The Impact of Virtual Reality Training with a Cognitive Load on Falling in Stroke Cases

Ahmed S. Ali [1*] Ph.D., Wael S. Shendy[1] Ph.D., Amr Hassan[2] MD,

Khaled Atef Abdelmonem[1] MSc., Ayman El Khatib [3] Ph.D.

Abstract

Background: One of the most frequent factors in long-term impairment is stroke. The most prominent, recurrent medical side effect after a stroke is falling, with a prevalence of 14% to 73%. Hip fractures, soft tissue injuries, fear of falling, increased immobility, and disability are all possible outcomes of falling as common medical complications. **Aim of the Study:** The current academic work seeks to trace and highlight how cognitively demanding virtual reality training decrease the chance of falling in severe stroke cases. **Procedures:** The study encompassed a sample of thirty stroke cases, males and females, with recurrent falls and a MoCA score higher than 26. The ages of the cases covered a range between 40 to 65 years old, with a medical issue that persisted for more than six months. The control group (CG) and the study group (SG) were randomly sub-categorized into two equal study domains. A typical regime of therapeutic workouts for cases who were at risk of falling was administered to the individuals in the control group. Cases in the study domain underwent the same treatment plan as those in the control domain, in addition to VR balance training and dual-task training utilizing the Nintendo Wii Fit system. Three sessions each week were held during the course of the four-week program. All falling variables were pre-and post-assessed for each case. Both Berg Balance Scale and the 16-item Fall scale were taken into account in the current research. The disparity in Gaming Scores for the Study domain on the International Efficacy Scale (FES-I) was calculated carefully. **Results:** The control group's scores on the 16-item Fall Efficacy Scale-International (FES-I) and the Berg Balance Scale did not noticeably improve following the treatment protocol. In the study groups, all metrics showed a clear improvement. Moreover, there was a clear disparity in the research group's gaming results between the first and 12th sessions. The study group witnessed a great improvement more than the control group in all study measures, according to a comparison of the effects after finishing the treatment protocols of both study domains ($P < 0.05$). **Conclusion:** The risk of falling in stroke cases may not be decreased by conventional therapeutic protocols. In addition to traditional balance training, virtual reality (VR) balance training adopting the Nintendo Wii Fit console combined with Dual task training is beneficial in reducing the hazard of falling in stroke cases. A potential strategy for reducing the probability of falling in stroke cases is VR balance training while taking into consideration the Nintendo Wii Fit system that is paired with Dual task training. Lowering the problem of falls in stroke cases should be regarded as one of the pillars of the physical rehabilitation program.

KeyWords: Stroke, Falling, Balance, Berg Balance Scale, Fall efficacy scale, Virtual reality, Nintendo Wii Fit, Dual task training, and Cognitive training.

DOINumber: 10.14704/NQ.2022.20.15.NQ88007 **NeuroQuantology2022;20(12):90-97**

Correspondingauthor: Ahmed S. Ali **Email:** dr.Shawky_2011@cu.edu.eg

Affiliations:

[1*]Lecturer, Physical Therapy department for Neurology, Faculty of Physical Therapy, Cairo University, Egypt; [2]Neurology department, Faculty of Medicine, Cairo University, Egypt; [3]Department of Physical Therapy, Faculty of Health Sciences, Beirut Arab University, Beirut, Lebanon.

Relevant conflicts of interest/financial disclosures:

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Introduction:

Strokes are neurological medical conditions of the central nervous system that persist longer than 24 hours and are brought on by cerebrovascular illnesses [1]. The essence of this medical complication lies in the rapid loss of brain functionality brought on by an obstruction in the blood supply to the brain. An obstruction or a hemorrhage may have caused ischemia in this case [2]. Cardiovascular fitness and ambulatory exercise are severely low in people with diabetic stroke. Mobility issues, especially with balance, are linked to low ambulatory activity. Deconditioning may be influenced by balance-related inactivity [3]. Low balance confidence and decreased quiet standing control are common in people with chronic stroke, and both conditions are indicative of cautious gait patterns [4].

The effects of falling after a stroke encompass hip fractures, soft tissue injuries, fear of falling, increased immobility, and increased ailment. Falling is common after a stroke. Falls can be incapacitating, and stroke survivors who live in the community experience a high fall rate [5].

