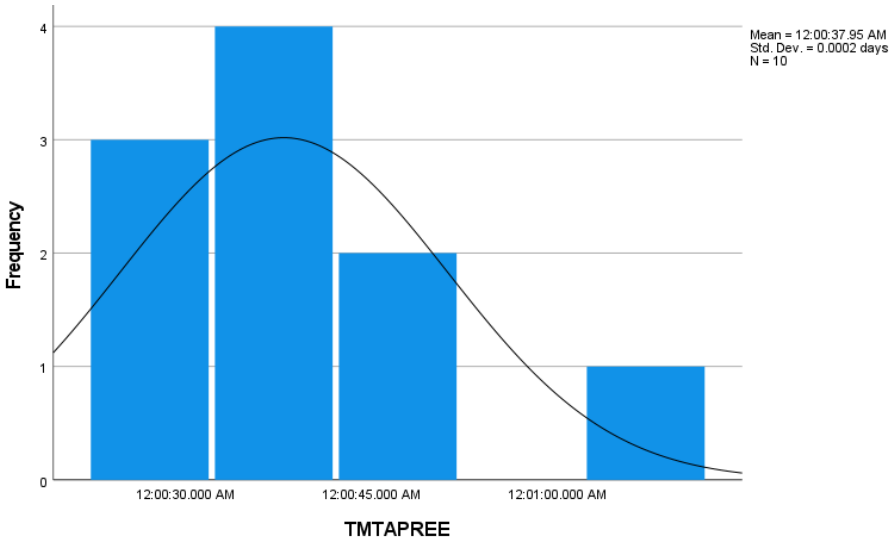
Graph 1.15: Normality plot of TUG-COG in CG (Shapiro-wilk test, p= 0.540)



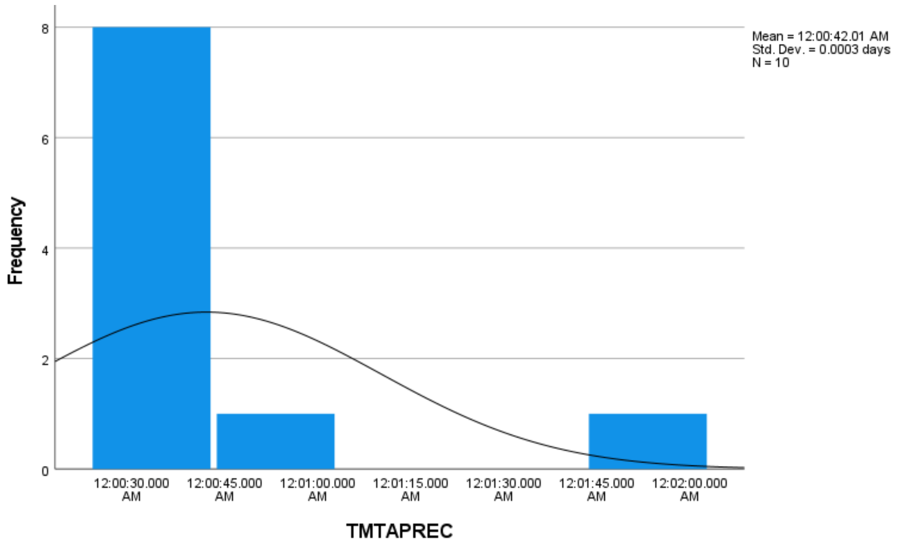
Graph 1.16: Normality plot of FGA in EG (Shapiro-wilk test, p= 0.093)



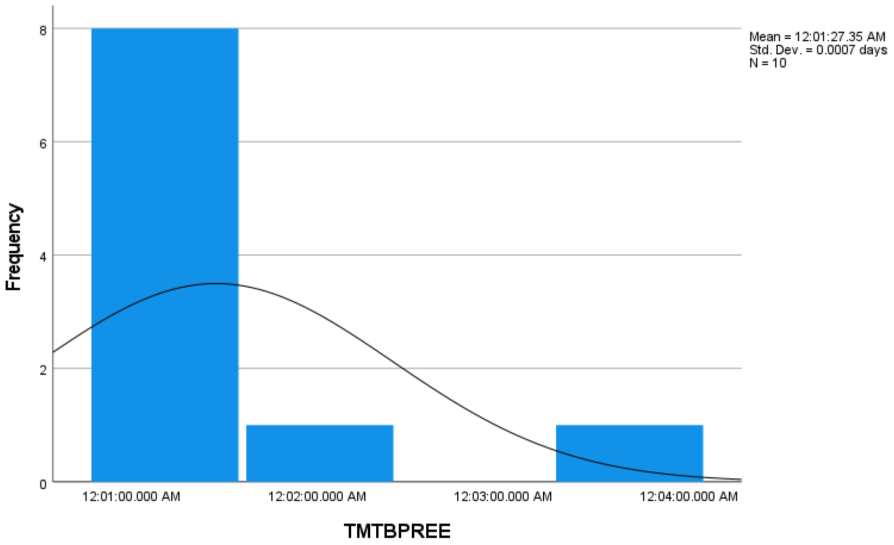
Graph 1.17: Normality plot of FGA in CG (Shapiro-wilk test, p= 0.048)



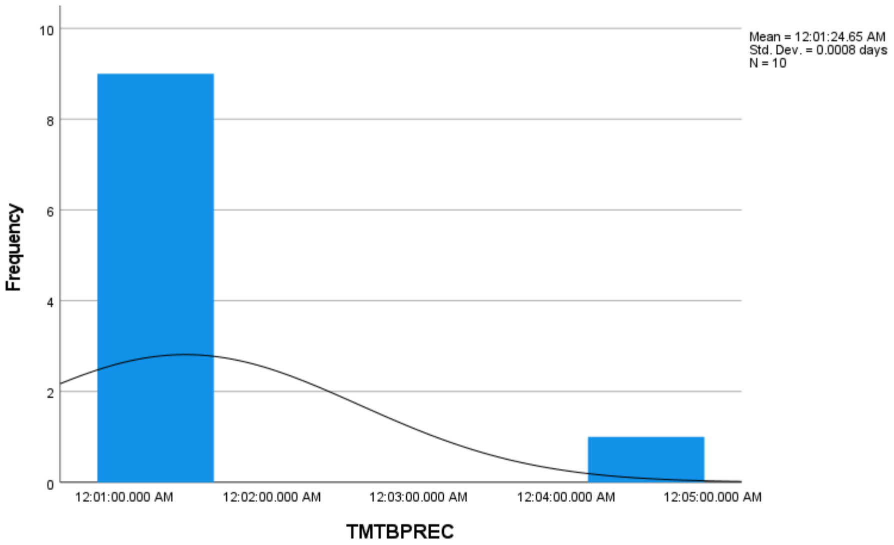
Graph 1.18: Normality plot of TMT-A in EG (Shapiro-wilk test, p= 0.254)



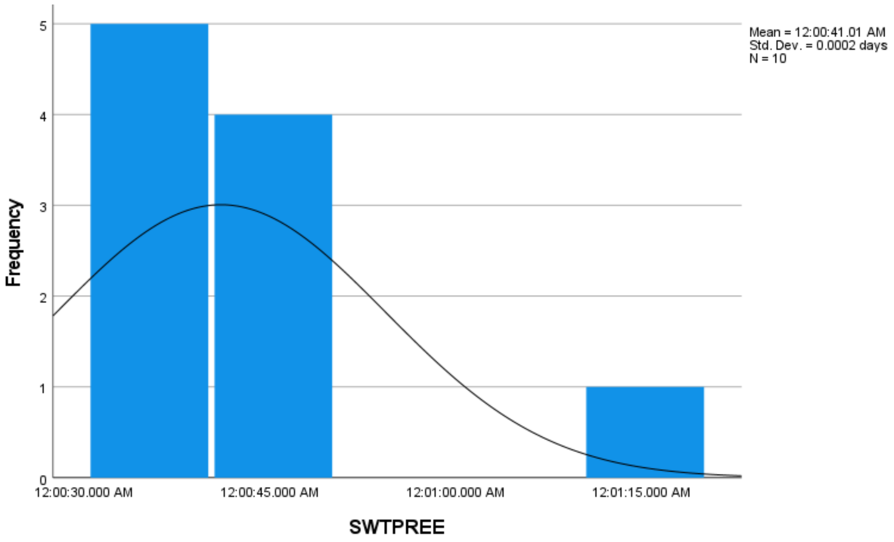
Graph 1.19: Normality plot of TMT-A in CG (Shapiro-wilk test, p= <.001)



