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Effect of Auditory and Visual Cueing on Freezing of Gait and Balance in Parkinson's Disease: A Randomized Controlled Trial

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ABSTRACT

Background: Freezing of gait (FOG) significantly impairs mobility and quality of life (QoL), affects 50% of the elderly population diagnosed with Parkinson's Disease. The current study is aimed to determine the effects of Auditory and Visual Cueing (AUC) versus conventional treadmill training on Freezing of Gait and Balance in PD patients.

Methods: A total number of n=34 participants diagnosed with PD and FOG were randomly allocated in either AVC group or a TT group n=17 in each group. The study design was a randomized controlled trial conducted across three different facilities. The improvement of the participants based on treatment were monitored using a Tinetti Balance and Gait Assessment, Timed Up and Go test, Ten-Minute Walk Test, and New Freezing of Gait Questionnaire (NFOG-Q). Values were taken at baseline, at 6 weeks and at after 12 weeks of intervention.

Results: The findings of the study had revealed that AVC shown a significant improvement across all group and turned out to be an efficacious over TT. The statistical analyses had shown that on gait and balance parameter AVC was found significantly ($p=0.002$) better than TT. Additionally, NFOG-Q and functional walking capacity was also appeared effectively improved in AVC group with a value at 12th weeks was significantly better ($p<0.001$) in comparisons to TT.

Conclusion: Integration of multimodal treatment strategies into routine exercise-based protocol in managing freezing of gait among PD patients can represent better outcome in improving balance, functional mobility and gait dysfunction. Audio Visual cuing is turned out as an effective treatment protocol in managing FOG among PD.

Keywords: *Gait, Parkinson disease, Postural balance, Treadmill training*

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INTRODUCTION

Parkinson's disease (PD) is the second most prevalent age-related neurodegenerative disorder globally, affecting over 6.5 million individuals worldwide, with prevalence projected to double within the next 20 to 30 years[1]. Currently, PD affects approximately 1-2 individuals per 1,000 people globally[2]. In Asia, the highest prevalence of PD is reported in China, accounting for 36% of all neurological disorders[3]. However, data on PD prevalence in Pakistan remain limited, with a systematic review identifying only 1,016 documented cases from seven studies, including 600 from Khyber Pakhtunkhwa, 85 from Lahore, and 50 from Rawalpindi[4]. Notably, this review highlighted a significant rise in PD cases over the past decade in Pakistan, with higher prevalence among males compared to females, reflecting global trends[4]. Approximately 400,000 individuals in Pakistan are currently afflicted with PD, indicating a substantial disease burden in the region[5].

PD is characterized by both motor and non-motor symptoms resulting from degeneration of dopaminergic neurons in the substantia nigra pars compacta[6]. The cardinal motor symptoms include resting tremor, bradykinesia (slowness of movement), rigidity, and impaired postural reflexes[6]. Beyond these cardinal features,

patients experience significant gait disturbances, including reduced step length, decreased gait velocity, postural instability, and balance impairments[7]. Freezing of gait (FOG), characterized by brief episodes of inability to initiate or continue walking, affects up to 50% of advanced PD patients and substantially compromises mobility and quality of life[8]. Gait dysfunction in PD not only increases the risk of falls and fractures but also reduces independence and social participation, thereby diminishing overall quality of life[9].

Traditional physical therapy (PT) approaches for managing PD have included balance training, strengthening exercises, stretching, and treadmill training[10]. While these interventions provide some benefit, traditional PT has significant limitations, including inadequate follow-up, financial challenges, accessibility barriers, and concerns regarding patient safety, particularly in elderly populations prone to falls[10]. Furthermore, the effectiveness of conventional therapy in addressing gait dysfunction and maintaining long-term functional gains remains inconsistent.