It may be possible to manage mobility decline and fall risk in older persons in addition to improving some cognitive abilities, particularly executive function and attention [6]. This could be extremely important in lowering fall risk and disability in cognitively challenged people [7]. A spectrum of cases may utilize the game-based application as a therapeutic solution in both clinics and at home. Virtual reality-based training (VR) is advantageous for enhancing community ambulation in stroke cases [8]. Furthermore, a safe training method for cognitive rehabilitation of memory and attention functionality in stroke cases is virtual reality intervention [9].

Wii workout games boost physical vitality, mental health, social engagement, and enjoyment in older persons. Furthermore, old persons can safely and successfully exercise with Wii fitness games [10]. Wii Fit balance training has been demonstrated to enhance balance control, which correlates to health gains [8].

"Training in the performance of a motor activity while simultaneously doing a cognitive task" is the definition of dual-task (DT) training. DT could effectively combine the two jobs and automate the execution of the main motor job [11]. Some examples of cognitive task domains are verbal fluency and mental tracking. Participants were to name as many terms from a particular category as they could for the verbal fluency challenge e.g., fruit. In the mental tracking exercise, individuals subtracted three items serially from a random value between 90 and 100 [6].

Methods:

Participants

Thirty Egyptian chronic stroke cases, aged 40 to 65, of both sexes, with a disease duration of more than six months, minimal spasticity, adequate cognitive capacities, and ambulant cases were included in this study. The general hospitals, physical therapy facilities, and outpatient clinics in Alexandria were used to find patients. The clinical assessment covers history taking and both general and neurological evaluation. Following thorough explanations of the study's objectives, methodology, potential advantages, use of cases' personal information and privacy rights, and the potentiality to drop out at any time, the cases have signed a clear, informed consent before initiating the protocol. All cases were evaluated while adopting the same processes.

Procedure

The current academic work excluded a spectrum of cases with visual, auditory, speech, and cognitive impairments, musculoskeletal disorders that affect gait, and cardiovascular medical complications. At random, the cases were split into the study group with nine females and six males, and the control group with eight females and seven males.

The control group underwent a conventional physical balancing program for 60 minutes, which included exercises for fall prevention, weight shifting, perturbations, and static postural control [12]. The study group also got a virtual reality balance workout utilizing the Nintendo Wii Fit console for forty-five minutes. The previously mentioned plan is done altogether with the standard physical therapy program of balance for fifteen minutes. Table tilt, tight rope, and soccer were the three balance board games used, and they all improved balance [13].

Firstly, the player set himself/herself on the balance board with no shoes on; the game simulates movement between the player and a figure on the screen; as the player moves on the WBB, pressure sensors in its corners vary, changing the avatar. The player of the table-tilting game acted as though a ball were moving to fit through a hole in the tilting board. In the tightrope game, the player adjusts his weight laterally on the balance board to keep the avatar moving across the rope while they try to avoid falling. In the heading Soccer game, the player uses his avatar to change his weight to head balls. Participants played memory games while completing memory jobs.

Measures

The BBS was employed to determine the balance. A higher score indicates better balance. It is composed of 14 items, each of which is scored on a 4-point scale. A total score (maximum = 56 points) is calculated by adding the scores from each of the 14 items. The validity and reliability of BBS have been evaluated among elderly individuals and stroke survivors [14], [15].

The 16-item Fall Efficacy Scale-International (FES-I) was used to measure fear of falling [16]. Participants used a Likert scale from 1 (not bothered) to 4 (extremely concerned) to rate their fear of falling during 16 common activities (very worried). The total score, which is the average of the 16 responses and ranges from 16 to 64 points, was adopted for data analysis. A greater fear of falling is indicated by a higher overall score. Stroke cases have tested the FES-I [17].

The current academic work adopted the Montreal Cognitive Assessment (MoCA) to rule out cognitive impairments because it has been validated in several populations, including stroke survivors. When administering the MoCA, participants must complete several separate activities that measure cognitive domains. Scores of 26 or below on the MoCA's total scale of 30 indicate the existence of cognitive impairment.

The Arabic MoCA has good sensitivity and specificity as a screening test for MCI. It has adequate internal consistency and test-retest reliability [18]. A strong association between Arabic MoCA and CAMCOG scores was used to demonstrate content validation. The MoCA Arabic's specificity rate was good (85.7%). More significantly, Arabic MoCA had a high (92.3%) sensitivity to MCI detection [19].