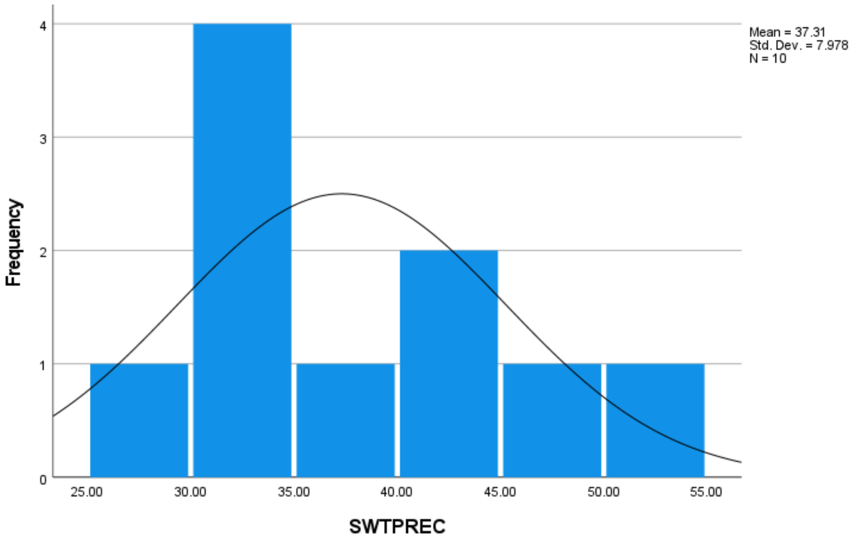
Graph 1.20: Normality plot of TMT-B in EG (Shapiro-wilk test, p= 0.001)



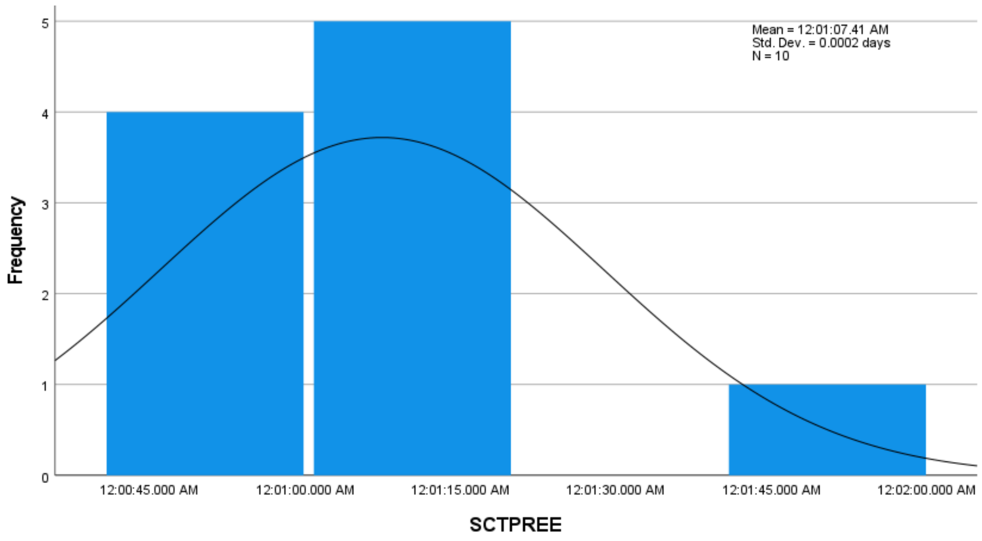
Graph 1.21: Normality plot of TMT-B in CG (Shapiro-wilk test, p= <.001)



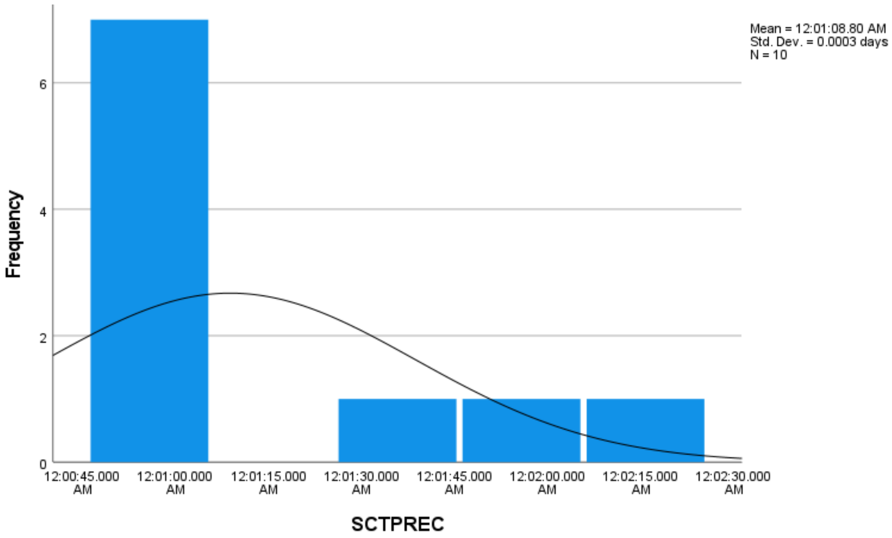
Graph 1.22: Normality plot of SWT in EG (Shapiro-wilk test, p= <.001)



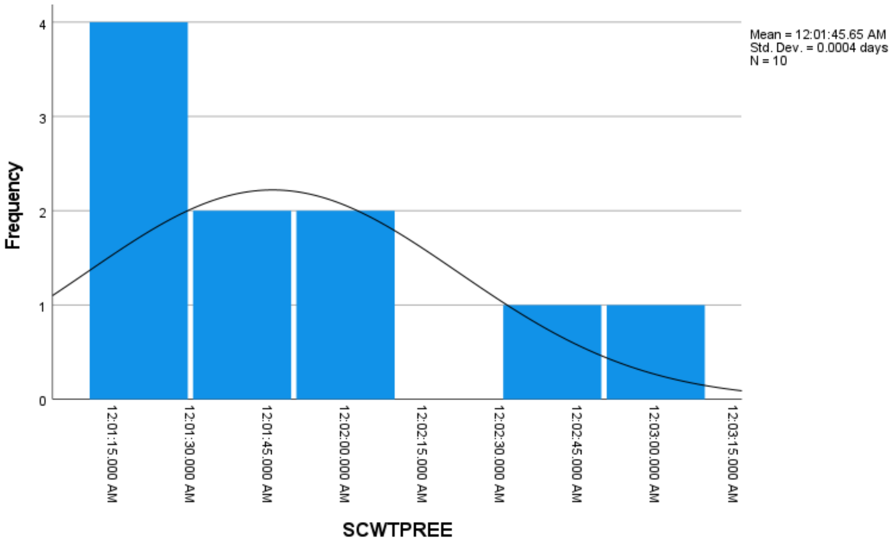
Graph 1.23: Normality plot of SWT in CG (Shapiro-wilk test, p= 0.667)



