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Sinusoidal Support Surface Translation versus Cawthorne-Cooksey Exercises for Unilateral Vestibular Hypofunction: A Quasi-Experimental Study

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Abstract- Background- Unilateral Vestibular Hypofunction (UVH) results in significant balance deficits, gait unsteadiness, and a high perception of subjective disability. While traditional Cawthorne-Cooksey exercises are a clinical mainstay relying on habituation, mechanical interventions like sinusoidal support surface translations (SSST) offer a technology-driven, specialized approach to challenging the vestibulo-spinal reflex (VSR) and facilitating sensory re-weighting. Objective- To compare the efficacy of traditional Cawthorne-Cooksey exercises and Sinusoidal Support Surface Translation exercises in patients presenting with unilateral vestibular deficits using the Dizziness Handicap Inventory (DHI) and Berg Balance Scale (BBS). Methods- A prospective, quasi-experimental study was conducted at the JKKMMRF College of Physiotherapy, Komarapalayam, with 20 participants (n = 10 per group) selected via purposive sampling. Group A performed the Cawthorne-Cooksey protocol involving progressive head, eye, and body movements. Group B underwent instrumental rehabilitation via mechanical sinusoidal support surface translations focusing on postural stability and rhythmic perturbations. Both protocols spanned 6 weeks (3 sessions/week). Baseline and post-intervention outcomes were evaluated using the DHI and BBS, and data were analyzed via paired and unpaired t-tests ($p < 0.05$). Results- Both groups showed significant within-group improvements ($p < 0.001$) after 6 weeks. However, Group B demonstrated significantly greater post-intervention gains than Group A. Group B achieved a superior post-intervention mean BBS score of 41.0 \pm 1.89 compared to 32.4 \pm 3.95 in Group A ($p < 0.0001$). Subjective handicap on the DHI also reduced more substantially in Group B (34.4 \pm 6.67) than in Group A (48.2 \pm 4.81). Conclusion- Sinusoidal support surface translation is a superior clinical intervention compared to Cawthorne-Cooksey exercises, offering more effective outcomes in restoring objective postural stability and mitigating the subjective impact of dizziness in patients with UVH.

Keywords— Vestibular Rehabilitation, Unilateral Vestibular Hypofunction, Cawthorne-Cooksey, Sinusoidal Translation, Postural Stability, DHI, Berg Balance Scale.

I. INTRODUCTION

Unilateral Vestibular Hypofunction (UVH) is a common clinical condition characterized by a functional deficit in the peripheral vestibular system on one side, disrupting normal vestibular signaling to the central nervous system. Disorders of vestibular function frequently destroy the receptor hair cells of the labyrinth, resulting in altered balance, spatial orientation, and equilibrium. This dysfunction can arise from central lesions or peripheral conditions, with the latter driven by a multitude of factors including localized infection, systemic inflammation, or vascular ischemia. Clinically, UVH most commonly occurs between the third and sixth decades of life, exhibiting a slightly higher incidence in women than in men.

Patients afflicted with UVH typically present with a distinct clinical triad: marked unsteadiness during standing and walking (postural instability and disequilibrium), severe difficulty focusing vision on fixed or moving targets during head motion (visual blurring/oscillopsia), and a staggering gait that increases the immediate risk of falls. These debilitating symptoms collectively compromise functional mobility and severely decrease overall quality of life.

Objective assessment and subjective impact are reliably evaluated in clinical practice using instruments such as the Romberg test, the Dizziness Handicap Inventory (DHI), and mobility-oriented clinical scales like the Berg Balance Scale (BBS).

To combat these deficits, vestibular rehabilitation therapy has historically relied on the Cawthorne-Cooksey exercise protocol, first proposed in 1946. This traditional methodology employs progressive, voluntary head and eye movements designed to promote central vestibular compensation through habituation and cellular adaptation. Despite its long-standing history, recent advancements in rehabilitation technology have introduced instrumental mechanical perturbations, such as sinusoidal support surface translations (SSST). Rather than relying solely on voluntary movements, SSST delivers automated, rhythmic, external multi-directional stimulus directly to the base of support. This mechanical challenge targets the Vestibulo-Spinal Reflex (VSR) and forces immediate sensory re-weighting within the central nervous system.