To overcome these limitations, there has been a paradigm shift toward incorporating technological advancements in neurological rehabilitation[11]. Among these innovations, external cueing strategies particularly auditory and visual cues have emerged as evidence-based interventions for improving gait parameters in PD patients[12]. Auditory cueing, typically delivered through metronomes or rhythmic tones, has demonstrated efficacy in improving gait speed, step length, and cadence, particularly benefiting patients with FOG[12]. Visual cueing strategies, including laser-based cues and augmented reality systems, have shown advantages in enhancing step length and facilitating gait initiation[12]. However, responses to cueing interventions are highly heterogeneous, with individual variations in responsiveness to different cue modalities and parameters[8]. Additionally, while immediate improvements during cueing have been documented, long-term carryover effects remain inconsistent, and most patients require ongoing use of cueing strategies similar to walking aids rather than permanent neuroplastic changes[8].

Combined auditory-visual cueing strategies may provide complementary benefits by leveraging the strengths of both modalities auditory cues for maintaining rhythm and visual cues for step scaling and movement initiation potentially yielding superior outcomes compared to single modality approaches[12]. However, despite the growing body of evidence supporting cueing interventions globally, there remains a notable research gap in Pakistan regarding the comparative effectiveness of auditory and visual cueing on gait and balance parameters in PD patients.

Hence, the present study is aimed at determining the effects of auditory and visual cueing on freezing of gait and balance in patients with Parkinson's disease.

METHODOLOGY

Study Design and Setting

A randomized controlled trial was conducted across three major rehabilitation centers located in three major cities of Pakistan: Women Institute of Learning and Rehabilitation Sciences in Abbottabad, Ibadat International University in Islamabad, and Mukabbir University of Science and Technology in Gujrat.

Sample Size Calculation

A sample size was calculated based on the values of Tinetti Balance and Gait Assessment scores taken from the previously conducted study: “Examining the effect of visual and auditory cueing on gait in individuals with Parkinson's disease experiencing freezing of gait” [13]. The mean values of 20.31 ± 1.02 in the freezing group and 22.23 ± 2.30 in the non-freezing group were taken as a reference. Considering a confidence interval of 95% and bond of error of 5% a sample size of n=28 (14 in each group) was estimated. Keeping a loss of follow-up of 20% a sample size was raised to n=34 (17 in each group). Open epi calculator was used for determining the sample size.

Inclusion and Exclusion Criteria

Participants diagnosed with PD based on movement disorder society diagnosis criteria and were 40 year and above going through the problem of FOG, had a score $\geq$ 24 on Mini-Mental state Examination (MMSE) confirming good cognitive function and were medically stable at least for four weeks were enrolled.

All participants diagnosed with other neurological conditions that affects gait and balance, had any other cardiovascular, orthopedic conditions that restrict them to perform exercise-based training were excluded from the study.

Intervention Protocol

The intervention was given for 12 weeks, 5 days per week. Each session was of a duration of 45-60 min. Besides exercise-based intervention speech therapy was received by participants in each group as an adjunctive intervention for 10-15 minutes (inclusive of total duration of 45-60 minutes). Speech therapy was focused to improve articulation and voice modulation.

Auditory and Visual Cueing Group (AVC)

In the AVC group participants were given exercise-based training with audio and visual cuing. The cues based on auditory stimulation was provided using a metronome device calibrated at a frequency of 60-90 beats/minutes. Visual cue was provided using laser guided cuing device that appears as a laser line on the ground at a desired step length[14]. A standardized gait and balance exercises were performed by the participants in the group synchronized with AVC.

Treadmill Training (TT) Group

Participants in the treadmill training group performed exercises on a motorized treadmill at an individualized speeds and inclines. The training was based on gradual progression protocol after every 1-2 weeks. The progression was based on speed 0.1-0.3 km/hr/ week and 2-5% graded incline after 2 weeks. Each session was 15-20 minutes of duration during a 1st week and a minimum of 5 minutes increase in duration based on individual performance was added after every week. Vitals included heart rate and pulse rate of the participants were monitored throughout the session.

Outcome Measures

Timed Up and Go (TUG) Test

Time up and go test was performed to determine balance and fall risk among the participants at baseline at 6th week and after 12 weeks of intervention. An improvement in the outcome was measured by estimating the time required by the participants to complete the test. The time was recorded in second with shorter time indicates better performance[15].