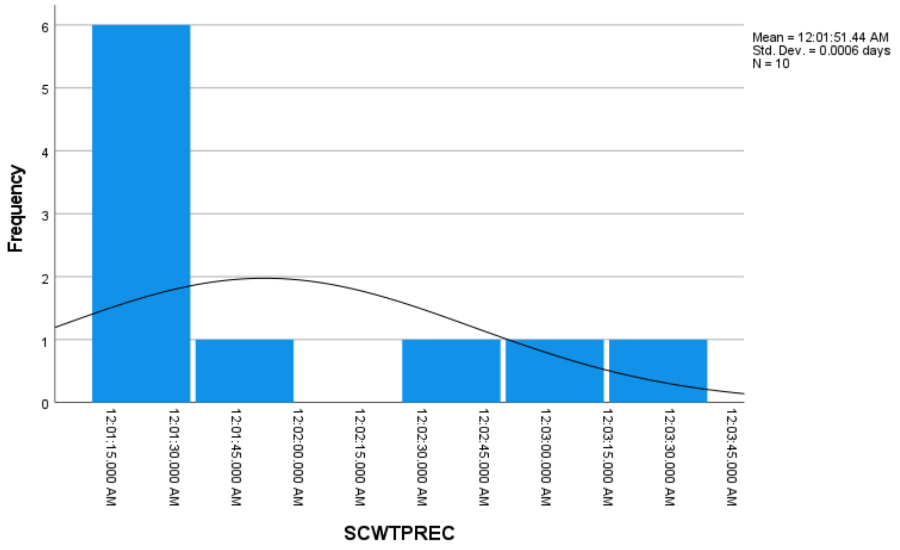
Graph 1.24: Normality plot of SCT in EG (Shapiro-wilk test, p= 0.247)



Graph 1.25: Normality plot of SCT in CG (Shapiro-wilk test, p= 0.003)



Graph 1.26: Normality plot of SCWT in EG (Shapiro-wilk test, p= 0.078)



Graph 1.27: Normality plot of SCWT in CG (Shapiro-wilk test, p= 0.019)

Table 1.2: Comparison of median within Group 1 & 2

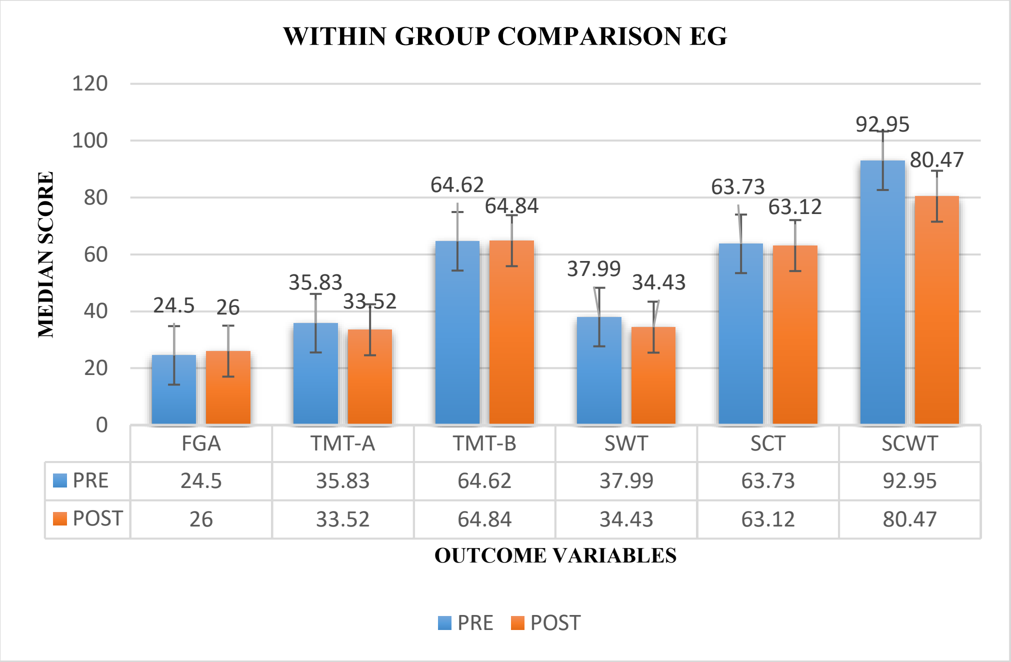
Variables	Group	Pre [Median (IQR)]	Post [Median (IQR)]	p
FGA	1	24.5 (3.0)	26 (2.25)	0.008
	2	25 (2.5)	25 (2.25)	1
TMT-A	1	35.83 (16.21)	33.52 (20.44)	0.105
	2	32.95 (14.62)	37.77 (19.85)	0.557
TMT-B	1	64.62 (43.46)	64.84 (41.91)	0.16
	2	64.27 (19.33)	67.00 (30.25)	0.432
SWT	1	37.99 (9.37)	34.43 (10.26)	0.02
	2	35.57 (12.69)	37.22 (12.74)	0.492
SCT	1	63.73 (23.69)	63.12 (22.71)	0.375
	2	52.68 (42.95)	58.59 (28.67)	1
SCWT	1	92.95 (51.87)	80.47 (14.08)	0.004
	2	89.49 (85.74)	91.40 (51.94)	0.77

Table 1.3: Comparison of median between Group 1 & 2

Variable	Group 1 [Median (Q1-Q3)]	Group 2 [Median (Q1-Q3)]	p [Exact sig. 2-tailed]
FGA	2.0 (1.50)	0.00 (0.00)	0.005
TMT-A	5.5 (12)	0.90 (9.9)	0.179
TMT-B	5.4 (35.44)	5.84 (15.70)	0.143
SWT	3.6 (2.68)	1.94 (8.41)	0.052
SCT	3.0 (10.99)	2.70 (15.36)	0.579
SCWT	27.5 (36.63)	1.91 (19.97)	0.004

*Group 1- Experimental Group (EG)

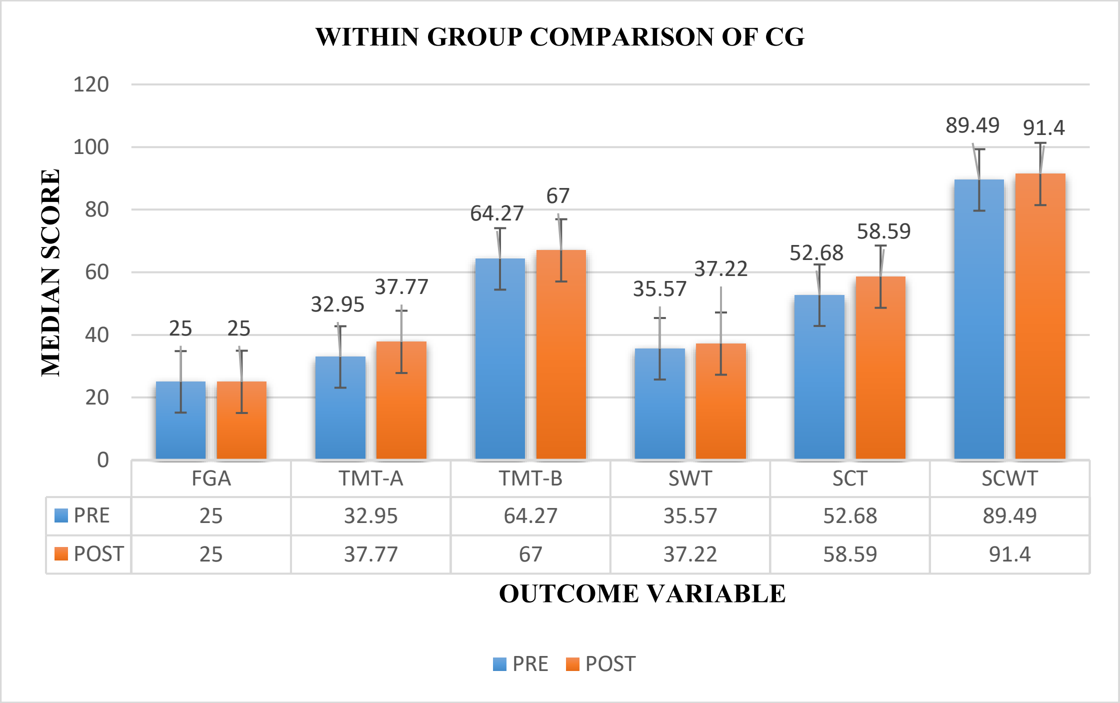
Group 2- Control Group (CG)