Currently, comparative evidence regarding whether these modern, instrumented mechanical protocols offer superior functional and subjective benefits over traditional active exercises remains limited. This study aims to bridge this gap by evaluating the relative efficacy of these two distinct interventions in patients with unilateral vestibular deficits.

II. MATERIALS AND METHODS

1. Study Design and Clinical Setting

This research was structured as a prospective, quasi-experimental study. The clinical trial and data collection were carried out within the specialized neuro-rehabilitation facilities at the JKKMMRF College of Physiotherapy, Komarapalayam.

2. Participants and Sampling

A cohort of 20 patients diagnosed with Unilateral Vestibular Hypofunction (UVH) was recruited for the study. Due to the specialized nature of the clinical presentation, purposive sampling was utilized to select and assign 10 participants to each of the two intervention arms.

- Inclusion Criteria: Patients with a verified clinical diagnosis of UVH, presenting with objective balance deficits, and possessing the cognitive ability to follow multi-step commands.
- Exclusion Criteria: Central vestibular lesions, fluctuating peripheral vestibular disorders (e.g., active Meniere's disease), or acute musculoskeletal conditions severely affecting gait or weight-bearing capacity.

Intervention Protocols

Both groups underwent their respective therapeutic regimens for a total duration of 6 weeks, scheduled at a frequency of 3 therapeutic sessions per week.

- Group A (Cawthorne-Cooksey Protocol): Participants performed the standard, structured Cawthorne-Cooksey habituation training. This protocol involved systematic, progressive head, eye, and upper body movements performed across varying positional postures—progressing from sitting to standing, and finally during active locomotion.
- Group B (Sinusoidal Support Surface Translation - SSST): Participants underwent automated, instrumental rehabilitation on a specialized dynamic platform. The intervention focused heavily on maintaining postural stability during continuous, mechanical sinusoidal support surface translations, delivering rhythmic perturbations that challenged the user's static and dynamic boundaries of equilibrium.

Outcome Measures

Pre-test (baseline) and post-test (6-week) clinical assessments were conducted for all 20 participants using two gold-standard metrics:

- Dizziness Handicap Inventory (DHI): A self-reported, 25-item questionnaire utilized to quantify the subjective impact of dizziness on physical, emotional, and functional subscales.

- Berg Balance Scale (BBS): A 14-item objective performance-based scale used to evaluate static balance and risk of falls through direct clinical observation of functional tasks.

Statistical Analysis

Statistical analysis was performed using SPSS software. Within-group changes from baseline to post-test were evaluated utilizing the Paired t-test to determine individual protocol efficacy.

Inter-group differences between Group A and Group B post-intervention were evaluated using the Unpaired t-test. For all statistical measures, the level of significance was strictly set at $p < 0.05$.

III. RESULTS

All 20 recruited participants completed the full 6-week intervention protocol. The intra-group and inter-group comparative data analyses are presented in the tables below.

Table 1: Intra-Group Comparison (Pre-test vs. Post-test)

Parameter	Group	Pre-Test (Mean)	Post-Test (Mean)	Mean Difference	Paired t-value
DHI Score	Group A	83.6	48.2	35.4	21.3^*
	Group B	85.0	34.4	50.6	27.5^*
BBS Score	Group A	22.4	32.4	10.0	20.256^*
	Group B	20.6	41.0	20.4	35.8^*

The Unpaired t-test confirmed that Group B achieved statistically superior improvements compared to Group A in both functional balance and handicap reduction.