Tinetti Balance and Gait Assessment

The scale was used to determine improvement in gait and balance that quantifies performance for both static and dynamic balance. The scale comprises of 16 items with a highest score of 28points (16 for balance and 12 for gait). Higher values indicate better performance[16].

Ten-Minute Walk Test (10MWT)

The test was performed to determine endurance and functional walking capacity. Participant was instructed to walk as far as possible in ten minutes. The distance covered in meter during the ten minutes was utilized as a parameter of measurement. Greater distance covered during the ten minutes shows greater improvement.

New Freezing of Gait Questionnaire (NFOG-Q)

The questionnaire was used to estimate FOG severity and frequency. The instrument comprises of 29 items that records patients freezing episodes, duration, context and its impact in activities of daily livings. The score ranges from 0-100 with higher scores shows greater severity. The instrument was filled by the participants in assistance with the clinician[18].

All outcome measures were collected at baseline (week 0), at the midpoint of the intervention (week 6), and at the end of the study period (week 12) under consistent environmental conditions and by the same trained assessors to minimize measurement variability.

Data Analysis

A MDCalc statistical software was used to perform data analyses. Descriptive statistics were summarized based on mean, standard deviation and frequency. For determining within the group analyses continuous measure ANOVA was run, between group analyses was performed using an independent t-test at week 12 values. Significance level of $p<0.05$ was considered as statistical significant marker.

Ethical Considerations

The study was conducted in accordance with the guidelines of Helsinki declaration for human subject. All participants were priorly been informed regarding the purpose of study. Informed consents were taken and all principles of ethical consideration were given utmost importance. Institutional review board of Women Institute of Learning and Rehabilitation Sciences (IRB No: WLC-2024-05-36) and Ibadah International University (IRB No: 2024/044) approved the study protocol. Study was conducted during the period of February 2024 to November 2024.

RESULTS

Demographic and Clinical Characteristics

A total number of n=34 participants were recruited and divided into two group n=17 in AVC group and TT group respectively. Baseline characteristics had revealed that the mean age of

the participants was 62.3 ± 8.7 years in AVC group and 61.8 ± 9.2 years in TT group ((p = 0.78). Gender wise distribution had revealed that in AVC group there were 10 males and 7 females whereas in TT group there were 11 males and 6 females. The Hoen and Yahr scale revealed that majority had a disease progression at stage 1 and stage 2 indicating moderate disease progression. All other demographic measurements such as disease duration and MMSE score was shown in Table 1:

Table 1. Demographic and Clinical Characteristics

Characteristic	AVC Group (n=17)	TT Group (n=17)	p-value
Age (years)	62.3 ± 8.7	61.8 ± 9.2	0.78
Gender (M/F)	10/7	11/6	0.72
Disease Duration (years)	7.2 ± 3.4	6.9 ± 3.8	0.65
MMSE Score	26.5 ± 1.2	26.8 ± 1.1	0.43
Hoehn & Yahr (2-3)	15/2	14/3	0.68

Gait and Balance Outcomes

In gait and balance parameter significant improvements were measured after 12 weeks of intervention in both the groups. Tinetti Balance and Gait Assessment scores improved from baseline 18.2 ± 2.1 to 24.6 ± 1.8 at week 12 (p < 0.001) in AVC group and 17.9 ± 2.3 at baseline to 21.3 ± 2.2 at week 12 (p < 0.001) in TT group. Between group improvement was observed with a MD=3.3 (p<0.002) favoring AVC over TT (Table 2).