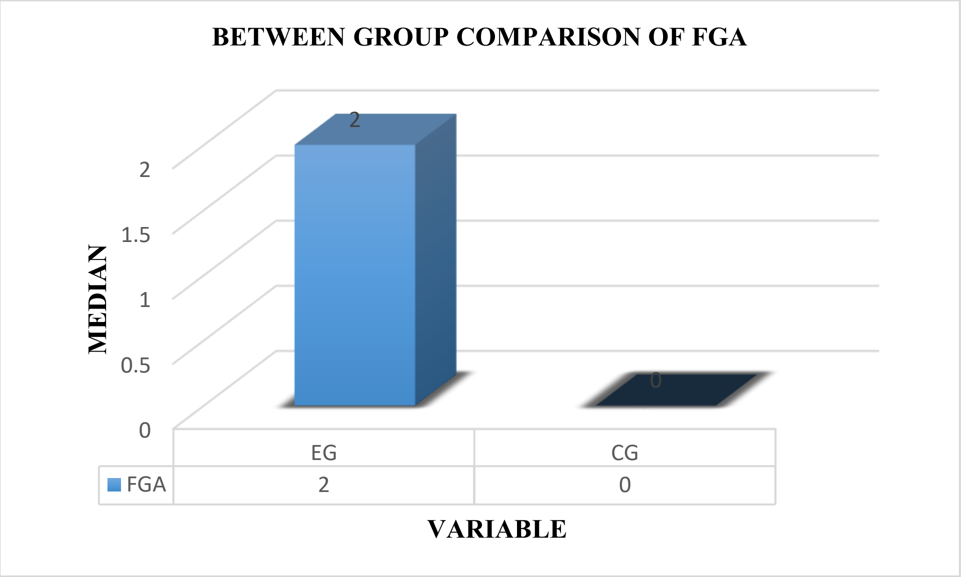
	FGA	TMT-A	TMT-B	SWT	SCT	SCWT
PRE	24.5	35.83	64.62	37.99	63.73	92.95
POST	26	33.52	64.84	34.43	63.12	80.47

Graph 1.28: Median FGA improved from 24.5 to 26 (p= 0.008); TMT A decreased from 35.83 to 33.52 (p= 0.105); TMT B slightly increased from 64.62 to 64.84 (p= 0.16); SWT decreased from 37.99 to 34.43 (p=0.02); SCT decreased from 63.73 to 63.12 (p= 0.375); SCWT decreased from 92.95 to 80.47 (p= 0.004), indicating improvements in gait and cognitive performance post-intervention.

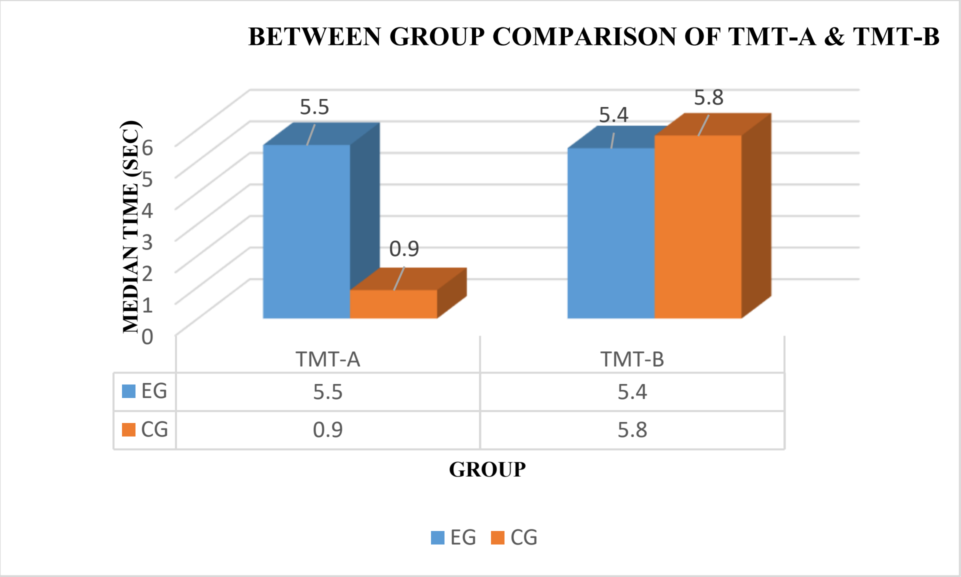
\



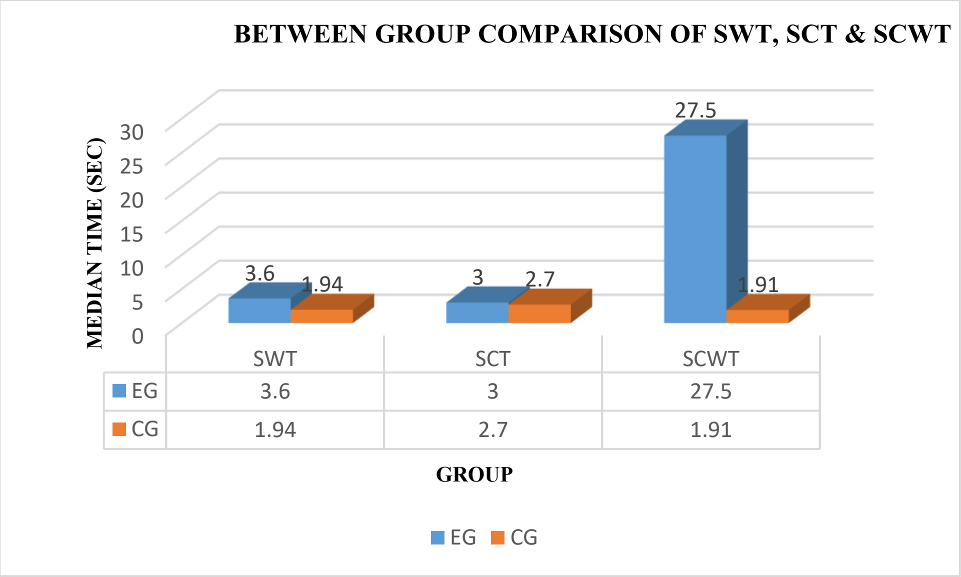
Graph 1.29: Median FGA remained the same at 25 (p= 1); TMT A increased from 32.95 to 37.77 (p= 0.557) and TMT B increased from 64.27 to 67 (p= 0.432), indicating slight worsening in processing speed; SWT increased from 35.57 to 37.22 (p= 0.492) and SCT increased from 52.68 to 58.59 (p= 1), suggesting minor decline in cognitive scores; SCWT increased from 89.49 to 91.4 (p= 0.77), indicating slight worsening in performance over time



Graph 1.30: Median FGA was 2 in EG and 0 in CG, indicating better gait performance in the EG (p = 0.05).



Graph 1.31: TMT A was 5.5 vs 0.9 in EG vs CG, showing a non-significant difference (p = 0.179); TMT B was 5.4 vs 5.8 in EG vs CG, indicating slightly slower performance in the EG (p = 0.143).



