Effect of Virtual Reality Interventions on Occupational Participation in Stroke Patients: A Rapid Systematic Review

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Key Words

- evidence-based practice
- virtual reality (VR)
- stroke
- occupational participation
- occupational therapy

This rapid systematic review of the literature examines the literature on effective occupational therapy virtual reality (VR) interventions in rehabilitation of individuals poststroke. This review provides a comprehensive overview and analysis of 25 studies that addressed common themes, including: upper extremity (UE) mobility, functional outcomes, Quality of Life (QoL), and functional performance, related to increasing occupational participation through VR. Findings reveal moderate strength of evidence for the use of VR interventions, in addition to conventional occupational therapy (OT), in supporting individuals' occupational performance and relative, functional factors contributing to participation in occupations, among individuals following a stroke. This review supports the use of VR interventions for individuals poststroke due to their innovativeness, adaptability, and ability to simulate real-life activities of daily living (ADLs), and supports the use of occupation-based VR interventions which can inform and guide intervention approaches for OT practitioners working in stroke rehabilitation.

Focused Clinical Question

The purpose of this rapid systematic review is to review the literature and critically appraise findings relevant to the following question: what is the effectiveness of VR interventions on improving occupational participation in adults following a stroke?

Statement of Problem and Background

Almost 800,000 people experience a new or recurrent stroke each year (Benjamin, 2017). Stroke is one of the leading

causes of serious long-term disability and limits individuals' ability to successfully return to life through occupational participation (Ashley et al., 2019). The third edition of the Model of Human Occupation by Gary Kielhofner defines occupational participation as "engagement in work, play, or ADLs that are desired and or necessary to one's well being" (Kielhofner, 2002). OT practitioners play a vital role in assisting individuals in regaining the functional, cognitive, and psychosocial factors necessary to resume participation in their desired occupations – thus, promotion of occupational participation is a core value and goal among OT practitioners when assisting individuals in their recovery following a stroke. OT care is traditionally provided through CT, which may consist of strength training, participation in limited, simulated ADLs, functional mobility training, and education. However, not all occupations are immediately accessible while in an inpatient hospital environment though, leaving a gap between the hospital and the real world execution in the area of successful occupational participation. There are certain tasks though that cannot be properly simulated in a hospital setting such as grocery shopping, driving, or sports. This is where the evolution of technology through VR systems can potentially bridge this gap in rehabilitative experiences while in the hospital, and promote overall occupational participation among individuals following a stroke.

Technology is rapidly changing society as a whole, this is no exception to the rehabilitation world. The use of VR is becoming more common as a form of entertainment, but does it have the potential to be more than that? Developers are making VR games that are as functional as they are fun. Games that showcase instrumental ADL activities like cooking, driving, and working are simulating real life experiences through the use of a simple headset (or remote). Therapists are newly integrating this technology into the rehabilitative setting, and with that comes the research and evidence to confirm if VR is actually improving occupational participation outcomes. This prompted the research question behind the systematic review: does VR influence occupational participation in stroke patients?

Method for Conducting the Evidence-Based Review

This rapid systematic review examined studies which evaluated the effectiveness of VR interventions on improving occupational performance and related factors. This search was conducted by the review authors, with oversight and guidance from the Indiana University OT Department and associated professors. The authors utilized MeSH terms for each search, and an electronic literature search was conducted on PubMed and EBSCOhost databases. The search terms included: *CVA, stroke, transient ischemic attack, VR, video game, augmented reality, gaming, digital, occupational participation, occupational performance, participation, independence.*

The review included the following inclusion criteria: individuals who have experienced a stroke, peer-reviewed articles with data from 2013 to present, studies including VR, global studies, and studies with occupation, occupational participation as outcomes. Articles were selected based upon relevance to topics that corresponded with virtual-reality interventions in stroke care. The following articles were excluded: meta-analyses, systematic reviews, and studies published earlier than 2013, articles not in English, articles including stroke interventions not related to VR, articles focusing on individuals with brain injuries, and studies not meeting the required outcome criteria.

Covidence was used to screen articles according to the designated inclusion and exclusion criteria. A total of 2,433 studies were imported from the two aforementioned databases for title and abstract screening. 59 duplicates were removed, leaving 2,374 studies for title and abstract screening. The team of five OT students participated in the review and screening process, and two students were required to agree on the screening decision for each article in order to move the article to the next review stage. Following the title and abstract screening, 152 articles were included for full text screening. A total of 25 articles were included in the full text review as they met all inclusion criteria. The PRISMA flow diagram, generated from Covidence, is pictured in Figure 1 below. This rapid systematic review utilized guidelines for the level of evidence which were defined as the following, and each included article's level of evidence is included in the table in Table 1 below.

