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COMPARATIVE EFFECTS OF VIRTUAL REALITY AND FRENKEL'S EXERCISES ON BALANCE, GAIT AND QUALITY OF LIFE IN PATIENTS WITH STROKE

Original Research

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ABSTRACT

Background: Stroke is a leading cause of disability and mortality worldwide, often resulting in significant motor deficits, including gait and balance impairments. Rehabilitation interventions, such as virtual reality and Frenkel's exercises, are widely employed to improve motor function and quality of life in stroke patients. These techniques focus on enhancing neuromuscular control, coordination, and functional independence during the recovery process. Despite their established benefits, direct comparative evidence between these two modalities remains limited.

Objective: To compare the effects of virtual reality and Frenkel's exercises on balance, gait, and quality of life in stroke patients.

Methods: A randomized clinical trial was conducted at the outpatient department of Islam Central Hospital, Sialkot, with a sample of 36 stroke patients selected through non-probability convenience sampling. Participants were randomly divided into two groups: Group A (virtual reality) and Group B (Frenkel's exercises), each comprising 18 participants. Balance, gait, and quality of life were evaluated using the Berg Balance Scale (BBS), Timed-Up and Go (TUG) test, and Stroke-Specific Quality of Life (SS-QOL) assessment, respectively. Each intervention was administered three times weekly for 30 minutes per session over six weeks. Data normality was assessed, and parametric tests, including paired and independent sample t-tests, were used for statistical analysis. A p-value of <0.05 was considered significant.

Results: Group A showed a significant improvement in BBS scores (35.81 ± 4.34 to 45.38 ± 3.32, $p < 0.001$) and SS-QOL scores (124.56 ± 19.59 to 209.06 ± 10.18, $p < 0.001$). Group B also demonstrated significant improvements, with BBS scores increasing from 35.50 ± 4.38 to 41.94 ± 2.64 ($p < 0.001$) and SS-QOL scores rising from 129.94 ± 17.19 to 188.94 ± 11.17 ($p < 0.001$). TUG test results revealed greater improvement in Group B (21.69 ± 2.89 to 13.81 ± 2.56, $p < 0.001$) compared to Group A (21.69 ± 2.77 to 16.69 ± 2.63, $p < 0.001$). Between-group analysis demonstrated that virtual reality was superior for balance and quality of life (BBS: $p = 0.003$; SS-QOL: $p < 0.001$), while Frenkel's exercises showed a greater effect on gait (TUG: $p = 0.004$).

Conclusion: Virtual reality training significantly improved balance and quality of life in stroke patients, whereas Frenkel's exercises were more effective in enhancing gait. These findings highlight the complementary benefits of both modalities in stroke rehabilitation, providing valuable insight for individualized patient care.

Keywords: Balance, Cerebral Infarction, Frenkel's Exercises, Gait, Quality of Life, Stroke, Virtual Reality.

INTRODUCTION

Stroke is a significant manifestation of cerebrovascular disease, ranking among the top five causes of mortality in the United States, with substantial morbidity and long-term disability (1). It is a potentially life-threatening condition characterized by inadequate perfusion of brain cells, leading to varying degrees of functional impairment. Strokes are classified into ischemic stroke, transient ischemic attack, and hemorrhagic stroke (2). Ischemic strokes, caused by a sudden interruption of blood flow to a part of the brain, account for 62.4% of all stroke cases, with lacunar strokes comprising approximately 25% of these events. Hemorrhagic strokes, affecting 10-15% of patients, are associated with high mortality rates (3). Pre-existing conditions such as hypertension, hyperlipidemia, and coronary artery disease significantly elevate the risk of stroke. Notably, around 60% of strokes occur in individuals with a history of transient ischemic attacks. Although strokes predominantly affect older adults, about 15% of cases occur in individuals aged 18 to 49 (4). Globally, stroke is the second leading cause of death and the third leading cause of combined death and disability, accounting for 12.2 million cases in 2019 alone (5). Between 2017 and 2047, the prevalence of stroke in the European Union is projected to rise by 27%, reflecting an urgent need for effective prevention and rehabilitation strategies (6).

Stroke survivors rarely achieve full recovery, with motor deficits and compromised functional independence being common outcomes. Despite variations influenced by lesion pathology and location, up to 90% recovery is possible within the first three months post-stroke, except for hemorrhagic cases (7). However, impaired balance control and reduced muscular activation heighten the risk of falls and limit the ability to perform activities of daily living (ADLs) (8). Therefore, rehabilitation efforts aim to restore voluntary movement, promote functional independence, and mitigate fall risks through a structured regimen of motor control exercises.

