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Research Protocol

Physiotherapy Section

Effect of Buteyko versus Diaphragmatic Breathing on Balance and Spatiotemporal Gait Parameters in Individuals with Motion Sickness: A Research Protocol for a Randomised Clinical Trial

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ABSTRACT

Introduction: Motion sickness arises from a conflict between visual and vestibular sensory inputs and provokes autonomic symptoms such as nausea and dizziness. Because these symptoms can cause functional impairment, pharmacological treatment options—often associated with adverse effects—are limited, increasing interest in non pharmacological interventions such as controlled breathing.

Need of the study: The Buteyko Breathing Technique (BBT) reduces minute ventilation through controlled nasal breathing and breath-holding, potentially influencing physiological responses related to motion sickness. However, existing studies have primarily examined these breathing techniques in isolation and have focused on autonomic or respiratory outcomes rather than functional measures. Furthermore, their relative effects on clinically important outcomes such as balance and spatiotemporal gait parameters remain unclear.

Aim: To evaluate the effectiveness of diaphragmatic breathing and Buteyko breathing on balance and spatiotemporal gait parameters in individuals with motion sickness.

Materials and Methods: This randomised, single-blind, single-centre clinical trial will be conducted at the Maharishi Markandeshwar Institute of Physiotherapy and Rehabilitation, Mullana-Ambala, Haryana, India, from May 2025 to July 2026. A total of 40 participants with a history of motion sickness and a Motion Sickness Susceptibility Questionnaire (MSSQ) score ≥ 15 will be recruited and randomly allocated to two groups: Buteyko Breathing (BBT) and Diaphragmatic Breathing (DB). The intervention will be administered four times per week for four weeks. The primary outcomes will be motion sickness susceptibility and balance performance, assessed using the Motion Sickness Susceptibility Questionnaire-Short (MSSQ-Short) and the Mini Balance Evaluation Systems Test (Mini-BESTest), respectively. Secondary outcomes will include sensory integration for balance, evaluated using the modified Clinical Test of Sensory Interaction on Balance (mCTSIB), and spatiotemporal gait parameters. Data normality will be assessed using the Shapiro–Wilk test. Non normally distributed data will be analysed using the Wilcoxon signed-rank test or Mann–Whitney U test. A p-value <0.05 will be considered statistically significant.

Keywords: Haemoglobin, Lungs, Partial pressure, Vestibular system

INTRODUCTION

Motion sickness (kinetosis) is a clinical syndrome that occurs when real or perceived motion elicits a stress response in the central nervous system, leading to a cascade of autonomic symptoms such as drowsiness, yawning, reduced alertness, pallor, cold sweating, dizziness, headache, nausea, and vomiting. These symptoms can be severe enough to cause marked functional impairment [1]. A widely accepted explanation is the sensory conflict theory, which proposes that a mismatch between visual input and vestibular signals from the inner ear triggers motion sickness [2].

Motion sickness is a common phenomenon across diverse populations and travel conditions. Epidemiological studies show that prevalence varies by mode of transportation, with seasickness being the most frequent form. Up to 25% of passengers on large ships develop symptoms within the first 2-3 days of travel, and the incidence may rise to 60% in smaller vessels during adverse weather. Car sickness affects approximately 4% of individuals, whereas motion sickness occurs in about 0.13% of train travellers and in less than 1% of passengers on commercial aircraft. Space motion sickness affects nearly 80% of astronauts during the initial days of space missions.

Susceptibility is higher among females, children aged 6–12 years, individuals with migraine or vestibular disorders, and those exposed to unfamiliar motion stimuli [3]. In one study of sailors, 34% reported seasickness, with nausea and cold sweats occurring in 87.5% and 50% of cases, respectively. Overall, the prevalence of motion sickness appears to be higher in women (60%) than in men (31%) [4].

Motion sickness has been associated with increased sensitivity to discrepant, or "conflicting," perceptual information arising from the visual, vestibular, and somatosensory systems, as well as with an impaired ability to adapt to these conditions. This difficulty in resolving apparent perceptual conflicts may also contribute to postural instability. Autonomic and vestibular symptoms associated with motion sickness can significantly compromise postural stability and gait performance.