- *"Level I:* Meta-analysis, systematic reviews, randomized controlled trials
- *Level II:* Two groups, nonrandomized studies (e.g. cohort, case-control)
- *Level III:* One group, nonrandomized (e.g. before and after, pretest and posttest)
- *Level IV:* Descriptive studies that include analysis of outcomes (single-subject design, case series)
- *Level V:* Case reports and expert opinions that include narrative literature reviews and consensus statements" (Sackett et al., 1996)

The authors utilized AOTA's Strength of Evidence Guidelines (2020) to determine the strength of the included studies. AOTA (2020) described the following strength of evidence:

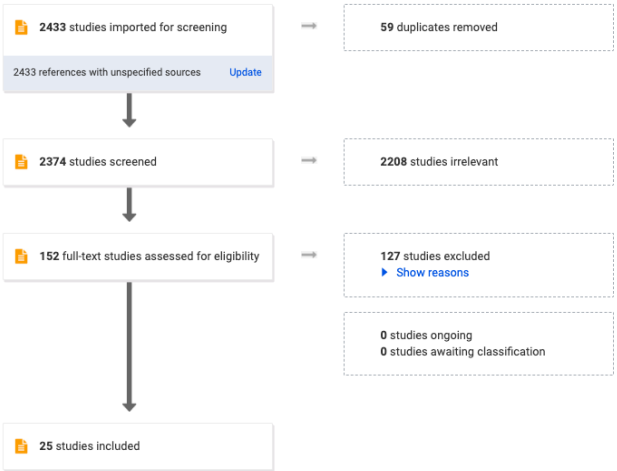
- "Strong: two or more level 1 studies
- Moderate: at least one level 1 high-quality study or multiple moderate-quality studies
- Low: small number of low-level studies, flaws present in the studies; limited number or size of studies, important flaws in study designs or

methods, lack of information on important health outcomes" (AOTA, 2020)

The 25 included articles included studies conducted in the following countries: Korea, Lithuania, China, Saudi Arabia, Brazil, Pakistan, United States, Portugal, and Germany. The articles were published between 2014-2022 and included VR interventions and individuals who had experienced a stroke. Within the 25 included articles, prominents themes relevant to the effect of VR interventions on occupational performance among individuals who have experienced a stroke were identified, which included:

- *Theme 1: Upper Extremity Mobility*
- *Theme 2: Functional Outcomes*
- *Theme 3: Quality of Life*
- *Theme 4: Functional Performance*

Figure 1



Results

This review includes a total of 25 studies. These findings have been clustered into four areas that showcase how occupational performance is impacted by virtual-reality based interventions in patients with stroke. The categories include UE mobility, functional outcomes, QoL, and functional performance. Supplemental Table 1 summarizes the studies included in this review.

Upper Extremity Mobility

Eight Level I randomized control studies, one Level 3 controlled pilot study, and one Level 4 case control study found that when compared with conventional OT treatment, the implementation of OT within a virtual environment resulted in increased UE function. Functional activities were performed with VR interventions through ADL-simulated tasks consisting of reaching for objects, writing, community mobility tasks, and instrumental ADLs. UE research in VR aimed to incorporate functional interactions within a virtual world through the use of specific VR devices such as the Armeo Spring robot, cell phone augmented reality system (CARS), Kinect sensor-based Saebeo orthosis glove, HandTutor glove, Rehametrics, and VR systems like Xbox Kinect to simulate ADL and IADL activities that involve UE mobility. There is strong evidence that VR interventions in addition to conventional OT have greater effectiveness on improving UE mobility then when compared to conventional OT alone.

Two level I studies used the Armeo Spring robot. One compared Armeo against conventional OT and the other compared the Armeo against the Kinect VR (Adomavičienė, 2019) and (El-Kafy, 2021). In both studies, the Armeo performed better than their counterparts and produced better results in the Wolf Motor Function Test (WMFT) and Action Research Arm Test (ARAT). One level 1 study compared Wii Sports Tennis, Wii Sports Bowling, and Cooking Mama against conventional OT. The group that participated in the Wii interventions scored better in on the Chedoke-McMaster Stroke Assessment for arm and hand and the Box and Blocks Test (Gonçalves 2018).

Five level I Randomized Controlled Trials (RCT) (Ain, 2021), (Li, 2019), (Mekbib, 2021), (Oh, 2019) and (Park, 2019) examined the effectiveness of VR using Xbox Kinect, Smart Board, CARS, and Motor Neuron VR (MNVR) systems to improve UE motor functioning in the shoulder, wrist, hand, coordination, and total functioning in the motor recovery of post stroke individuals. All five studies showed significant improvement in the total and proximal components of the FMA-UE assessment, showing greater participation in functional activities within the VR environment.

One level I RCT study (Rodriguez, 2021) shows significant decrease in pain and muscle tone in the intervention group via Modified Ashworth Scale (MAS) scores and clinical observations of muscle tone in UE. There was an observable and statistically significant difference regarding the physical and functional dimension of ADLs and IADLs in the Stroke Impact Scale 3.0 in the intervention group. The intervention group utilized specific VR devices including a HandTutor glove, 3DTutor, and Rehametrics that are based on intensive and repetitive practice through movement and feedback from a virtual environment that simulates ADLs and community mobility.