	SWT	SCT	SCWT
EG	3.6	3	27.5
CG	1.94	2.7	1.91

Graph 1.32: Median SWT was 3.6 in EG and 1.94 in CG, showing higher improvement in EG (p = 0.052); median SCT was 3 vs 2.7, indicating slightly better performance in EG (p = p= 0.579); median SCWT was 27.5 in EG and 1.91 in CG, indicating significantly better performance in EG (p = 0.004).

DISCUSSION

The present study investigated the effects of multimodal VR, using CCEs, on locomotion and cognitive outcomes in older adults with MCI. The novelty of the study lies in its focus on older adults who do not have vestibular disorders

but are at risk of mobility and cognitive decline, and in targeting interventions that are expected to produce improvement in locomotion and cognitive performance. Unlike previous studies that focused either on conventional VR or combined Multimodal VR with additional computerized cognitive training or virtual reality technology in patients with vestibular dysfunction, healthy older adults or older adults with MCI, where as in this program cognitive tasks are integrated within vestibular exercises without any external cognitive load which makes it practical, cost-effective, and feasible for community-dwelling older adults and can simultaneously improve walking ability and executive function.

Following eight weeks of intervention, significant improvement in walking was observed only in the experimental group. Cognitive outcomes showed selective improvement: SCWT, which assesses higher-order executive control such as inhibitory function and selective attention, improved in the experimental group, whereas TMT-A and B, and SWT & SCT, did not show significant changes. These findings suggest that VR embedded with simple cognitive tasks, balance and flexibility exercises can selectively improve executive function while enhancing walking performance.

The study hypothesized that multimodal VR would improve both locomotion and cognitive outcomes in older adults with MCI. Findings partially support this hypothesis. Gait significantly improved in the experimental group that received multimodal vestibular rehabilitation, whereas no significant change was observed in the control group that received structured exercises.

Various vestibular rehabilitation protocols have been used to assess gait and mobility in older adults. However, only a few studies have specifically examined the effects of CCE, especially when delivered in a multimodal or multicomponent form.

This aligns with a randomized clinical trial in older adults with chronic dizziness demonstrated significant gains in postural control and dynamic gait tasks after vestibular rehabilitation, reinforcing the role of vestibular-specific training in enhancing locomotor performance.[17] More recent studies delivering CCE and multicomponent training via telerehabilitation reported significant improvements in Timed Up and Go (TUG) and Short Physical Performance Battery (SPPB) scores, both established indicators of mobility and gait performance in older adults.[15]

Taken together, this evidence suggests that CCE particularly when delivered in a multimodal form can be a promising intervention to enhance locomotion and functional mobility in aging populations.

The vestibular system contributes to spatial orientation and navigation by providing real-time information about head and body movements. Its reflexive control of gaze and balance is closely integrated with voluntary movement and locomotion. Multimodal Cawthorne-Cooksey Exercises (MMCE) simultaneously stimulate vestibular, visual, and proprioceptive systems, enhancing sensory integration, postural adjustments, and anticipatory control. This multisensory engagement provides a physiological basis for the observed improvements in gait and functional locomotion in older adults with mild cognitive impairment.[19] This suggests that vestibular-specific stimulation, by enhancing sensory integration and postural control is more effective for gait improvement in older adults than general exercise alone. The absence of these multimodal stimuli may explain the minimal improvement observed in the control group.

Selective cognitive improvements were observed only in SCWT in the experimental group. This supports the hypothesis specifically for higher-order executive function but not for processing speed, attention, or task-switching as measured by TMT and early Stroop tests.

This suggests that vestibular-based multimodal rehabilitation may facilitate executive functioning, particularly the ability to suppress automatic responses and engage controlled processing. It aligns with the study that repetitive galvanic vestibular stimulation in healthy older adults led to faster Stroop interference reaction times, indicating enhanced inhibitory processing, although no improvement was observed in dual-task accuracy. These findings align with our results in highlighting that vestibular interventions exert domain-specific benefits on executive control mechanisms. [20]

By contrast, in another study it was observed that while MMCE improved processing speed (TMT-A) and cognitive flexibility (TMT-B), Stroop error interference did not show significant change. This discrepancy may reflect differences in task sensitivity (time vs. error indices) or the selective responsiveness of executive domains to vestibular training. But when combined with cognitive therapy produced superior gains in working memory and attention compared to cognitive therapy alone.[21] Together, these findings suggest that vestibular rehabilitation—whether exercise-based or stimulation-based—can enhance executive functions such as inhibitory control, though the pattern of improvement may vary across specific outcome measures.

SCWT requires inhibitory control and executive processing, suggesting that vestibular rehabilitation preferentially benefits higher-order cognition rather than basic attention or processing speed. These results are consistent with reports linking vestibular input to executive function and memory.

Vestibular rehabilitation may enhance inhibitory control by engaging multisensory networks that integrate vestibular, cerebellar, and cortical inputs. Vestibular signals are linked to visuospatial ability, attention, memory, and executive functioning, providing a neural framework for orientation and goal-directed behavior. These pathways project extensively to cortical regions, including the prefrontal cortex and anterior cingulate cortex, supporting conflict monitoring, suppression of automatic responses, and spatial navigation. In parallel, cerebellar integration of vestibular input facilitates adaptive inhibitory processes through connections with the dorsolateral prefrontal cortex. By promoting neuroplastic changes across these multisensory and executive networks, vestibular stimulation strengthens attentional control, response selection, and conflict resolution mechanisms, thereby improving performance in inhibitory control. Animal and human studies suggest that vestibular input promotes hippocampal neurogenesis, upregulates brain-derived neurotrophic factor (BDNF), and enhances synaptic plasticity. SCWT, requiring conflict monitoring and inhibition, may thus be particularly sensitive to vestibulardriven cortical modulation. [14,22,23]

Cognitive stimulation is as essential as physical practice. When rehabilitation tasks include problem-solving demands, they activate executive functions and support the growth of additional neural links.[24]

The absence of significant changes in TMT A and B may reflect preserved baseline performance, leading to ceiling effects, or insufficient intervention duration to affect broader cognitive domains. SWT and SCT, which primarily reflect automatic reading and color naming, also showed no improvement, consistent with their limited reliance on executive control. Thus, cognitive benefits appear task-specific and most evident in domains involving inhibitory control and complex executive processes.

Older adults who took part in the program showed better walking ability, which indicates that regular guided exercise can help them move more confidently and safely. Those who performed strengthening, flexibility, and balance exercises, combined with simple mental tasks (like naming words or counting backwards) showed improvement in complex abilities, such as staying focused and controlling automatic reactions. These are important skills for daily life, like avoiding distractions while crossing a busy street. On the other hand, more basic mental abilities such as simple attention, quick reactions, and switching between tasks did not show much change. This suggests that these functions may need either more time or different types of brain training to improve. In simple terms, any kind of structured exercise can make walking easier, but exercises that challenge both the body and the mind at the same time may give an extra boost to higher-level thinking skills.

CONCLUSION

Multimodal Vestibular rehabilitation significantly improved functional gait and selective cognitive function (SCWT) in older adults, while other outcomes remained unchanged. These findings suggest that targeted vestibular exercises can enhance gait stability and specific aspects of cognition, likely through neuroplastic adaptation and improved sensory integration. Incorporating vestibular-based interventions into routine mobility programs may therefore be beneficial for maintaining functional independence and reducing fall risk in this population.

LIMITATIONS & RECOMMENDATIONS FOR FUTURE STUDY

A key strength of this study is its use of a low-cost, structured intervention protocol that can be feasibly implemented in community and clinical settings. Additionally, by assessing both gait and cognitive domains, the study reflects the multidimensional impact of vestibular rehabilitation, which is particularly relevant for older adults with MCI who face increased risks of both mobility impairment and cognitive decline.