Statistical analysis:

The SPSS Package software for Windows, version 25, was adopted to conduct the statistical analysis for the current academic work (SPSS, Inc., Chicago, IL). The following elements were covered by the statistical procedures: Data from descriptive statistics, such as the mean and standard deviation for age, the Berg balance scale, the fall efficacy scale, the Chi-square test (2-test) to compare the study group and the control group while accounting for the distribution of stroke types, and the Independent (Unpaired) t-test to assess the age variable between the two study domains.

2X2 mixed design MANOVA (multivariate analysis of variance) test. The tested variables of interest (balance scale and Fall effectiveness scale) were compared across various groups and periods using MANOVA. The first independent variable (between subject factors) was the tested group with two levels (control group and study group). The testing period, which was split into two levels, served as the second independent variable (inside the subject factor) (pre-treatment and post-treatment). The second dependent variables were the balance scale and the overall efficacy scale. To compare between sessions within each game name, use a one-way repeated measures ANOVA test. Significant level: At a probability threshold of 0.05, all statistical analyses were observably clear (P>0.05).

Results:

In the Pre-treatment phase, there was no discernible difference between the two study domains for age or stroke side (p>0.05). **(Table 1,2), (Figure 1,2).**

Table (1): Comparison of mean values of age (year) between the control group and study group.

Items	Age (Mean ±SD)
Control group (n=15)	59.30 ±4.49
Study group (n=15)	58.30 ±7.93
t-value	0.270
P-value	0.733
Significance	NS

SD: standard deviation; **P-value:** probability value; **NS:** non-significant

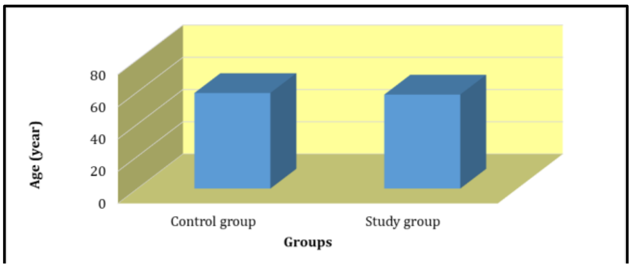

Figure (1): Mean values of age in the control group and study group.

Table (2): Distribution of the affected side of stroke in the control group and study group

Items	Stroke type	
	Right hemiplegia	Left hemiplegia
Control group (n=15)	3 (20.00%)	12 (80.00%)
Study group (n=15)	3 (20.00%)	12 (80.00%)
Chi-square value	1.067	
P-value	0.587	
Significance	NS	

SD: standard deviation; **P-value:** probability value; **NS:** non-significant

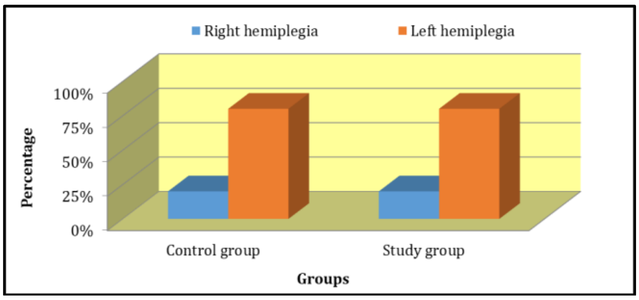

Figure (2): Distribution of stroke in the control group and study group.

A 2x2 mixed design MANOVA statistical analysis identified a crystal-clear discrepancy between the study domains, the measuring periods, and the interaction effect on all dependent variables **(Table 3).**

Table (3): Overall main effect of mixed design MANOVA for all dependent variables

Source of variation	Wilk's Lambada value	Partial Eta² (η^2)	F-value	P-value	Significant
Tested groups effect	0.675	0.325	8.408	0.001	S
Measuring period effect	0.491	0.509	18.127	0.0001	S
Interaction effect	0.649	0.351	9.480	0.001	S

P-value: probability value;**S:** Significant

The Berg Balance Scale rose exponentially (P=0.0001; P>0.05) after treatment compared to before treatment within the study group, while there was no clear disparity (P=0.562; P>0.05) within the control group, according to the statistical analysis using the MANOVA test. **(Table 4), (Figure 3)**

Table (4): Comparison between mean values of pre-and post-treatment Berg balance scale within each group.