One level IV case-control study (Adams, 2019) shows strong evidence that performance measures produced by a software using motion in a virtual environment can be a valid indicator of UE motor status. There is a high correlation between software measures of the Saebo Glove orthotic that was equipped with an enhanced version of the Kinect sensor and clinical assessments of hand function such as the WMFT, FMA-UE, and Box and Blocks Test.

Functional Outcomes

Four Level 1 and one Level 3 studies reviewed VR as an intervention technique for stroke patients. The functional outcomes assessed throughout these articles include reaching, cognitive skills, mood, and functional use of extremities that support a participant's occupational participation. Two studies that focused on functional outcomes, one from the use of Wii Sports during their VR intervention, and the other using Elements VR system that focuses on upper limb and cognition training. One of these studies was an RCT and the other a pre-post cohort study, both of which compared VR based OT combined with conventional therapy (CT) to CT alone. Both these studies supported greater results within the regaining and maintenance of functional skills compared to CT alone. (Rogers et. al., 2019) and (Zanona et. al., 2019).

Two studies assessing a VR intervention through the Microsoft Kinect System found that VR interventions combined with CT had similar effects in functional outcomes compared to patients who had CT alone. Both studies had similar intervention plans, which included functional and cognition based VR. While these studies found significant increases in outcome measures in the intervention group compared to their own baseline, there was no significant difference between the intervention and control group for either study (Ho et. al., 2019) and (Lin et. al., 2020). The last article is a RCT that assesses the effect of VR based UE training on brain function compared to CT. The results from this study implies that both CT and VR therapy had comparable data that increased brain function (Lee et. al., 2015).

Quality of Life

Evidence of four studies was strong and linked improvement in QoL with the combination of participation in CT and VR. In the level 1 articles, there were significant improvements in role limitations, HAMD and EQ-VAS scores with also a decrease in pain levels in both groups however there was more of a significance in the VR + OT group.

Within the three level 1 articles, the effects of CT (the control group) vs VR + CT (experimental group) were examined. One RCT showed that there were significant improvements in role limitations within just the CT+VR group, however the depression and FMA scores improved significantly within both groups. In comparison to just the CT group at the end of the session, the scores were significantly higher within the CT+VR group (Shin et. al., 2015). One RCT found that there was a significant decrease in pain and depression levels while also a significant increase in scores of assessments that measure QOL within both groups but they were more significant within the CT+VR group (Rodríguez-Hernández et al., 2021). One RCT assessed VR through the use of the Nintendo Wii and CT through the use of the NDT approach (Şimşek et al., 2016). The study found that the use of VR and NDT was on par to the NDT approach alone when assessing one's improvement on their QOL (Şimşek et al., 2016). Within the Level 3 article, the VR intervention was assessed through the use of the RehabMaster where the patients were able to choose from four different types of games. They found that improved scores of the FMA leads to increased quality of participation with their meaningful occupations which thus leads to an overall improved QOL (Shin et al., 2014).

These improvements all lead to increased involvement when participating within their meaningful occupations, thus leading to increased quality of their participation. All of these aspects are of high importance when determining one's QOL based on each individual.

Functional Performance

Five functional performance studies, including two level II cohort studies and three level I RCT studies were analyzed. There is moderate evidence for the effectiveness of virtual-reality interventions improving factors necessary for overall functional performance for individuals following a stroke. Therapeutic interventions included utilization of a VR exercise program (VReP), a VR-based game system, the Rehago virtual rehabilitation software training, a VR-based simulation of ADLs, and a RAPAEL smart glove.

One level I RCT (Yi Long et al., 2020) evaluated the implementation of a VR-based game system called "Doctor Kinetic" where the 34 participants in the intervention group completed rehabilitation games on a touch-controlled computer screen, with real-time feedback of a human-shaped model on the screen. The intervention focused on improving self-efficacy and ADL performance. During the training sessions, individuals focused on performing the ADL tasks and game actions efficiently with the feedback from the VR system. Results indicated a positive improvement in occupational performance for both the VR and control group, but there was no significant difference between the two groups. Although the improvement was not clinically significant, a positive increase on occupational performance scores were found, supporting the use of VR on improvement of performance in everyday, functional activities, which relates to the overall theme of functional performance.

One level II cohort study (Lee, 2015) evaluated the effectiveness of a VReP on 10 participants' total cognitive functioning, ADL performance, and UE motor function. The intervention consisted of a VReP using the Interactive Rehabilitation and Exercise System (IREX), where participants played a variety of games focusing on gross motor movements and coordination, and participation in simulated leisure activities including drumming, soccer, and juggling. The results indicated improved total cognitive

functioning, improved overall ADL performance, and UE motor function among the individuals who received the VReP. These functional skills, including UE motor performance and cognitive functioning, support participation in ADL and functional performance among individuals in their daily lives following a stroke.