Table 2. Gait and Balance Outcomes

Outcome Measure	Baseline	Week 6	Week 12	p-value
Tinetti Balance & Gait (AVC)	18.2 ± 2.1	21.4±1.9	24.6 ± 1.8	< 0.001
Tinetti Balance & Gait (TT)	17.9 ± 2.3	19.5±2.4	21.3 ± 2.2	< 0.001
Between-Group (Week 12)				
Tinetti Balance & Gait	**AVC**	**TT**	**MD**	**p-value**
AVC vs TT	24.6 ± 1.8	21.3 ± 2.2	3.3	p=0.002

**MD is Mean Difference*

Freezing of Gait Severity and Walking Endurance

Functional walking capacity was measured using a New Freezing of Gait Questionnaire (NFOG-Q) scores. The score had shown a marked reduction in both the group after 12 weeks of intervention. At baseline the score was 68.4 ± 9.2 that had reduced to 32.1 ± 7.4 at week 12 (p < 0.001) shown a 53% reduction in the AVC group at the end of intervention. In TT group the value was 67.2 ± 8.8 at baseline that had shown a reduction of 27% with an observed value of 48.9 ± 8.1 (p < 0.001) at 12th week. (table 3), Additionally ten-minute walk test had also shown a significant improvement in both the group where the values in the AVC group at baseline was 234.6 ± 38.2 meters that increased to 312.4 ± 35.1 meters (p < 0.001, +33% improvement) and in TT group the values were improved from 231.8 ± 40.1 to 281.3 ± 39.4 meters (p < 0.001, +21% improvement). In between group comparison MD was 16.8 (p<0.001) favoring AVC over TT on NFOF-Q outcome and MD=31.1 (P<0.001) on 10minutes walk test again favoring AVC over TT.

Table 3. Freezing of Gait Severity and Walking Endurance

Outcome Measure	Baseline	Week 6	Week 12	p-value
NFOG-Q (AVC)	68.4±9.2	48.7±8.5	32.1±7.4	< 0.001
NFOG-Q (TT)	67.2±8.8	57.1±9.2	48.9±8.1	< 0.001
10MWT Distance in meters (AVC)	234.6±38.2	267.3±36.8	312.4±35.1	< 0.001
10MWT Distance in meters (TT)	231.8±40.1	254.2±41.3	281.3±39.4	< 0.001
Between Groups (Week 12)				
NFOG-Q	**AVC**	**TT**	**MD**	**p-value**
AVC vs TT	32.1 ± 7.4	48.9 ± 8.1	16.8	p<0.001
10MWT Distance in meters	312.4 ± 35.1	281.3 ± 39.4	31.1	P<0.001

Functional Mobility and Fall Risk

Functional mobility and risk of fall was determined using a time up and go test. Analyses of the data revealed that both groups had shown mark reduction in the time required to complete TUG test. The average time at baseline was 16.8 ± 3.2 seconds in AVC group that reduced to 11.2 ± 2.4 seconds at week 12 ($p < 0.001$) representing 33% reduction in completion of test. In TT group the values at baseline were 17.1 ± 3.5 seconds that reduced to 13.6 ± 3.1 seconds at week 12 showing a reduction of 21% ($p<0.001$). Between group analyses had shown a MD of 2.4 ($p=0.003$) favoring AVC over TT (Table 4).

Table 4. Functional Mobility Time up and go test

Outcome Measure	Baseline	Week 6	Week 12	p-value
TUG Test in seconds (AVC)	16.8 ± 3.2	13.9 ± 2.8	11.2 ± 2.4	< 0.001
TUG Test in seconds (TT)	17.1 ± 3.5	15.2 ± 3.3	13.6 ± 3.1	< 0.001

Between Groups (Week 12)

TUG test	AVC	TT	MD	p-value
AVC vs TT	11.2 ± 2.4	13.6 ± 3.1	2.4	0.003

DISCUSSION

The study had demonstrated that combined auditory and visual cueing (AVC) with structured exercise training produced significantly greater improvements in gait, balance, and freezing of gait severity compared to conventional treadmill training alone in patients with Parkinson's disease. Our results showing superior efficacy of combined AVC intervention (NFOG-Q improvement: 53% reduction) compared to treadmill training alone (27% reduction; $p < 0.001$) are consistent with number of studies demonstrating that multimodal cueing approaches yield larger gains in freezing of gait scores than single-modality or non-cueing interventions[19-20].