Item	Berg balance scale (Mean ±SD)	
	Control group (n=15)	Study group (n=15)
Pre-treatment	43.90 ±4.60	45.80 ±3.70
Post-treatment	45.10 ±4.48	51.70 ±2.05
Mean difference	1.20	5.90
Improvement %	2.73%	12.88%
F-value	0.349	19.375
P-value	0.562	0.0001
Significant	NS	S

SD: standard deviation; **P-value:** probability value; **NS:** non-significant; **S:** Significant

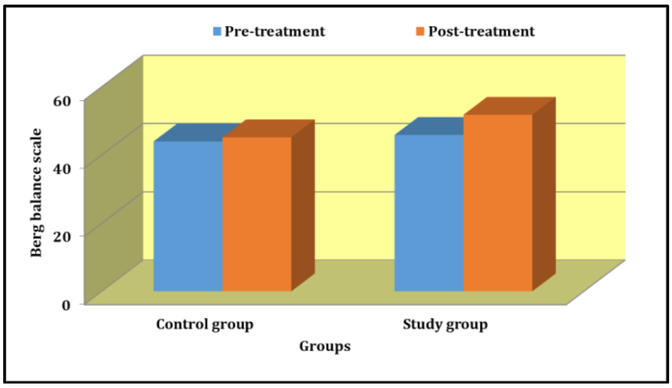

Figure (3): Mean values of pre-and post-treatment Berg balance scale within each group.

Through adopting the MANOVA test in the current study, no clear variance in the phase before starting the treatment plan of the Berg balance scale (P=0.323; P>0.05) was observed. However, a noticeable variance in the phase after the treatment plan of the Berg balance scale (P=0.001; P<0.05) between the two study domains. Increased values in the berg balance scale after finishing the treatment plan indicate a great improvement according to **Table no. 5** and as highlighted in **Figure no. 4.**

Table (5): Comparison of mean values of pre- and post-treatment Berg balance scale between both study domains.

Item	Berg balance scale (Mean ±SD)	
	Pre-treatment	Post-treatment
Control group (n=15)	43.90 ±4.60	45.10 ±4.48
Study group (n=15)	45.80 ±3.70	51.70 ±2.05
F-value	1.033	17.901
P-value	0.323	0.001
Significant	NS	S

SD: standard deviation; **P-value:** probability value; **NS:** non-significant; **S:** Significant

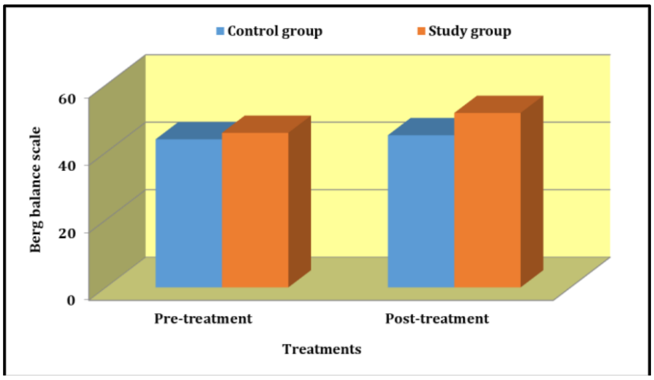

Figure (4): Mean values of pre-and post-treatment Berg balance scale between both groups.

The statistical analysis by MANOVA test reflected the decrease in the Fall efficacy scale after finishing the treatment plan in comparison to the phase before the treatment plan (P=0.0001; P<0.05). No clear disparity is noticed with the control group (P=0.241; P>0.05). After ending the treatment plan, decreased values of the fall efficacy scale were observed as an indication of a vast amendment as shown in both Table no. 6 and Figure no. 5

Table (6): Comparison between mean values of pre-and post-treatment Fall efficacy scale within each group.

Item	Fall efficacy scale (Mean ±SD)	
	Control group (n=15)	Study group (n=15)
Pre-treatment	28.50 ±1.35	29.60 ±2.50
Post-treatment	27.59 ±1.95	23.50 ±2.22
Mean difference	0.91	6.10
Improvement %	3.19%	20.61%
F-value	1.470	33.190
P-value	0.241	0.0001
Significant	NS	S

SD: standard deviation; **P-value:** probability value; **NS:** non-significant; **S:** Significant

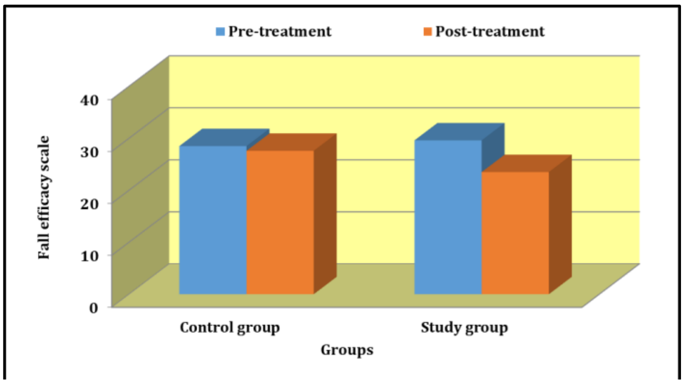

Figure (5): Mean values of pre-and post-treatment Fall efficacy scale within each group.