One level II cohort study (Chen, et al., 2022) examined the effectiveness of the Rehago software on 48 post-stroke individuals' functional performance. In the intervention, participants utilized the Rehago software in a simulated mirror therapy mode, with training targeting different body parts for the purpose of upper limb rehabilitation. The mirror therapy mode further supported the participation and rehabilitation of stroke patients as they could use their unaffected side to mirror actions to their affected side. The results found an observable improvement in the participants' functional performance. These results support the utilization of VR in improving overall functional performance for individuals following a stroke.

One Level I RCT study (Faira et al., 2016) examined the effectiveness of a VR-based simulation of ADLs called "The Reh@ City" on improving 9 individual's cognitive functioning. Cognitive functioning is a necessary component supporting overall functional performance as cognition is necessary to participate in and execute daily functional tasks independently. The intervention allowed participants to practice completing simulated ADL tasks in 3-D environments including a post office, bank, supermarket, and a pharmacy. Results indicated an improvement in individuals global cognitive functioning, as well as other cognitive aspects including attention, memory, and visuospatial abilities.

One Level I RCT study (Shin et a., 2016) examined the impact of a RAPAEL Smart Glove intervention on improving 24 individuals' distal UE function and ADL/IADL performance. UE function supports an individual's functional performance as the UE is frequently used to perform daily tasks and especially targeted in OT interventions to support functional performance. The participants utilized the Smart Glove to complete simulated ADL tasks including cooking, cleaning, turning pages, and squeezing oranges. Results indicated an improvement in distal UE function and improvements in the ADL/IADL performance levels for individuals, supporting the utilization of the Smart Glove to improve distal UE function and ADL/IADL performance, to further support functional performance for individuals following a stroke.

Limitations

Limitations in several of the studies incorporated into the review included lack of long-term follow up, baseline differences, small sample size, lack of control groups, and lack of blinding of researchers to the treatment groups. In addition, few studies did not incorporate the use of control groups and failed to describe their specific conditions.The definition or description of VR varied from study to study. Generalization of results of all of the studies was limited due to the studies taking place within a variety of countries.

Conclusions

Results from the articles display significant evidence supporting VR interventions to be just as effective, if not more effective, than CT alone when addressing occupational participation. When assessing UE mobility, VR combined with conventional OT groups had more substantial results compared to the control group that was only receiving OT. The articles assessing functional outcomes, such as cognitive functions and performance skills, concluded that VR interventions had comparable results to CT alone. While both groups had a significant change in functional outcome skills, there was no significant difference between the control and experimental group's progression. Research assessing the effectiveness of VR interventions on QoL found a significant increase in mood and a decrease in depression and anxiety. Overall results found the QoL was increased for stroke patients who participated in VR intervention combined with CT. Moderate evidence supports the use of VR interventions to support functional performance through ADL, performance function, and cognitive training. Results from these five articles supported the use of VR interventions to enhance occupational performance, but did not find the results significantly different from the control groups receiving only CT.

The literature and methods analyzed within this review all require further research before practitioners can draw definite conclusions from the effect of VR interventions for stroke patients. This research needs to be done as a Level I RCT, and there needs to be a large population size for the data to be considered substantial. There also needs to be a more definite explanation of occupational participation within the literature, as well as more consistent outcome measures used to determine occupational participation. Longevity of the effects of this intervention needs to be assessed through follow ups to determine the maintenance of results.

Occupational therapists, students, and researchers can use the implications from this review to guide their future practices. VR appears to be a promising intervention for stroke patients to increase in areas of occupational participation and function as the current research shows that it is comparable to CT. However, more research needs to be done before clinicians can draw a definite conclusion.

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References

Adams RJ, Ellington AL, Armstead K, Sheffield K, Patrie JT, & Diamond PT. (2019). Upper extremity function assessment using a glove orthosis and virtual reality system. OTJR: *Occupational Therapy Journal of Research*. 2019;39. (2):81-89. doi:10.1177/1539449219829862

Adomavičienė, A., Daunoravičienė, K., Kubilius, R., Varžaitytė, L., & Raistenskis, J. (2019). Influence of new technologies on post-stroke rehabilitation: A comparison of Armeo Spring to the Kinect System. Medicina, 55(4), 98. MDPI AG. Retrieved from http://dx.doi.org/10.3390/medicina55040098

Ain, Q. U., Khan, S., Ilyas, S., Yaseen, A., Tariq, I., Liu, T., & Wang, J. (2021). Additional effects of xbox kinect training on upper limb function in chronic stroke patients: A Randomized Control Trial. *Healthcare*, *9*(3), 242. https://doi.org/10.3390/healthcare9030242