Virtual reality (VR) has emerged as a novel therapeutic tool, offering an immersive and interactive interface for motor and cognitive rehabilitation (9). By simulating real-world scenarios and providing sensory feedback, VR enhances motor learning and encourages physical activity in risk-controlled environments (10). The application of VR-based treadmill gait training has shown promising results in improving balance and gait in individuals with Parkinson's disease, stroke, and geriatric populations (11). However, challenges such as motion sickness caused by mismatched visual and physical walking speeds remain. Research suggests that aligning visual flow with actual walking speed significantly enhances rehabilitation outcomes (12).

Frenkel's exercises, in contrast, focus on restoring balance and coordination through a series of progressive, rhythmical movements that require precision and concentration (13). These exercises, performed in various positions such as sitting, standing, or lying down, emphasize repetition and visual guidance to improve motor control. Over time, patients with sensory impairments may advance to performing exercises with their eyes closed, further enhancing proprioceptive feedback and control (14). Frenkel's exercises have been particularly effective in promoting healthy aging and improving neuromuscular coordination in stroke patients (15).

This study seeks to compare the effects of virtual reality and Frenkel's exercises on balance, gait, and quality of life in patients recovering from stroke. By examining these two distinct therapeutic approaches, this research aims to identify optimal rehabilitation strategies to maximize functional recovery and improve patient outcomes.

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METHODS

The study was designed as a randomized clinical trial and was registered with ClinicalTrials.gov under the identifier NCT06509646, available at https://clinicaltrials.gov/study/NCT06509698. The estimated sample size was calculated to be 36 participants, accounting for a 20% attrition rate. This calculation was based on G*Power software, using data from the Berg Balance Scale (BBS), which measures balance. Significant differences between two means were considered, with the mean ± standard deviation (SD) of the control group being 42.4 ± 6.3 and the experimental group 49.9 ± 6.0 (52).

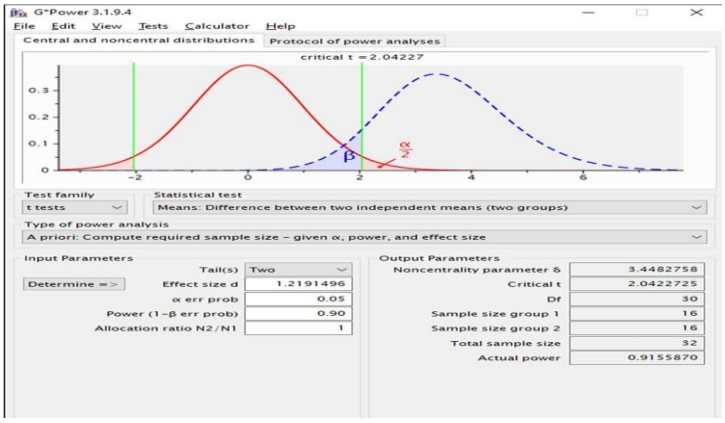

Figure 1 Sample size

A non-probability convenience sampling technique was employed to recruit participants, and the study duration spanned from 25 November 2023 to 10 June 2024. Data collection was conducted at the physiotherapy outpatient department of Islam Central Hospital, Sialkot. Eligible participants included male and female stroke patients aged 40 to 65 years with a history of stroke ranging from one to five months (sub-acute stroke phase). The inclusion criteria were restricted to survivors of ischemic stroke with no prior exposure to virtual reality-based rehabilitation and those who achieved a Mini-Mental State Examination (MMSE) score of ≥24. Exclusion criteria included patients with major behavioral or mental health disorders, recent myocardial infarction, quadriplegia, Parkinson's disease, lower limb fractures, lower extremity deep vein thrombosis, malignant tumors, or other unstable illnesses, as well as individuals diagnosed with vestibular conditions.

Figure 2 VIRTUAL REALITY GROUP, 2 A & B (soccer heading), C, D & E (Torso twist), F (Kicking), G & H (basic running).