However, several limitations should be acknowledged. The modest sample size may have reduced statistical power for detecting subtle cognitive changes. The intervention duration of eight weeks, while sufficient for gait improvements, may not have been long enough to induce widespread cognitive gains. Furthermore, the study did not include neuroimaging or biomarker assessments, which could have provided mechanistic insights into the observed improvements. Several potential confounding factors may have influenced the outcomes. Baseline differences in mobility, cognitive reserve, or prior levels of physical activity could have shaped participants' responsiveness to the intervention. In addition, engagement and motivation among control group participants may have contributed to improvements in gait, thereby reducing the apparent between-group contrast. Furthermore, daily activities outside the intervention were not fully controlled, which may have introduced variability in cognitive or motor outcomes.

To strengthen internal validity in future research, methodological refinements are recommended. Stratified randomization based on baseline gait and cognitive scores would help to ensure balanced groups. Assessor blinding should be implemented to minimize potential bias, and monitoring or standardizing participants' daily activity levels could further reduce extraneous influences. Activity logs can provide valuable insights into external physical or cognitive activities, while extending the duration of the intervention or including booster sessions may allow detection of delayed cognitive changes.

Longitudinal studies should investigate whether improvements in gait and executive function are sustained over time. Neuroimaging methods (e.g., fMRI, EEG) and biomarker analyses (e.g., BDNF levels) could clarify the neural mechanisms underlying vestibular rehabilitation. From a translational perspective, future work should prioritize the development of low-cost, community-based programs that can be implemented in clinics, senior centers, or even at home. Finally, extending outcome assessment to include fall risk, dual-task walking, daily activities, and overall quality of life will enhance the real-world relevance of this line of research.

SUMMARY

This study was conducted to examine the effect of multimodal Cawthorne-Cooksey exercises on gait and cognitive function in older adults with mild cognitive impairment. A total of 20 participants underwent an 8-week intervention program, and their gait and cognition were assessed using standardized outcome measures. The results showed significant improvements in both gait performance and cognitive flexibility following the intervention. These findings suggest that multimodal vestibular rehabilitation through multimodal Cawthorne-Cooksey exercises is a simple and effective approach to enhance mobility and cognition in older adults with MCI.

STATEMENT OF FUNDING

Source of Funding: Not Applicable

Nature of Funding: Not Applicable

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ANNEXURES

ANNEXURE- I

INFORMED CONSENT

Informed Consent form to participate in a clinical trial

Study Title: Effect of Multimodal Cawthorne-Cooksey Exercises on enhancing locomotion and cognitive functions in older adults with mild cognitive impairment: A Single-Blind Experimental Design

Study Number:

Subject 's Name: _____________ Subject 's Initials: _________

Date of Birth / Age: _______

Address of the Subject_____________

Qualification _____________________

Occupation: Student/Self-Employed/ Service/Housewife/Others (Please tick as appropriate)

Please initial box

(Subject)

I. I confirm that I have read and understood the information sheet dated _______ [ ] for the above study and have had the opportunity to ask questions.

II. I understand that my participation in the study is voluntary and that I am [ ] free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected.

III. I understand that the Ethics Committee and the regulatory authorities will not need my permission to look at my health records both in respect of the current study and any further research that may be conducted in relation to it, even if I withdraw from the trial. I agree to this access. However, I understand that my identity will not be revealed in any information released to third parties or published.

IV. I agree not to restrict the use of any data or results that arise from this [ ] study provided such a use is only for scientific purpose(s)

V. I agree to take part in the above study. [ ]

Signature (or Thumb impression) of the Subject/Legally Acceptable Representative:

____

Date: _____/ ____/ _____

Signatory 's Name: ____

Signature of the Investigator: ____

Date: Study Investigator 's Name: _______________________________

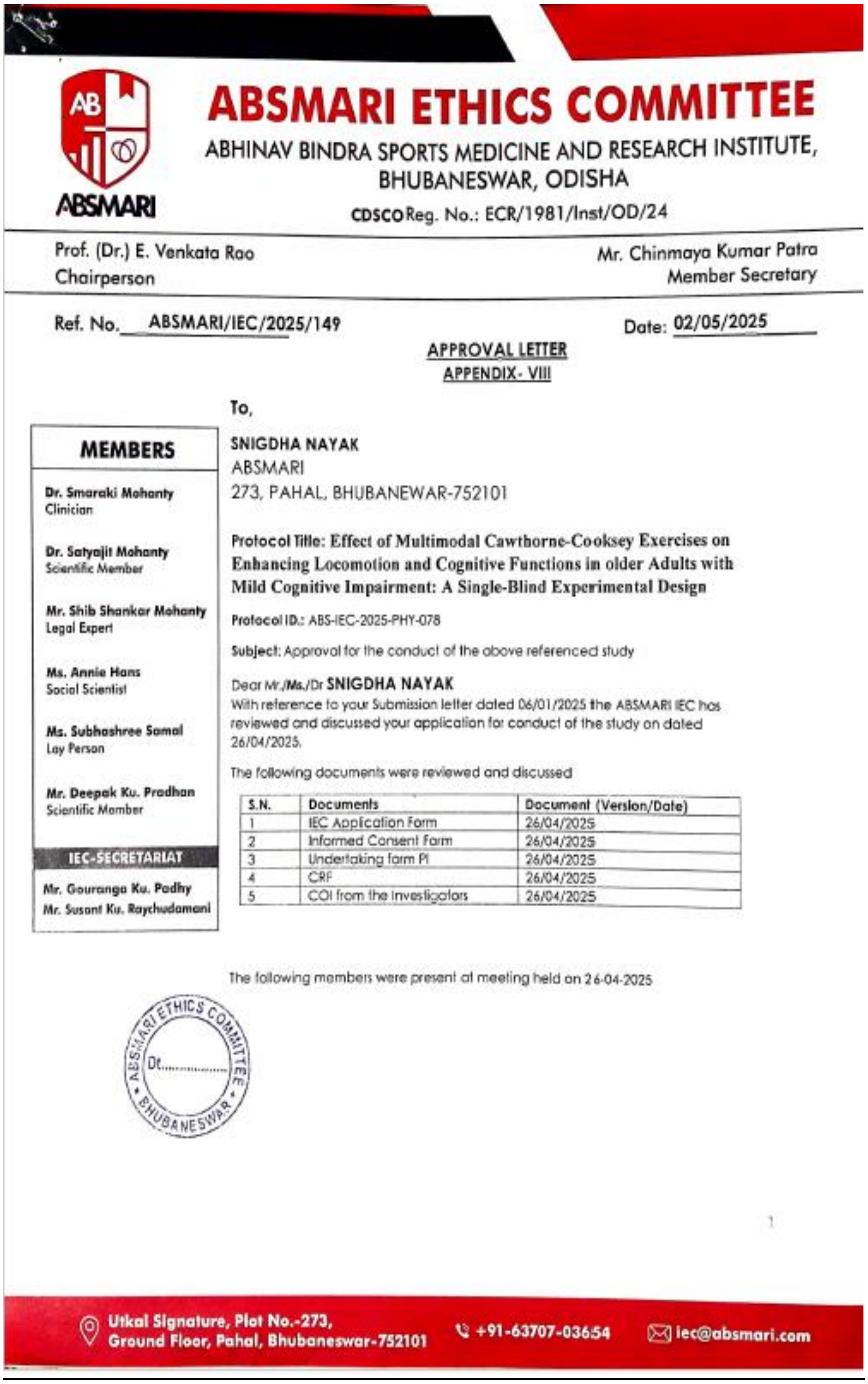
Signature of the Witness: _______________

Date: _______/ ________/ _________

Name of the Witness: _________________________________

*Copy of the Patient Information Sheet and duly filled Informed Consent Form shall be handled over to the subject or his/her attendant.