American Occupational Therapy Association. (2020). Guidelines for systematic reviews. https://research.aota.org/DocumentLibrary/AOTA%20SR%20instructions%20Dec2020.pdf?_ga=2.203876496.1420473151.1682096433-1767567560.1680832914

Ashley, K. D., Lee, L. T., & Heaton, K. (2019). Return to work among stroke survivors. workplace health & safety, 67(2), 87–94. https://doi.org/10.1177/2165079918812483

Benjamin, E. J., Blaha, M. J., Chiuve, S. E., Cushman, M., Das, S. R., Deo, R., de Ferranti, S. D., Floyd, J., Fornage, M., Gillespie, C., Isasi, C. R., Jiménez, M. C., Jordan, L. C., Judd, S. E., Lackland, D., Lichtman, J. H., Lisabeth, L., Liu, S., Longenecker, C. T., Mackey, R. H., … American Heart Association Statistics Committee and Stroke Statistics Subcommittee (2017). Heart Disease and Stroke Statistics-2017 Update: A Report From the American Heart Association. Circulation, 135(10), e146–e603. https://doi.org/10.1161/CIR.0000000000000485

Chen, C., Kreidler, T., Ochsenfahrt, A. (2022). Rehago- A home-based training app using VR to improve functional performance of stroke patients with mirror therapy and gamification concept: A pilot study. *Healthcare of the future*, 292, 91-95. https://doi.org/10.3233/SHTI220330

El-Kafy, E. M. A., Alshehri, M. A., El-Fiky, A. A.-R., & Guermazi, M. A. (2021). The effect of virtual reality-based therapy on improving upper limb functions in individuals with stroke: A randomized controlled trial [Original Research]. Frontiers in Aging Neuroscience, 13. https://doi.org/10.3389/fnagi.2021.731343

Faria, A., Andrade A., Soares, L., Badia S. B. (2016). Benefits of virtual reality based cognitive rehabilitation through simulated activities of daily living: A randomized controlled trial with stroke patients. *Journal of Neuro-Engineering and Rehabilitation*, 13(96). https://doi.org/10.1186/s12984-016-0204-z

Gonçalves, M. G., Piva, M. F. L., Marques, C. L. S., Costa, R. D. M. da ., Bazan, R., Luvizutto, G. J., & Betting, L. E. G. G.. (2018). Effects of virtual reality therapy on upper limb function after stroke and the role of neuroimaging as a predictor of a better response. Arquivos De Neuro-psiquiatria, 76(Arq. Neuro-Psiquiatr., 2018 76(10)), 654–662. https://doi.org/10.1590/0004-282X20180104

Ho TH, Yang FC, Lin RC, Chien WC, Chung CH, Chiang SL, Chou CH, Tsai CK, Tsai CL, Lin YK, Lee JT. (2019) Impact of virtual reality-based rehabilitation on functional outcomes in patients with acute stroke: a retrospective case-matched study. *Journal of Neurology.* doi: 10.1007/s00415-018-09171-2. Epub 2019 Jan 4. PMID: 30610428.

Kielhofner, G. (2002). Model of Human Occupation: Theory and application. Third Edition. Philadelphia, PA: Lippincott, Williams and Wilkins.

Lee K. (2015). Effects of a VR-based exercise program on functional recovery in stroke patients. Part 1. *Journal of physical therapy science. 27*(6). 1637-1640. https://doi.org/10.1589/jpts.27.1637

Lee SH, Kim YM, Lee BH. (2015) Effects of virtual reality-based bilateral upper-extremity training on brain activity in post-stroke patients. *Journal of Physical*

Therapy Science. doi: 10.1589/jpts.27.2285. Epub 2015 Jul 22. PMID: 26310884; PMCID: PMC4540864.

Li C, Song X, Chen S, Wang C, He J, Zhang Y, Xu S, Yan Z, Jia J, Shull P. Long-term effectiveness and adoption of a cellphone augmented reality system on patients with stroke: randomized controlled trial JMIR serious games 2021;9(4):e30184. https://doi.org/10.2196/30184

Lin RC, Chiang SL, Heitkemper MM, Weng SM, Lin CF, Yang FC, Lin CH. (2020) Effectiveness of early rehabilitation combined with virtual reality training on muscle strength, mood state, and functional status in patients with acute stroke: A randomized controlled trial. *Worldviews on Evidence Based Nursing*. doi: 10.1111/wvn.12429. Epub 2020 Mar 25. PMID: 32212254.