Assessment tools included the MMSE, Berg Balance Scale (BBS), Timed Up and Go Test (TUG), and Stroke-Specific Quality of Life (SS-QOL) Scale. Ethical considerations were meticulously followed throughout the study. Randomization was achieved through a computer-generated random-number table, assigning participants to two groups (18 participants each). Group A underwent virtual reality-based interventions, while Group B participated in Frenkel's exercises. Both interventions were administered three times per week for six weeks. Data were analyzed using SPSS (Statistical Package for Social Sciences), version 25.

The virtual reality group engaged in activities designed to enhance motor coordination and balance, such as soccer heading, torso twisting, kicking, and basic running. These activities simulated real-world environments to provide an immersive rehabilitation experience. In contrast, the Frenkel's exercise group performed structured activities, including hip and knee flexion, hip abduction and adduction, and placing a foot over marked areas, which aimed to restore balance and coordination through progressive, rhythmic, and controlled movements.

Figure 3 FRENKEL'S EXERCISE GROUP, (hip and knee flexion), 2(hip abduction and adduction), 3 (placing a foot over a mark area)

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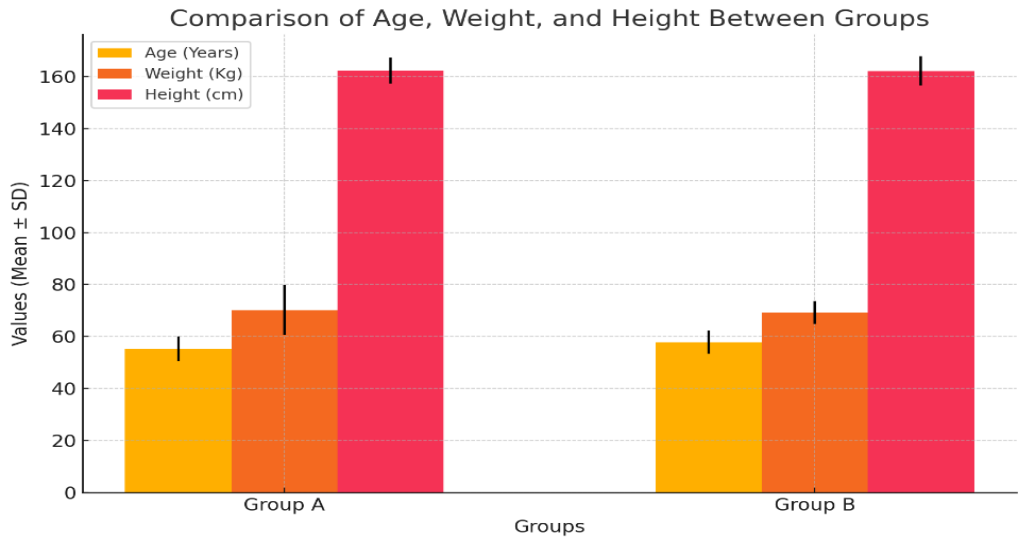
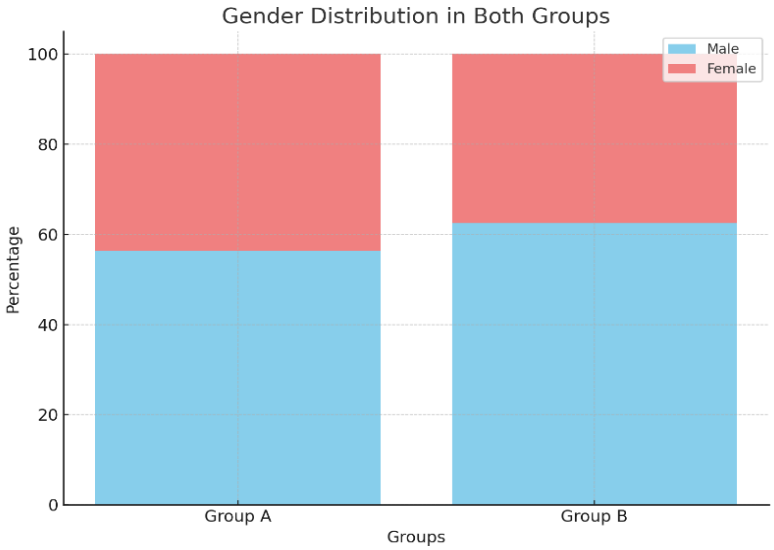
RESULTS

The results demonstrated comparable demographic characteristics between Group A (virtual reality) and Group B (Frenkel's exercises). The mean age of participants was 55.38 ± 4.77 years in Group A and 57.81 ± 4.48 years in Group B. Similarly, the mean weight was 70.25 ± 9.64 kg and 69.25 ± 4.42 kg for Groups A and B, respectively, while the mean height was 162.20 ± 4.95 cm in Group A and 162.13 ± 5.66 cm in Group B. Gender distribution indicated 56.3% males and 43.8% females in Group A, compared to 62.5% males and 37.5% females in Group B. These baseline similarities ensured a balanced comparison of interventions.