The results of the statistical analysis using the MANOVA test showed that there was no clear disparity between the control group and the study group in the pre-treatment Fall efficacy scale (P=0.237; P>0.05), but that there was a noticeable disparity in the post-treatment Fall efficacy scale (P=0.0001; P <0.05). **(Table 7), (Figure 6).**

Table (7): Comparison of mean values of pre-and post-treatment Fall efficacy scale between both groups

Item	Fall efficacy scale (Mean ±SD)	
	Pre-treatment	Post-treatment
Control group (n=15)	28.50 ±1.35	27.59 ±1.95
Study group (n=15)	29.60 ±2.50	23.50 ±2.22
F-value	1.494	19.047
P-value	0.237	0.0001
Significant	NS	S

SD: standard deviation; **P-value:** probability value; **NS:** non-significant; **S:** Significant

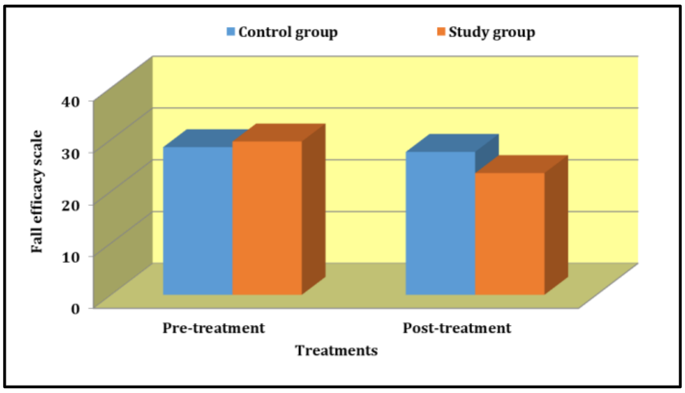

Figure (6): Mean values of pre-and post-treatment Fall efficacy scale between both groups.

The main effects of tested study domains (F= 16.228; P= 0.002; Partial eta^2= 0.802), measuring period (F= 39.280; P= 0.0001; Partial eta^2= 0.814), and group x period interaction (F= 6.507; P= 0.021; Partial eta^2= 0.619) were noticed carefully in multivariate assessments by one-way repeated measuring ANOVA for outcomes measures (P <0.05) as portrayed in **Table no.8**

Table (8): Overall main effect of one-way repeated measuring ANOVA-test on balance and Falling

Source of variation	Wilk's Lambada value	Partial Eta² (η²)	F- value	P-value	Significant
Tested groups effect	0.198	0.802	16.228	0.002	S
Time (session) effect	0.186	0.814	39.280	0.0001	S
Interaction effect	0.381	0.619	6.507	0.021	S

P-value: probability value;**S:** Significant

Table tilt game, tight robe game, and heading soccer game all had substantially higher scoring in the 12th session compared to the first session, according to a one-way repeated measures ANOVA test (P=0.002, P>0.05). Improvement is shown by higher scores in the twelfth session compared to the first one **(Table 9). (Figure 7).**

Table (9): One-way repeated measuring ANOVA-test on balance and falling by game name.

Sessions	Game name (Mean ±SD)		
	Table tilt (n=15)	Tight robe (n=15)	Heading soccer (n=15)
1st session	6.60 ±4.81	5.46 ±4.72	9.60 ±2.16
12th session	19.60 ±9.55	17.08 ±5.12	30.82 ±12.20
Change	13.00	11.62	21.22
Improvement %	66.32%	68.03%	68.85%
F-value	17.403	39.095	30.090
P-value	0.002	0.0001	0.0001
Significance	S	S	S

P-value: probability value;**S:** Significant

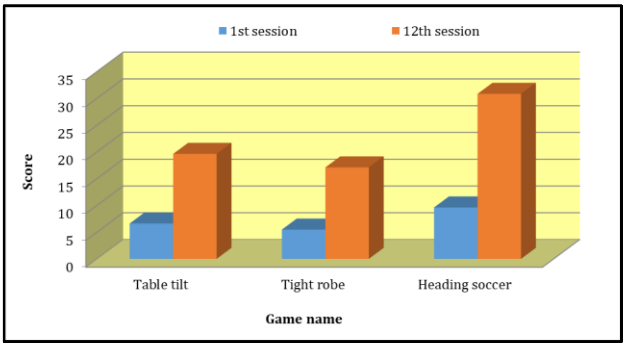

Figure (7): Mean values of balance and falling score between 1st session and 12th session within each game name.