Mekbib, D. B., Debeli, D. K., Zhang, L., Fang, S., Shao, Y., Yang, W., Han, J., Jiang, H., Zhu, J., Zhao, Z., Cheng, R., Ye, X., Zhang, J., & Xu, D. (2021). A novel fully immersive virtual reality environment for upper extremity rehabilitation in patients with stroke. *Annals of the New York Academy of Sciences*, 1493(1), 75-89. https://doi.org/https://doi.org/10.1111/nyas.14554

Oh, Y. B., Kim, G. W., Han, K. S., Won, Y. H., Park, S. H., Seo, J. H., & Ko, M. H. (2019). Efficacy of virtual reality combined with real instrument training for patients with stroke: a randomized controlled trial. *Archives of physical medicine and rehabilitation*, 100(8), 1400–1408. https://doi.org/10.1016/j.apmr.2019.03.013

Park, M., Ko, MH., Oh, SW. *et al.* (2019). Effects of VR-based planar motion exercises on upper extremity function, range of motion, and health-related quality of life: a multicenter, single-blinded, randomized, controlled pilot study. *Journal of NeuroEngineering Rehabilitation* 16, 122. https://doi.org/10.1186/s12984-019-0595-8

Rodríguez-Hernández, M., Criado-Álvarez, J. J., Corregidor-Sánchez, A. I., Martín-Conty, J. L., Mohedano-Moriano, A., & Polonio-López, B. (2021). Effects of virtual reality-based therapy on quality of life of patients with subacute stroke: A three-month follow-up randomized controlled trial. *International journal of environmental research and public health*, *18*(6), 2810.https://doi.org/10.3390/ijerph18062810

Rodríguez-Hernández, M., Polonio-López, B., Corregidor-Sánchez, A.-I., Martín-Conty, J. L., Mohedano-Moriano, A., & Criado-Álvarez, J.-J. (2021). Effects of specific virtual reality-based therapy for the rehabilitation of the upper limb motor function post-ictus: Randomized controlled trial. Brain Sciences, 11(5), 555. MDPI AG. Retrieved from http://dx.doi.org/10.3390/brainsci11050555

Rogers JM, Duckworth J, Middleton S, Steenbergen B, Wilson PH. (2019) Elements virtual rehabilitation improves motor, cognitive, and functional outcomes in adult stroke: evidence from a randomized controlled pilot study. *Journal of Neuro-Engineering and Rehabilitation*. doi: 10.1186/s12984-019-0531-y.

Rowland, T. J., Cooke, D. M., & Gustafsson, L. A. (2008). Role of occupational therapy after stroke. *Annals of Indian Academy of Neurology,* 11(Suppl 1), S99–S107.

Sackett, D. L., Rosenberg, W. M., Gray, J. A., Haynes, R. B., & Richardson, W. S. (1996). Evidence based medicine: what it is and what it isn't. BMJ (Clinical research ed.), 312(7023), 71–72. https://doi.org/10.1136/bmj.312.7023.71

Şimşek, T. T., & Çekok, K. (2016). The effects of Nintendo Wii TM-based balance and upper extremity training on activities of daily living and quality of life in patients with sub-acute stroke: a randomized controlled study. *International Journal of Neuroscience*, *126*(12), 1061-1070. https://doi.org/10.3109/00207454.2015.1115993

Shin, J. H., Park, S. B., & Jang, S. H. (2015). Effects of game-based virtual reality on health-related quality of life in chronic stroke patients: a randomized, controlled study. *Computers in biology and medicine*, *63*, 92-98. https://doi.org/10.1016/j.compbiomed.2015.03.011

Shin, J., Kim, M., Lee, J., Kim, S., Lee, S., Seo B., Choi, Y. (2016). Effects of virtual reality-based rehabilitation on distal upper extremity function and health-related quality of life: A single-blinded, randomized controlled trial. *Journal of Neuro-Engineering and Rehabilitation*, 13(17). https://doi.org/10.1186/s12984-016-0125-x

Yi Long, R., Zhang, J. (2020). Effects of virtual reality training on occupational performance and self-efficacy of patients with stroke: A randomized controlled trial. *Journal of Neuro-Engineering and Rehabilitation*, 17(150). https://doi.org/10.1186/s12984-020-00783-2

Zanona, De Souza, Aidar, De Matos, Santos, Paixão,

Sampaio, Almeida Junior, Monte-Silva. (2019) Use of virtual rehabilitation to improve the symmetry of body temperature, balance, and functionality of patients with stroke sequelae. *Annal of Neuroscience.* 166-173. doi: 10.1159/000488581.

Table 1: Evidence Table				
Theme 1: Upper Extremity Mobility				
Author/Year	**Level of Evidence/ Study Design/ Participants/ Inclusion Criteria**	**Intervention and Control Group**	**Outcome measures**	**Results**
Gonçalves, M. G., et al. (2018). https://doi.org/10.1590/0004-282X20180104	Level of Evidence: Level I N = 18 Age Range: Older than 18 Inclusion Criteria: -Over 18 years -First ischemic stroke within 3-6 months of study -Level of motor function upper limb equal or superior to Chedoke-McMaster Stroke Assessment -Diagnosis confirmed by neuroimaging	**VR Intervention:** All patients received 30 minutes of physiotherapy and 30 minutes of OT. The intervention group received VR training in addition to the standard OT and physiotherapy. Games like Wii sports, and cooking mama were used to simulate activities like meal prep. Sessions for the intervention group were a total of 60 minutes long and were held twice a week. Control Group: Participants in the control group received 30 minutes of physiotherapy only.	**Outcome Measures:** -Chedoke McMaster Stroke Assessment -Box and Blocks Test -Barthel Index -NIHSS -mRS -Scandinavian Stroke Scale -Stroke Impact Scale All outcome measures were administered before and after intervention took place.	**Results:** VRT combined with conventional rehabilitation showed positive results in improving upper limb function. Improvement was seen as demonstrated by the Barthel Index, Scandinavian Stroke Scale, mRS, and NIHSS. The Stroke Impact Scale also showed statistical significance in improving quality of life in stroke patients.