Both groups exhibited significant improvements across all measured outcomes, with distinct differences in post-intervention scores. For balance, Group A improved from 35.81 ± 4.34 to 45.38 ± 3.32, while Group B improved from 35.50 ± 4.38 to 41.94 ± 2.64, with post-intervention scores showing greater efficacy of virtual reality ($p = 0.003$). In gait performance, Group A demonstrated a reduction in Timed-Up and Go (TUG) scores from 21.69 ± 2.77 to 16.69 ± 2.63, whereas Group B improved from 21.69 ± 2.89 to 13.81 ± 2.56, indicating a stronger impact of Frenkel's exercises on mobility ($p = 0.004$). Regarding quality of life, Group A improved significantly from 124.56 ± 19.59 to 209.06 ± 10.18, while Group B showed an increase from 129.94 ± 17.19 to 188.94 ± 11.17, with virtual reality showing superior effects ($p < 0.001$). These findings highlight the differential impacts of the two interventions, with virtual reality excelling in balance and quality of life improvements, and Frenkel's exercises being particularly effective in enhancing mobility.





Group A= Virtual Reality Group, Group B= Frenkel's Exercise Group

Charts summarize the demographic data of both groups. The mean age was 55.38 ± 4.77 years in Group A and 57.81 ± 4.48 years in Group B. The mean weight was 70.25 ± 9.64 kg in Group A and 69.25 ± 4.42 kg in Group B, while the mean height was 162.20 ± 4.95 cm in Group A and 162.13 ± 5.66 cm in Group B. Gender distribution showed 56.3% males and 43.8% females in Group A, and 62.5% males and 37.5% females in Group B. These values indicate comparable demographic characteristics between the two groups.

Table 1: Between Group Studies of Berg Balance Scale (BBS)

Variables	**Group A (Mean+S.D)**	**Group B (Mean+S.D)**	**Sig.**
Pre-intervention score	35.81 +4.34	35.50 +4.38	.841
Post-intervention score	45.38 +3.32	41.94 +2.64	.003

Within Group Studies of Berg Balance Scale (BBS)

		Mean	N	Std. Deviation	Sig. (2-tailed)
Pair 1	Pre-Intervention Score of BBS	35.81	16	4.34	.000
(Group A)	Post-Intervention Score of BBS	45.38	16	3.32	
Pair 2	Pre-Intervention Score of BBS	35.50	16	4.38	.000
(Group B)	Post-Intervention Score of BBS	41.94	16	2.64	

Table 1 presents the comparative analysis of Berg Balance Scale (BBS) scores between Group A (virtual reality) and Group B (Frenkel's exercises). Pre-intervention scores showed no significant difference between groups (Group A: 35.81 ± 4.34, Group B: 35.50 ± 4.38, p = 0.841). However, post-intervention scores revealed a statistically significant improvement in Group A compared to Group B (Group A: 45.38 ± 3.32, Group B: 41.94 ± 2.64, p = 0.003). Within-group analysis demonstrated highly significant improvements in both groups, with Group A increasing from 35.81 ± 4.34 to 45.38 ± 3.32 (p = 0.000) and Group B improving from 35.50 ± 4.38 to 41.94 ± 2.64 (p = 0.000). These results highlight the superior efficacy of virtual reality interventions in enhancing balance compared to Frenkel's exercises.