Sensory conflict among visual, vestibular, and proprioceptive inputs disrupts the central nervous system's ability to coordinate anticipatory and reactive postural adjustments, resulting in increased postural sway and altered gait patterns. This conflict has also been shown to affect dynamic components of gait, such as head tilts, pivotal turning, stepping over obstacles, and dual-task performance (e.g., consecutive subtraction by 3 from 100 while walking) [1]. Balance

control and gait stabilisation depend on the integrated processing of visual, vestibular, and proprioceptive information. Walking is often easier when individuals focus on a fixed visual target, whereas changes in visual focus can alter gait characteristics, including cadence, postural sway, and balance. Motion sickness has been associated with impaired balance and gait performance, which can adversely affect functional mobility and quality of life [5]. Similarly, vestibular dysfunction is characterised by gait abnormalities, including slower walking speed, increased gait variability, and reduced coordination compared with healthy individuals. These impairments alter walking biomechanics and spatiotemporal gait parameters, thereby increasing the risk of falls and difficulties in activities of daily living. Consequently, gait assessment is essential for identifying functional deficits and guiding appropriate rehabilitation strategies [1]. Furthermore, gait and balance disturbances in individuals with motion sickness have been linked to deficits in sensory integration and dynamic postural control, particularly during visually demanding or cognitively loaded tasks [6,7].

Conventional pharmacological therapy involves antihistamines and anticholinergic agents. Although antihistamines may provide symptomatic relief, they are often accompanied by adverse effects such as sedation and impaired performance [8]. These limitations have stimulated interest in non pharmacological strategies, particularly physiotherapy-based and behavioural approaches such as controlled breathing [9,10]. Slow, paced diaphragmatic breathing (DB) has been shown to enhance parasympathetic activity, increase vagal tone, and stabilise autonomic function, with studies in pilots, trainees, and virtual reality users demonstrating reductions in motion sickness severity [10].

Among breathing-based methods, the Buteyko Breathing Technique (BBT) and DB are two of the most commonly applied approaches in respiratory and autonomic regulation therapy. BBT aims to reduce minute ventilation by intentionally slowing and lightening breathing through nasal breathing, breath counting, distraction techniques (such as gentle rocking or walking), and specific lifestyle practices, including side-lying sleep postures and, in some cases, nocturnal mouth taping to promote nasal airflow. The central goal is to correct chronic hyperventilation, elevate arterial carbon dioxide levels, and thereby improve oxygen unloading from haemoglobin via the Bohr effect, ultimately enhancing tissue oxygenation [11-13].

The BBT employs superficial breathing combined with intermittent short breath-holding episodes. This approach normalises carbon dioxide levels, which may help reduce dizziness and nausea by stabilising autonomic functions [11,14]. In contrast, DB emphasises slow, deep breathing from the abdomen in coordination with diaphragmatic descent. Such breathing has been found to reduce symptoms of motion sickness, thereby improving comfort in motion-susceptible individuals [15]. Given that motion sickness is related to autonomic dysfunction, BBT and DB may exert beneficial effects through different physiological mechanisms. The present study is therefore designed to compare the effects of Buteyko breathing and DB on motion sickness symptoms, balance, and spatiotemporal gait parameters in individuals with motion sickness [1,5].

REVIEW OF LITERATURE

Motion sickness typically presents with drowsiness, yawning, decreased vigilance, excessive salivation, pallor, and cold sweating, which can progress to nausea and vomiting if exposure continues. These symptoms are often associated with impairments in postural control [1].

Pai SN and Prabhu SS evaluated balance and gait in young adults aged 18-25 years with frequent motion sickness using the Motion Sickness Susceptibility Questionnaire-Short Form (MSSQ-SF) and the Mini-BESTest balance scale. Individuals with greater motion sickness susceptibility demonstrated significantly poorer balance and gait performance than controls, with particular deficits in anticipatory and reactive postural adjustments [1].

In a study by Rai RH et al., 80 young adults underwent a short-term BBT intervention, which produced significant physiological changes, including increased heart rate, reduced systolic blood pressure, and improved airway function as measured by FEF25-75%. These effects were attributed to modulation via elevated CO_2 levels, which influence breathing dynamics in accordance with the Bohr effect. The study demonstrated that BBT induces measurable alterations in cardiovascular parameters and respiratory function, responses that are closely linked to autonomic nervous system regulation. Given that autonomic imbalance is recognised as the contributing mechanism underlying motion sickness, these findings provide a plausible physiological basis for incorporating breathing-based interventions into motion sickness management strategies [13].

Similarly, Owen N et al., assessed 34 participants and reported that MSSQ scores correlated positively with postural sway, particularly under challenging sensory conditions such as eyes closed on foam ($r=0.45$, $p<0.01$), indicating that greater susceptibility to motion sickness is associated with reduced postural stability [7].