El-Kafy, E. M. A., et al., (2021) https://doi.org/10.3389/fnagi.2021.731343	**Level of Evidence:** I **Study Design:** Two-armed, double-blind, RCT **N =** 40 **Age Range**: 50- 60 years **Inclusion Criteria:** -50-60 years -Confirmed chronic stroke diagnosis -6 months from last stroke -Spasticity of 1, 1+, or 2 according to Modified Ashworth Scale -Cognitive abilities to understand directions	**VR Intervention:** Physiotherapists delivered a three-part treatment program to those in the intervention group. The first phase included muscle facilitation exercises and PNF. The second part included grasping and reaching tasks with the affected upper limb. The third part included the Armeo Spring VR program that simulated a range of upper limb tasks. This took place during 2 hour sessions 3 times a week for 3 months. Control: The control group participated in the first two phases listed above. They also did this for 2 hour sessions 3 times a week for 3 months.	**Outcome Measures:** -Action Research Arm Test (ARAT) -Wolf Motor Function Test (WMFT) -Hand grip measurements with dynamometer All outcome measures were administered and recorded before and after intervention.	**Results:** The VR group showed improvement in upper limb functionality. This could partly be attributed to the enjoyment and volition that comes with motor activities that are more enjoyable and are meaningful tasks. There were significant differences in the mean scores for ARAT and WMFT between pre- and post- treatment for both groups. There was no significant difference between the two groups at baseline, however, after intervention significant differences favored the experimental group with a confidence interval of 0.01.
Mekbib, D. B., et al., (2021) https://doi.org/https://doi.org/10.1111/nyas.14554	**Level of Evidence: I** **Study Design:** Single-Blinded, RCT N = 23	**VR Intervention:** The intervention group (VR group) underwent both the VR intervention plus OT.	**Outcome Measures:** -Fugl- Meyer Upper Extremity -Barthel Index -Mini-Mental State	**Results:** Results concluded that patients have reduced UE impairment and increased independence

	Age: Older than 18 **Inclusion Criteria:** -Moderate to severe UE impairments due to first episode of ischemic or hemorrhagic stroke -Stroke duration not exceeding 3 months after stroke -Adults (older than 18 years) -Normal hearing and vision -No severe cognitive impairments based on MMSE	The VR tasks included reaching, grasping, and releasing tasks. The program used was mirroring neuron VR Rehab, a program that uses VR to help patients execute real world tasks with their affected limb. This treatment was delivered by an Occupational Therapist. The timing of this intervention consisted of 1 hour of VR and 1 hour of OT for 4 days per week over 2 weeks.	Examination Outcome measures were administered before and after intervention took place.	in ADL after VR intervention is paired with OT. The authors have concluded that VR training using the MNVR-Rehab promotes better proximal and distal movements and may have a positive impact on the recovery of UE function and ADLs as proven by FM-UE and BI assessments.
Li C, et al., (2021) DOI: 10.2196/30184	**Level of Evidence: I** **Study Design:** Double-Blind, RCT **N = 30** **Age Range:** Between 20 and 70 years **Inclusion Criteria:** >20 or <70 -First incidence of a stroke with unilateral	**VR Intervention:** The intervention used a cell phone augmented reality system (CARS) to test the effectiveness of VR intervention in addition to conventional OT. Participants in the intervention were administered 30 minutes of conventional OT and 30 minutes of CARS. CARS used	**Outcome Measures:** -Fugl-Meyer Assessment of Upper Extremity -Action Research Arm Test -Mini-Mental State Exam All outcome measures were administered	**Results:** Compared with conventional OT, CARS and conventional OT rehabilitation proved to be more effective in improving both upper limb function and cognitive function. CARS enhanced upper extremity recovery in patients with stroke. This intervention showed greater