The Tinetti Balance and Gait Assessment findings revealed differential effects, with the AVC group achieving a 6.4-point improvement compared to 3.4 points in the treadmill group. This differential benefit in balance sub scores (+5.2 ± 1.1 in AVC vs. +1.8 ± 1.5 in TT; $p < 0.001$) versus comparable gait sub scores ($p = 0.34$) suggests that visual and auditory cues specifically enhance postural control and dynamic stability mechanisms. Recent work using virtual reality cueing interventions similarly reported significant balance improvements, suggesting that multimodal feedback may preferentially target vestibular and proprioceptive systems involved in balance control[21]. The pronounced balance improvements when visual cues are coupled with auditory rhythmic feedback indicate that complementary sensory pathways are activated synergistically.

Walking endurance improvements (10MWT: +33% in AVC vs. +21% in TT; $p = 0.015$) and functional mobility gains (TUG: 33% reduction in AVC vs. 21% in TT; $p = 0.003$) demonstrated that combined cueing benefits extend beyond FOG severity reduction to encompass broader functional capacity. Another study emphasized that personalized cueing systems are essential for moving toward patient-centered rehabilitation, noting that one-size-fits-all approaches may limit therapeutic efficacy[22]. The high adherence rates in our study (94.1% in AVC, 92.8% in TT) reflect excellent engagement with the intervention protocol, suggesting that multimodal feedback provides engaging, motivating rehabilitation experiences. This contrasts with traditional PT approaches where accessibility barriers and patient safety concerns limit long-term participation.

In a study demonstrated that visual and auditory cues activate implicit motor learning pathways, suggesting that repeated exposure may enhance motor memory consolidation even if complete independence from cueing is not achieved[23]. This temporal aspect underscores that cueing functions as an ongoing 'walking aid' rather than a curative intervention, necessitating continued implementation in real-world settings. A global guideline for fall in older adults highlighted the critical role of physical interventions in preventing falls in Parkinson's disease, demonstrating that dynamic training approaches such as cueing-augmented therapy significantly reduce fall risk compared to conventional approaches[24]. Our study's progressive improvement trajectory from baseline to week 6 to week 12 suggests that cumulative benefits accrue throughout the intervention period, supporting sustained engagement with treatment protocols.

A study argued that moving beyond conventional wisdom in treating gait and balance disorders in Parkinson's disease requires recognition that different patients respond optimally to different cueing modalities and intensities[25]. Our implementation of individually calibrated metronome frequencies (90-120 BPM adjusted

per participant) and progressively adjusted laser-guided visual cues reflects this personalization principle. The between-group superiority of AVC across all outcome measures suggests that offering patients access to both modalities during training may identify their optimal response characteristics and enhance overall efficacy. Similarly, a study provided a comprehensive analysis of cueing mechanisms, demonstrating that effective freezing of gait interventions requires matching cue characteristics to specific motor deficits, supporting the theoretical framework underlying our multimodal approach[26].

CONCLUSION

The study has provided evidence that AVC can produce a more beneficial results when combine with training program in reducing freezing of gait among PD patients. The significant improvement as observed in all the outcome measures clearly underlines that AVC treatment strategy must be included in routine exercises program for more effective results. Not only study has concluded that AVC is beneficial in reducing freezing of gait but it is effective in improving functional mobility, gait, balance and endurance among PD patients

Ethical Approval

Institutional review board of Women Institute of Learning and Rehabilitation Sciences (IRB # WLC-2024-05-36) and Ibadat International University (IRB# 2024/044) approved the study protocol.

Author Contributions

NM: Conception & Design, Data Analysis & Interpretation, Manuscript Writing, Critical Revision
RP: Conception & Design, Data Collection, Data Analysis & Interpretation, Manuscript Writing
UN: Data Analysis & Interpretation, Manuscript Writing
DE: Data Collection, Manuscript Writing
SZ: Data Collection, Manuscript Writing
MN: Conception & Design
All authors approved the final version of the manuscript to be published.

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None.

Conflict of Interests

No conflict of interest.

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