Table 2: Inter-Group Comparison (Group A vs. Group B)

Parameter	Group A (Mean Diff)	Group B (Mean Diff)	Difference of Means	Unpaired t-value
DHI Score	35.4	50.6	15.2	5.634^*
BBS Score	10.0	20.4	10.4	13.59^*

Key Finding: While both modalities enhanced patient tracking, the instrumental SSST protocol (Group B) yielded double the objective functional balance improvement on the BBS (mean difference of 20.4 vs. 10.0) and accelerated the reduction of subjective dizziness handicap by an additional 15.2 points compared to the traditional protocol.

IV. DISCUSSION

The clinical findings of this prospective study confirm that while both vestibular rehabilitation protocols are highly effective in treating UVH, instrumented sinusoidal support surface translations (Group B) produce statistically superior objective and subjective outcomes compared to traditional Cawthorne-Cooksey exercises (Group A).

The positive trajectory observed within Group A is primarily mediated by the classical neurological mechanism of habituation. As established by Gans (2010), habituation training relies on targeted, repeated exposure to specific, provocatively challenging head and eye movements. This repetitive sensory exposure triggers central synaptic depression, effectively "desensitizing" the vestibular nuclei and cerebral cortex to the distressing vestibular-visual conflicts that induce dizziness. However, recent multicenter data published in Frontiers in Neurology (2026) underscores that generic, manual habituation programs often lack the mechanical precision and multi-planar intensity required to optimally accelerate neural plasticity within complex, dynamic postural environments.

Conversely, the superior functional gains demonstrated by Group B stem from the mechanisms of sensory substitution and neural sensory re-weighting. Continuous, automated mechanical perturbations force the central nervous system to rapidly re-prioritize intact visual and peripheral somatosensory inputs over the corrupted, asymmetrical signals originating from the defective unilateral labyrinth. Current neurological literature, including studies in Advances in Clinical and Experimental Medicine (2025), emphasizes that instrumented tools deliver a highly consistent, predictable, yet physically challenging rhythmic perturbation that directly activates the "Ankle Strategy". By forcing the patient to continuously secure their center of mass over a translating base of support via rapid, micro-muscular adjustments around the ankle joint, SSST markedly reduces total body sway and accelerates functional recovery.

These outcomes align with earlier foundational trials by Corna et al. (2003) and Szuturm et al. (1994), which proved that dynamic instrumental conditioning leads to significantly greater reductions in postural sway than head-eye exercises alone. Furthermore, these results closely adhere to the Academy of Neurologic Physical Therapy's Updated Clinical Practice Guidelines (Hall et al., 2022/2025). These guidelines offer a "Strong Evidence" recommendation for supervised, exercise-based rehabilitation, explicitly advocating for customized, targeted protocols that directly isolate individual postural control deficits—a clinical criteria directly satisfied by the mechanical translations utilized in this trial. Consequently, integrating mechanical perturbations into modern clinical setups provides a highly effective pathway for reducing fall risks and maximizing independence in the UVH population.

Limitations

This study is constrained by its relatively small clinical sample size (n = 20) and its non-randomized, quasi-experimental design. Additionally, long-term post-intervention retention effects were not documented. Future trials should implement randomized controlled designs utilizing larger multi-center cohorts and extended follow-up timelines.

V. CONCLUSION

Sinusoidal support surface translation represents a highly effective and clinically superior intervention for individuals suffering from Unilateral Vestibular Hypofunction. It yields significantly greater advancements in both objective postural stability (BBS) and subjective handicap reduction (DHI) when compared directly against the historical gold-standard Cawthorne-Cooksey protocol. Accordingly, this study successfully rejects the Null Hypothesis (H_0) and accepts the Alternate Hypothesis (H_1), validating mechanical sinusoidal translation as an optimal tool for advanced vestibular physical therapy management.

Administrative Declarations

- Ethical Clearance: Informed consent was obtained from all individual participants prior to enrollment. The study protocol was thoroughly reviewed and conducted in strict accordance with the ethical standards established by the Institutional Review Board.
- Conflict of Interest: The author declares no personal, institutional, or financial conflicts of interest associated with this research.

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