Table 2: Between Group Studies of Timed-Up & Go Test

Variables	**Group A (Mean+S.D)**	**Group B (Mean+S.D)**	**Sig.**
Pre-intervention score	21.69 + 2.77	21.69 + 2.89	1.000
Post-intervention score	16.69 + 2.63	13.81 + 2.56	.004

Within Group Studies of Timed-Up & Go Test (16)

		Mean	N	Std. Deviation	Sig. (2-tailed)
Pair 1	Pre-Intervention Score of TUG	21.69	16	2.77	.000
(Group A)	Post-Intervention Score of TUG	16.69	16	2.63	
Pair 2	Pre-Intervention Score of TUG	21.69	16	2.89	.000
(Group B)	Post-Intervention Score of TUG	13.81	16	2.56	

Table 2 summarizes the Timed-Up and Go (TUG) test results, comparing Group A (virtual reality) and Group B (Frenkel's exercises). Pre-intervention scores were identical between the groups (Group A: 21.69 ± 2.77, Group B: 21.69 ± 2.89, p = 1.000). Post-intervention, both groups demonstrated significant improvements, with Group B showing a greater reduction in TUG scores compared to Group A

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(Group A: 16.69 ± 2.63, Group B: 13.81 ± 2.56, p = 0.004). Within-group analysis revealed significant progress for both groups, with Group A decreasing from 21.69 ± 2.77 to 16.69 ± 2.63 (p = 0.000) and Group B improving from 21.69 ± 2.89 to 13.81 ± 2.56 (p = 0.000). These findings highlight the enhanced impact of Frenkel's exercises on mobility and functional performance.

Table 3: Between Group Studies of Stroke Specific Quality of Life (SS-QOL)

Variables		**Group A (Mean+S.D)**	**Group B (Mean+S.D)**		**Sig.**
Pre-intervention score		124.56 + 19.59	129.94 + 17.19		.416
Post-intervention score		209.06 + 10.18	188.94 + 11.17		.000
Within Group Studies of Stroke Specific Quality of Life (SS-QOL)					
		Mean	N	Std. Deviation	Sig. (2-tailed)
Pair 1 (Group A)	Pre-Intervention Score of SS-QOL	124.56	16	19.59	.000
	Post-Intervention Score of SS-QOL	209.06	16	10.18	
Pair 2 (Group B)	Pre-Intervention Score of SS-QOL	129.94	16	17.19	.000
	Post-Intervention Score of SS-QOL	188.94	16	11.17	

Table 3 outlines the Stroke-Specific Quality of Life (SS-QOL) scores, comparing Group A (virtual reality) and Group B (Frenkel's exercises). Pre-intervention scores showed no significant difference between the groups (Group A: 124.56 ± 19.59, Group B: 129.94 ± 17.19, p = 0.416). Post-intervention scores demonstrated a significant improvement in both groups, with Group A showing a more substantial increase (Group A: 209.06 ± 10.18, Group B: 188.94 ± 11.17, p = 0.000). Within-group analysis revealed highly significant enhancements, with Group A improving from 124.56 ± 19.59 to 209.06 ± 10.18 (p = 0.000) and Group B improving from 129.94 ± 17.19 to 188.94 ± 11.17 (p = 0.000). These results indicate that virtual reality interventions had a more pronounced positive impact on stroke-specific quality of life.

Table 4: Within Group & between Group Comparison of Balance, Gait, and Quality of Life in the Group A (n=16) and Group B (n=16) at pre and post intervention

Outcom e Measure s	**Group A**			**Group B**			**Pb Value**	
	Pre	**Post**	**Pa Value**	**Pre**	**Post**	**Pa Value**	**Pre**	**Post**
BBS	35.81 +4.34	45.38 +3.32	<0.00*	35.50 +4.38	41.94 +2.64	<0.00*	.841	.003*
TUG	21.69 +2.77	16.69 + 2.63	<0.00*	21.69 +2.89	13.81 + 2.56	<0.00*	1.00	.004*

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Outcom e Measure s	Group A			Group B			Pb Value	
	Pre	Post	Pa Value	Pre	Post	Pa Value	Pre	Post
SS-	124.56+19.	209.06+10.	<0.00	129.94+17.	188.94+11.	<0.00*	.416	.000
QOL	59	18	*	19	17			*

Table 4 presents the within-group and between-group comparisons of balance, gait, and quality of life in Group A (virtual reality) and Group B (Frenkel's exercises). For the Berg Balance Scale (BBS), Group A improved significantly from 35.81 ± 4.34 to 45.38 ± 3.32 ($p < 0.001$), while Group B improved from 35.50 ± 4.38 to 41.94 ± 2.64 ($p < 0.001$); between-group differences post-intervention were also significant ($p = 0.003$). In the Timed-Up and Go (TUG) test, Group A improved from 21.69 ± 2.77 to 16.69 ± 2.63 ($p < 0.001$), and Group B improved from 21.69 ± 2.89 to 13.81 ± 2.56 ($p < 0.001$), with significant between-group differences post-intervention ($p = 0.004$). For Stroke-Specific Quality of Life (SS-QOL), Group A showed greater improvement from 124.56 ± 19.59 to 209.06 ± 10.18 ($p < 0.001$) compared to Group B, which improved from 129.94 ± 17.19 to 188.94 ± 11.17 ($p < 0.001$); the post-intervention between-group difference was highly significant ($p < 0.001$). These findings underscore the superior efficacy of virtual reality interventions in enhancing balance, gait, and quality of life.