Joshi S assessed balance parameters in individuals with and without motion sickness. The study population consisted of adults susceptible to motion sickness, along with a matched control group without such susceptibility. The procedure employed standardised balance assessment tools, likely including posturography and clinical balance tests, to evaluate static and dynamic postural control. Outcome measures comprised various balance indices, such as sway velocity, limits of stability, and proprioceptive scores. The findings indicated that individuals with motion sickness exhibited significantly poorer balance performance than those without motion sickness, suggesting an association between vestibular sensitivity and postural control deficits [14].

Mehta D et al., compared the immediate effects of two non pharmacological breathing techniques—Buteyko Breathing Technique (BBT) and breath stacking—on physiological parameters in patients who had undergone laparoscopic cholecystectomy. Participants were randomly allocated to one of the two interventions, and primary outcome measures (heart rate, respiratory rate, and oxygen saturation) were assessed immediately post-intervention. The findings demonstrated that both techniques significantly influenced cardiorespiratory variables, supporting the potential utility of controlled breathing exercises in post-operative care. This study was considered particularly relevant because the immediate effects on heart rate, respiratory rate, and oxygen saturation reflect autonomic regulation, which is also implicated in the symptomatology of motion sickness [16].

Stromberg SE et al. examined the effectiveness of paced Diaphragmatic Breathing (DB) at six breaths per minute in 43 motion-susceptible individuals. Their findings showed that rhythmic DB effectively enhanced parasympathetic activity, as evidenced by increased Heart Rate Variability (HRV) indices. Furthermore, participants in the experimental group experienced a significant reduction in motion sickness severity during provocative stimuli compared with the control group. These results highlight the role of the vagus nerve in regulating autonomic responses and suggest that controlled DB may serve as a feasible non pharmacological intervention for improving motion tolerance in susceptible individuals [17].

The present study aimed to compare the effects of BBT and DB on motion sickness symptoms, balance, and spatiotemporal gait parameters in individuals with motion sickness, and to determine which strategy provides superior clinical and functional outcomes.

Primary objectives:

- To determine the effectiveness of BBT on motion sickness symptoms, balance, and spatiotemporal gait parameters in individuals with motion sickness.
- To determine the effectiveness of DB on motion sickness symptoms, balance, and spatiotemporal gait parameters in individuals with motion sickness.

Secondary objective:

- To compare the effectiveness of BBT and DB in improving motion sickness symptoms, balance, and spatiotemporal gait parameters in individuals with motion sickness.

Null hypothesis (H_0): There is no significant difference between BBT and DB in their effects on motion sickness symptoms, balance, and spatiotemporal gait parameters in individuals with motion sickness.

Alternative hypothesis (H_1): There is a significant difference between BBT and DB in their effects on motion sickness symptoms, balance, and spatiotemporal gait parameters in individuals with motion sickness.

MATERIALS AND METHODS

This will be a randomised, single-blind, single-centre clinical trial conducted at the Maharishi Markandeshwar Institute of Physiotherapy and Rehabilitation, Mullana, Ambala, Haryana, India from May 2025 to July 2026. Ethical approval has been obtained from the Institutional Ethics Committee (MMIMSR/IEC/2024-3105), and written informed consent will be obtained from all participants before enrollment. The trial has been prospectively registered with the Clinical Trials Registry of India (CTRI/2025/05/086308).

Inclusion criteria:

- Age 18–25 years, chosen to target college-going students with high travel exposure and to maintain demographic homogeneity, consistent with the reference study [1];
- History of motion sickness;
- MSSQ-SF score of 15 or higher [18].

Exclusion criteria:

- Current ear infection or ear infection within the previous six weeks, vestibular disorders, or other major neurological conditions such as cerebellar ataxia or Parkinson's disease;
- Benign Paroxysmal Positional Vertigo (BPPV), vertigo, Ménière's disease, or significant hearing loss;
- Visual loss or blindness;
- Seasickness or simulator sickness as the primary complaint;
- Unwillingness to participate or inability to provide informed consent.

Sample size calculation: In the study by Pai SN and Prabhu SS, the reported total Mini-BESTest scores were 22.80±1.971 for individuals with motion sickness and 25.667±1.290 for healthy controls, corresponding to an effect size of approximately 1.7 [1]. As this represents a very large effect size, a more conservative effect size of d=1.0 was selected for the present sample size calculation. Using an alpha level of 0.05 and 80% power, the required sample size was estimated to be 16 participants per group.