ANNEXURE- II



ABSMARI

ABSMARI ETHICS COMMITTEE

ABHINAV BINDRA SPORTS MEDICINE AND RESEARCH INSTITUTE,
BHUBANESWAR, ODISHA
CDSCO Reg. No.: ECR/1981/Inst/OD/24

Prof. (Dr.) E. Venkata Rao
Chairperson

Mr. Chinmaya Kumar Patra
Member Secretary

Ref. No. ABSMARI/IEC/2025/149

Date: 02/05/2025

APPROVAL LETTER
APPENDIX- VIII

MEMBERS

Dr. Smaraki Mohanty
Clinician

Dr. Satyajit Mohanty
Scientific Member

Mr. Shib Shankar Mohanty
Legal Expert

Ms. Annie Hans
Social Scientist

Ms. Subhashree Samal
Lay Person

Mr. Deepak Ku. Pradhan
Scientific Member

IEC-SECRETARIAT

Mr. Gouranga Ku. Padhy
Mr. Susant Ku. Raychudamani

To,

SNIGDHA NAYAK
ABSMARI
273, PAHAL, BHUBANEWAR-752101

Protocol Title: Effect of Multimodal Cawthorne-Cooksey Exercises on Enhancing Locomotion and Cognitive Functions in older Adults with Mild Cognitive Impairment: A Single-Blind Experimental Design

Protocol ID.: ABS-IEC-2025-PHY-078

Subject: Approval for the conduct of the above referenced study

Dear Mr./**Ms.**/Dr **SNIGDHA NAYAK**
With reference to your Submission letter dated 06/01/2025 the ABSMARI IEC has reviewed and discussed your application for conduct of the study on dated 26/04/2025.

The following documents were reviewed and discussed

S.N.	Documents	Document (Version/Date)
1	IEC Application Form	26/04/2025
2	Informed Consent Form	26/04/2025
3	Undertaking form PI	26/04/2025
4	CRF	26/04/2025
5	COI from the investigators	26/04/2025

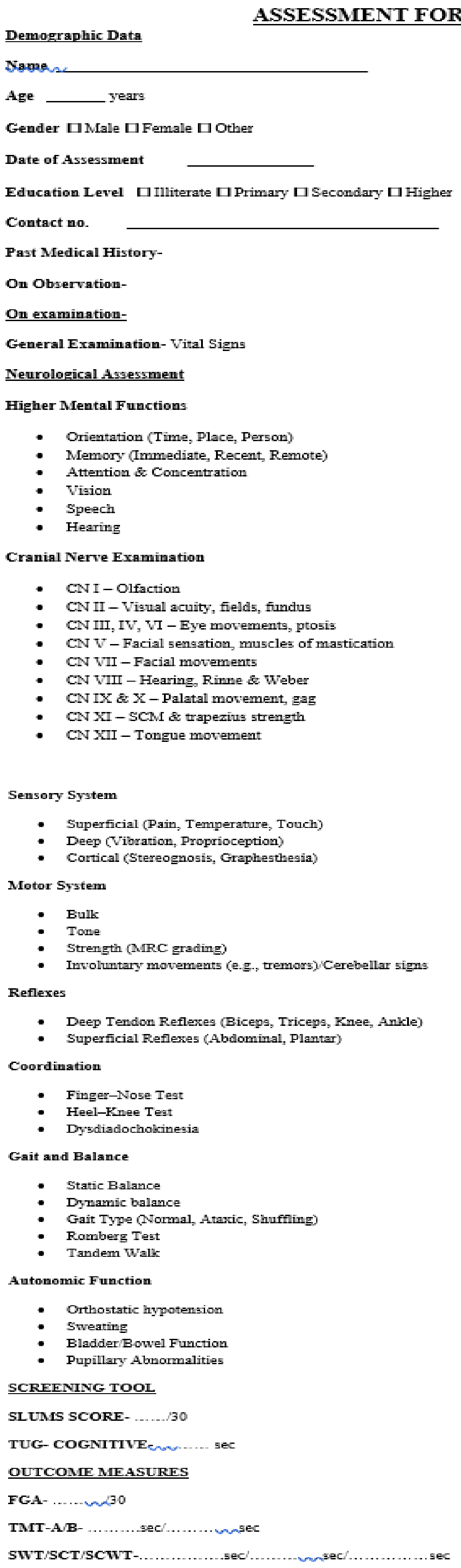
The following members were present at meeting held on 26-04-2025

Dt.....................

1

Utkal Signature, Plot No.-273, Ground Floor, Pahal, Bhubaneswar-752101 **+91-63707-03654** **iec@absmari.com**

ANNEXURE-III



ASSESSMENT FORM

Demographic Data

Name ____________________________________

Age _______ years

Gender ☐ Male ☐ Female ☐ Other

Date of Assessment _______________

Education Level ☐ Illiterate ☐ Primary ☐ Secondary ☐ Higher

Contact no. ______________________________________

Past Medical History-

On Observation-

On examination-

General Examination- Vital Signs

Neurological Assessment

Higher Mental Functions

- Orientation (Time, Place, Person)
- Memory (Immediate, Recent, Remote)
- Attention & Concentration
- Vision
- Speech
- Hearing

Cranial Nerve Examination

- CN I – Olfaction
- CN II – Visual acuity, fields, fundus
- CN III, IV, VI – Eye movements, ptosis
- CN V – Facial sensation, muscles of mastication
- CN VII – Facial movements
- CN VIII – Hearing, Rinne & Weber
- CN IX & X – Palatal movement, gag
- CN XI – SCM & trapezius strength
- CN XII – Tongue movement

Sensory System

- Superficial (Pain, Temperature, Touch)
- Deep (Vibration, Proprioception)
- Cortical (Stereognosis, Graphesthesia)

Motor System

- Bulk
- Tone
- Strength (MRC grading)
- Involuntary movements (e.g., tremors)/Cerebellar signs

Reflexes

- Deep Tendon Reflexes (Biceps, Triceps, Knee, Ankle)
- Superficial Reflexes (Abdominal, Plantar)

Coordination

- Finger–Nose Test
- Heel–Knee Test
- Dysdiadochokinesia

Gait and Balance

- Static Balance
- Dynamic balance
- Gait Type (Normal, Ataxic, Shuffling)
- Romberg Test
- Tandem Walk

Autonomic Function

- Orthostatic hypotension
- Sweating
- Bladder/Bowel Function
- Pupillary Abnormalities