DISCUSSIONS

The findings of this study align with existing research, demonstrating the efficacy of virtual reality (VR) and Frenkel's exercises as core rehabilitation methods for stroke patients. Previous studies by Haque et al. (2023) and Akinci et al. (2023) highlighted the effectiveness of Frenkel's exercises and robot-assisted rehabilitation in improving balance and gait, which is consistent with the improvements observed in the Frenkel's exercise group in the current study (16, 17). The significant advancements in Berg Balance Scale (BBS) and Timed-Up and Go (TUG) scores further support these findings, emphasizing the utility of Frenkel's exercises for enhancing balance and gait from baseline levels.

Virtual reality has emerged as a promising modality in stroke rehabilitation, offering immersive and engaging platforms for motor recovery. The findings of this study support the work of De Rooij et al. (2021), which emphasized the potential of VR to improve motor function and quality of life among stroke survivors by increasing patient engagement and motivation (18). This study demonstrated significant improvements in balance, gait, and quality of life in the VR group, with superior outcomes compared to the Frenkel's exercise group. These results are also in agreement with Cortés-Pérez et al. (2020), who found that immersive VR yielded better balance outcomes compared to conventional therapy, underscoring the need for innovation in stroke rehabilitation practices (20).

While this study supports the growing body of evidence advocating for VR as a priority intervention for subacute stroke patients, certain limitations should be acknowledged. The generalizability of the findings is limited to subacute stroke patients with similar demographic and clinical profiles. Additionally, adherence to protocols and the long-term sustainability of improvements were not evaluated. Although VR interventions demonstrated marked superiority in balance improvements, other factors, such as accessibility, cost-effectiveness, and patient-specific preferences, require further exploration to optimize the implementation of VR technology in clinical practice.

Debates surrounding the inconsistent findings of VR efficacy in existing literature highlight the complexity of this intervention. For instance, Keskin et al. (2020) reported no significant differences in outcomes with VR use, in contrast to the current study, which observed significant improvements in BBS, TUG, and SS-QOL scores, favoring VR over Frenkel's exercises (21). These discrepancies may be attributed to variations in study design, patient characteristics, and the timing of rehabilitation interventions. This study focused on subacute stroke patients, aligning with evidence suggesting that early-phase rehabilitation through innovative modalities like VR promotes better recovery of sensorimotor functions and motor learning (19). By providing robust data supporting the superiority of VR in improving balance, this study contributes to the growing advocacy for the integration of VR into stroke rehabilitation protocols.

The strengths of this study include its randomized design, well-defined inclusion criteria, and the use of validated outcome measures. However, further research is warranted to evaluate the long-term effects of these interventions, the impact of patient compliance, and the cost-effectiveness of VR rehabilitation in diverse populations. Addressing these gaps will provide a comprehensive understanding of the optimal use of VR and Frenkel's exercises in stroke recovery.

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CONCLUSION

In conclusion, this study demonstrated that virtual reality training significantly enhanced balance and quality of life in stroke patients, showcasing its potential as a priority intervention for rehabilitation. On the other hand, Frenkel's exercise training proved to be particularly effective in improving gait, highlighting its value in addressing specific motor impairments. Both interventions contributed positively to the recovery process, with their unique strengths offering tailored benefits depending on the rehabilitation goals. These findings underscore the importance of incorporating innovative and targeted approaches to optimize functional recovery and overall well-being in stroke rehabilitation programs.

AUTHOR CONTRIBUTIONS

Author	Contribution
Aqsa Arif	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Kirn Arshad	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Sana Tariq	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Shiza Sundas	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Nida Tariq	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Anum Kabir*	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Ahmad Ammar Asif	Contributed to study concept and Data collection Has given Final Approval of the version to be published

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