The sample size was calculated using the formula:

$n= \{2 * (Z(1-\alpha/2) + Z(1-\beta))2 * \sigma^2\}/d2$

$$n = \frac{2(1.96 + 0.84)^2(1)^2}{(1)^2}$$

$n = 2 \times (2.8)^2 = 2 \times 7.84 = 15.68$

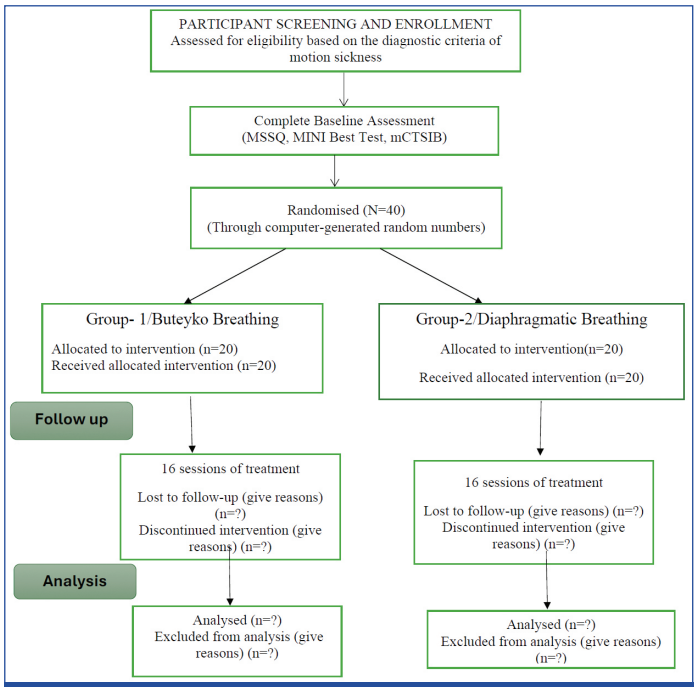
$n \approx 16$

Using Cohen's d=1.0, α=0.05, power=80%, G*Power yielded 16 participants per group.

A total of 32 participants were required to account for an anticipated 20% dropout rate, the sample size was increased to 40 participants, with 20 allocated to each group.

Study Procedure

Participants will be randomly assigned to two groups using a computer-generated simple randomisation method [Table/Fig-1]:



[Table/Fig-1]: Consolidated Standards of Reporting Trials (CONSORT) flowchart.

- Group 1- Buteyko breathing and
- Group 2- Diaphragmatic Breathing (DB).

Computer-generated randomisation (1:1 ratio) will be concealed via a secure web platform, with allocation retrieved by a separate research assistant after baseline assessment. The outcome assessor and data analyst will be blinded; participants and the therapist will not be.

All participants will be informed about the study procedures, risks, and benefits in their native language. The intervention will be administered over four weeks, four days per week. Sessions will be delivered in groups, with each group receiving 30-minute sessions, conducted four times per week for four weeks.

Group 1: Buteyko Breathing Technique (BBT)

Participants in the BBT group will receive supervised sessions from a trained physiotherapist. Following a brief relaxation period in a comfortable sitting position, participants will perform nasal breathing with reduced breathing volume and relaxed chest and shoulder muscles. The intervention will include control pause exercises, involving a gentle nasal inhalation, comfortable exhalation, and voluntary breath hold at end-expiration until the first urge to breathe. Reduced-volume breathing cycles (approximately 4 minutes each) and control pause exercises will be repeated three times per session with short rest intervals. Sessions will be conducted four days per week for four weeks under physiotherapist supervision [11,13].

Group 2: Diaphragmatic Breathing (DB)

Participants in the DB group will perform supervised slow, deep breathing exercises in a comfortable seated or supine position. With one hand placed on the chest and the other on the abdomen, participants will be instructed to inhale slowly through the nose for approximately six seconds, allowing abdominal expansion while minimising chest movement, followed by a 6-second exhalation. The exercise will be performed at a rate of approximately six breaths per minute in sets of 10-15 breaths with short rest intervals between sets. A physiotherapist will supervise all sessions to ensure correct

S. No.	Research phase	2024				2025				2026		
		Sept	Oct	Nov	Dec	Jan- Mar	Apr- June	Jul- Sept	Oct- Dec	January	February	March
1.	Title Submission	X										
2.	SPC Meeting		X									
3.	Ethical Committee Submission			X								
4.	Data Collection					X						
5.	DataAnalysis										X	
6.	Submission											X

[Table/Fig-2]: Gantt chart.

technique and promote relaxation and parasympathetic activation [17]. Participants will maintain a comfortable, supported posture with the head in midline alignment and eyes closed while focusing on gentle abdominal breathing without forceful expiration. This technique aims to enhance diaphragmatic activation, promote relaxation, and improve autonomic regulation [10,15].