SCREENING TOOL

SLUMS SCORE- ……/30

TUG- COGNITIVE-……… sec

OUTCOME MEASURES

FGA- ………/30

TMT-A/B- ……….sec/……….sec

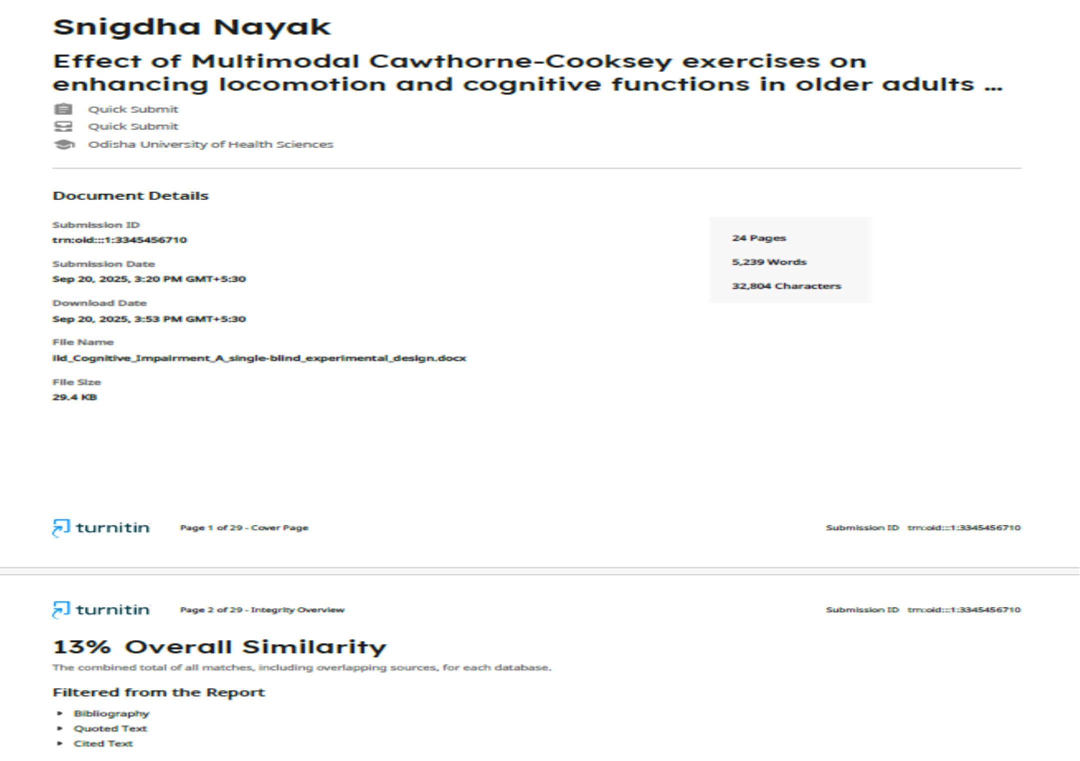
SWT/SCT/SCWT-…………….sec/……….sec/……………sec

ANNEXURE- IV

MASTERCHART

AGE		FGA		TMT-A				TMT-B							STROOP TEST							
EG	PRETEST SCORE	POSTTEST SCORE	TIME	ERROR	TIME	ERROR	TIME	ERROR	TIME	ERROR	WORD	ERROR	WORD	ERROR	COLOR-NAMING	ERROR	COLOR-NAMING	ERROR	WORD-COLOR	ERROR	WORD-COLOR	ERROR
60	24	25	01"07'50		44'92		03"48'03	10	01"31'51		42.58		38.47		01"55'71	1	01"18'99	1	02"51'12		01"26'30	
68	23	26	33.18		21:36.0		01"19"00		52.53		31.33		26.37		56.92		58.12		01"52'26		01"10'81	
68	23	25	36.53		45.19		55.45		01"16'81		40.55		37.09		01"17'13		01"14'78		01"42'30		01"25.79	
63	24	27	22.52		16.47		45.86		41.88	1	30.23		29.85		44.34	1	43.05		01"09'76	7	01"03'77	
62	23	25	47.34		35.8		56'20		01"05'55	2	01"16'42		42.69		01"03'34		01"01'08		01"31'72		01"22'79	
66	29	29	31.77		49'68		02"25'08		01"35'45		41.71		45.19		01"18'45		01"14'72		01"58'95	2	01"24.10	
68	25	27	35.12		31'24		58'12		43.67		35.43		31.76		64'13		56'56		94'18		89	
64	26	26	38.31		27'43		71'12		69.12		42.67		40.55		57'14		53'45		80'34		78'16	
68	26	28	22.14		21'10		52'23		45.31		33.87		31.2		40'34		49'56		70'65		72'18	
67	25	26	45.12		40'14		82'45		85.24		35.32		31.15		76'57		68'12		85'19		75'56	
CG																						
63	28	28	30.25		28'12		01"15'22		46'34		27.01		39'12		52.23	2	55.65		01"16'10	1	01"20'12	
61	25	25	32.79		40.36		47.56		55'16		37.66		33.25		51.92	2	54.23		01"10'67	1	01"21'87	
76	18	18	01"59'41		01"35'92		04"43'04		02"20'18		52.44		46.12		02"07'32	3	01"32'89	2	03"29'66	2	03"14'12	2
62	25	26	28.95		26.89		47.53		56.64		32.13		34.17		48.09		51.19		01"14'95	1	01"18'82	
72	25	25	27.04		30'42		58'42		01"20'15		30.05		33'25		57'74		01"12'30		01"43'27	2	01"50'23	
64	23	23	47.06		46'80		01"26'15		01"36'15		40.53		45.95		01"54'48	1	01"40'28		02"58'17	2	02"09'55	1
73	26	26	41'76		50'24		71'14		78"72		33'48		35'31		86'23		76'42		153'43		138.32	
61	27	26	36'56		45'23		58'34		62'45		31'35		29'12		53'13		61'54		87'70		88'34	
65	24	24	23'15		21'22		70'12		71'55		43'21		43'05		45'76		48'90		91'28		94'46	
63	25	25	33'12		35'19		48'98		50'12		45'23		51'51		51'09		52'09		69'12		65'19	

ANNEXURE- V



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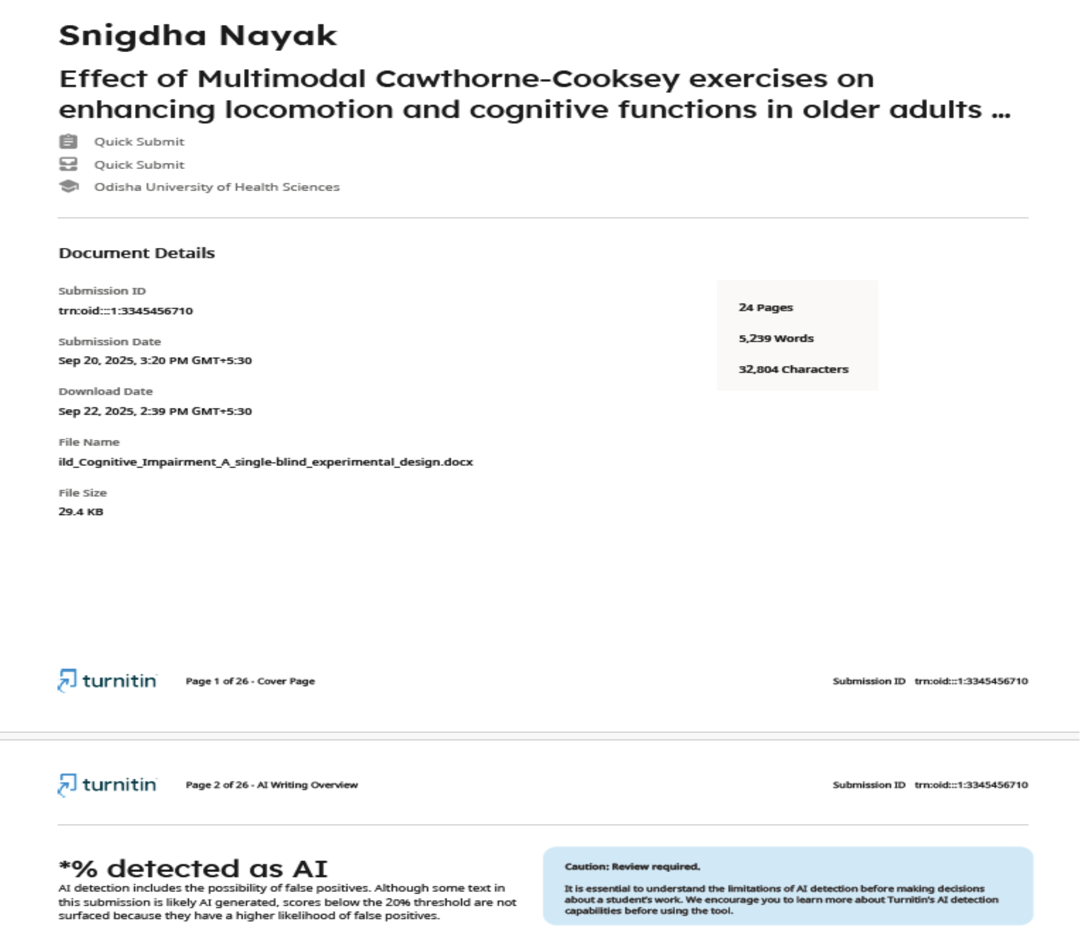

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