Discussion:

The objective of the current academic work was to trace how cognitive load training in virtual reality affected stroke cases' risk of falling. The Berg Balance Scale (BBS) was higher in the study group after the therapeutic plan in comparison to before initiating the therapeutic plan. However, there was no discernible disparity in the control group, according to statistical analysis using the MANOVA test. Increased BBS values within the study group from pre- to post-treatment indicate improvement.

The fall efficacy scale (FES) was vastly lower in the study group after the treatment phase compared to before the treatment phase, but there was no discernible disparity in the control group, according to the MANOVA test. Improvement is indicated by lower FES values within the study group post-treatment compared to pre-treatment.

According to recent academic research, cognitively demanding virtual reality training markedly reduced the risk of falling in stroke cases. **Han Suk Lee et al.,** who agreed on the impact of VR on lower extremity function in chronic stroke cases, accepted this interpretation as well. The functional outcomes of gait, balance, lower limb mobility, lower limb strength, and lower limb muscle tone may all be improved in chronic stroke patients with VR training [20]. All cases greatly improved in their ability to balance, according to the findings of **Cho et al.,** who also used a variety of video games to enhance the case's balance, coordination, strength, and upper limb coordination [21].

The findings of **Liepert et al.** which claimed that the general benefits of virtual reality, combined with several advantages specific to video-capture VR, are compelling arguments for including this technology in the toolkit available in clinical settings, were supported by a substantial improvement in the study group after treatment. As a result of market demand, user interest, and technological advancements, a variety of video-capture platforms are now widely available.

These platforms are undeniably useful as intervention tools in the rehabilitation of individuals suffering from neurological and musculoskeletal illnesses. Motivated patients would be encouraged to repeat their movements, which would assist them to improve their condition, which is difficult to achieve with traditional therapy [22].

"A high-end Human-Machine Interface that combines technologies such as computer graphics, image processing, pattern recognition, artificial intelligence, networking, sound systems, and others to produce computer simulation and interaction that gives the feeling of being present through multiple synthetic feedback channels such as virtual, aural, haptic, and others" [23] is what virtual reality is described as. The enhancement can be linked to the fact that visual feedback in virtual reality can be used to boost widespread cortical regions in the brain. The remodeling of sensorimotor circuits may be triggered by visual information [24, 25]. Stroke patients can attain the goal of managing their body state by adjusting their body's center of gravity with the aid of visual feedback [26].

The study group's improvement could be linked to the potential value of VR training for enhancing ADL and physical strength. This is thought to be because high-intensity, repetitive, task-oriented trainingwhich is frequently employed as an evidence-based therapeutic strategy in chronic stroke casescan be improved by VR training [20]. Furthermore, Wii exergames increase physical activity, cognitive stimulation, social support, and enjoyment in older persons, improving cognition, physical function, and psychosocial outcomes. Furthermore, older folks can safely and successfully exercise with Wii fitness games. [27].

On another level, to improve upper limb function, Laver et al. discovered that traditional therapy methods were no more effective than using virtual reality and interactive video games. When used in conjunction with routine treatment, virtual reality may improve daily living tasks and upper limb function (to increase overall therapy time). The impact of virtual reality and interactive video games on gait speed, balance, participation, and quality of life could not be deduced from the available data. In this study, time since stroke onset, degree of disability, and device type (commercial or personalized) was not found to be significant predictors of outcome. Although not statistically significant, a higher dose (almost 15 hours total intervention time) and a customized virtual reality program looked to be preferable [28].

Dual-task (DT), as well as VR, were adopted successfully in the current work. DT training is the way of performing a motor task while simultaneously performing a cognitive task (memory exercises like making word lists, letter-number sequences, and memory games), to produce a correlation between the two tasks and "automate" the execution of the primary motor task [11]. This work's outcomes portrayed that cognitive load training in virtual reality had a substantial impact on falls in stroke cases.

Conclusion:

The current academic work concluded that there was a markedly noticeable relationship between cognitive load and virtual reality training for stroke cases who were at risk of falling. The study suggests that this combination leads to better results and can be adapted to manage stroke cases with a risk of falling.

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