Primary Outcome Measures

1. Motion Sickness Susceptibility Questionnaire (MSSQ): Self-administered by participants under PT supervision. The MSSQ will be used as the tool, which comprises two sections: childhood experiences (before age 12) and adult experiences (at/after age 12), each scored on a four-point scale (0=never, 1=rarely, 2=sometimes, 3=frequently). The total MSSQ score (range: 0-54) is calculated by summing all item responses across both sections, yielding a childhood score (0-27), an adult score (0-27), and a combined total; the short-form (MSSQ-Short) uses a reduced item subset producing a total score of 0-27, with higher scores indicating greater susceptibility. In the present study, participants with an MSSQ-Short score ≥15 will be included. The full-length MSSQ demonstrates high internal consistency (Cronbach's α=0.86) and test-retest reliability (r>0.8), while the short-form shows strong psychometric properties (α=0.87, test-retest r≈0.9, predictive validity median r=0.51) [18].

2. Mini Balance Evaluation Systems Test (Mini-BESTest): The Mini Balance Evaluation Systems Test (Mini-BESTest) is a comprehensive balance assessment tool designed to evaluate dynamic balance across four distinct domains: anticipatory postural adjustments, reactive postural control, sensory orientation, and dynamic gait. The test comprises 14 items scored on a 2-point ordinal scale (0=severe impairment, 1=moderate impairment, 2=normal), yielding a total score ranging from 0 to 28, with higher scores indicating better balance performance [19,20].

Secondary Outcome Measure

3. Modified Clinical Test of Sensory Interaction on Balance (mCTSIB): The Modified Clinical Test of Sensory Interaction on Balance (mCTSIB) evaluates the contributions of visual, vestibular, and somatosensory systems to balance through four 30-second conditions. Balance is quantified by postural sway, with higher sway indicating poorer stability. Performance is assessed based on the ability to maintain balance for up to 30 seconds and the degree of postural sway observed under each condition. Increased sway or inability to maintain balance indicates impaired sensory integration and postural control. The mCTSIB has demonstrated good reliability and validity for identifying sensory-specific balance impairments [21].

4. Spatiotemporal Gait Parameters: Participants will walk a 10-meter walkway with footprints recorded using a paper-and-ink method. Speed (m/s) will be calculated as distance divided by stopwatch-measured time. Step length (cm) is the linear distance between heel contacts of contralateral feet, averaged over three consecutive steps. Step width (cm) is the perpendicular distance between the longitudinal axes of two consecutive footprints, measured from mid-heel to mid-heel. Stride length (cm) is the distance between two successive heel contacts of the same foot, calculated as the sum of two consecutive step lengths. Cadence (steps/min) equals total steps divided by trial time, multiplied by 60. All parameters will be averaged across three trials for reliability [22]. The study timeline is illustrated in [Table/Fig-2].

All outcome measures will be assessed at baseline (pre-test) before the initiation of the intervention and reassessed at the end of the 4-week intervention period (post-test). All the outcomes, except the MSSQ, will be administered by a blinded outcome assessor. Long-term sustainability of treatment effects will not be evaluated.

STATISTICAL ANALYSIS

Statistical analyses will be conducted using Statistical Package for Social Sciences (SPSS) version 26.0, with a two-tailed p-value <0.05 considered statistically significant. Baseline characteristics will be analysed descriptively. An Intention-to-treat analysis, appropriate for an RCT, will be performed, and missing data will be handled using multiple imputation where appropriate.

Normality of the data will be assessed using the Shapiro-Wilk test. For normally distributed data, paired and unpaired t-tests will be used for within-group and between-group comparisons, respectively, with results reported as mean±standard deviation. For non normally distributed data, the Wilcoxon signed-rank test and Mann-Whitney U test will be applied, with results reported as median (interquartile range). Bonferroni-adjusted significance thresholds will be considered for secondary outcomes. Cohen's d will be reported for t-tests and η^2 for non parametric between-group comparisons where appropriate, and 95% confidence intervals will also be reported.

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