	hemiparesis -Chronicity >7 days but <180 years -MMSE score greater than or equal to 20 -Brunnstrom stage of upper limb greater than or equal to 3 -Visual and mental ability to participate in protocol	task-oriented games that involved reaching, cognitive, and motor tasks. This intervention was administered 5 days a week for a total of 2 weeks. **Control:** The control group engaged in 1 hour of conventional occupational therapy for 5 days a week for a total of 2 weeks.	before and after intervention	improvement in the FMA-UE and ARAT scores. There were also comparable improvements on the Barthel Index.
Adomavičienė, A., et al., (2021) http://dx.doi.org/10.3390/medicina55040098	**Level of Evidence:** Level I **Study Design:** Double-blind, randomized control trial **N =** 42 **Age Range:** 60-74 years **Inclusion Criteria:** -Ischemic or hemorrhagic stroke confirmed by neuroimaging -60-74 years of age	**VR Intervention:** **Armeo robot group-** This group did CT for 3 hour sessions 5 days a week. In addition to this they did training with the Armeo robot for 45-minutes a day for 10 sessions. The Armeo robot training consisted of sequenced motor tasks followed by short rests. **Kinect Group**- The Kinect group participants were also in CT for the same time as	**Outcome Measures:** -FMA-UE -Modified Ashworth Scale -Box and Blocks Test -MMSE -Addenbrooke's Cognitive Examination-Revised -Hospital Anxiety and Depression scale All outcome measures were conducted before and after intervention.	**Results:** Short-term, two-week training programs with new technology has a positive effect and showed significant improvements in functional self-care, UL motor ability, memory, visuo-spatial abilities, and decreased anxiety levels. The Kinect system showed more statistically significant figures in improving UL functionality than the Armeo robot. However, the Armeo

	(according to WHO's definition of elderly people) -Stroke-affected arm paresis -Disturbed deep and superficial sensation -MMSE score >21 points	the Armeo group. Instead of Armeo robot training though, they used Kinect VR for 45 minutes a day for 10 sessions. The Kinect sessions also consisted of sequenced motor tasks followed by short rests.		robot-assisted technology decreased anxiety in stroke patients. Overall, the Kinect data favor the hypothesis and show increased UL functionality in stroke-affected patients.
Rodriguez-Hernandez, M., et al., (2021) http://dx.doi.org/10.3390/brainsci11050555	● **Level of Evidence:** 1 ● **N** = 46 ● **M Age:** 51.5 years old ● **Intervention:** 23 ● **Control:** 20 ● **Inclusion Criteria:** Age (18-85 years old), maximum evolution time of 6 months, upper limb motor involvement Fugl-Meyer Assessment and Modified Ashworth Scale, dependence in ADLs Stroke impact scale 3.0, life expectancy greater than 6 months (absence	**VR Intervention:** The protocol for the experimental group receiving conventional treatment and VR exposure therapy involved specific VR devices including HandTutor glove, 3DTutor, and Rehametrics. These systems are based on intensive and repetitive practice through movement instructions and feedback with virtual environments and tasks that imitate movements necessary for poststroke individuals to participate in their daily lives. The technology simulated ADLs and community mobility	**Outcome Measures:** ● Fugl-Meyer Assessment for Upper Extremity (FMA-UE) ● Modified Ashworth Scale (MAS) ● Stoke Impact Scale 3.0 (SIS) Each outcome measure was administered before the start of treatment, at 3 weeks post-intervention, and 3 months after its completion.	**Results:** Based on this studies' objectives, the key findings were the significant differences in the decrease of pain between both intervention groups, and especially in the experimental group post intervention. Statistically significant differences were reported in both groups on the overall HRQoL. There was a statistically significant (p-value= 0.001) decrease in muscle tone via MAS scores and was notably higher in participants in the experimental group. There was an observable and statistically significant

	of life threatening diagnoses such as end-stage cancer ● Absence of other serious and disabling pathology	with the use of gamification. Functional skills were targeted and displayed through the virtual environment game and the exergames were personalized according to the functional capacity of the patient.		difference at baseline, post-intervention, and follow-up regarding the physical and functional dimension of ADLs and IADLs in the SIS 3.0. Overall, the effectiveness of VR is evident in the results of this study relating to the study objectives of improving poststroke individuals UE functioning in order to participate in everyday activities and occupations.
Oh YB, et al., (2019) https://doi.org/10.1016/j.apmr.2019.03.013	● **Level of Evidence:** 1 ● **N**= 31 ● **M Age:** 52.5 years old ● **Intervention:** 17 ● **Control:** 14 ● **Inclusion Criteria:** ● Experience a first-episode stroke shown by a brain CT or MRI, evaluated for a period of 6 months post stroke onset, between ages	**VR Intervention:** The experimental group's intervention participated in VR (VR) combined with real instrument training. The VR environment included real instrument training devices such as a thumb pinch, doorknob, button, air tube, gas valve, tool turn, and steering wheel to complete the virtual activity demands fed through the simulated computer technology.	**Outcome Measures:** ● Muscle Manual Testing (MMT) ● Fugl-Meyer Assessment Upper-Extremity Scale (FMA-UE) ● Hand Grip Test ● Modified Ashworth Scale (MAS) ● 9-Hole Peg Test 9-HPT) ● Box and Block Test The outcome measures were administered	**Results:** The study found that both combined real instrument training with VR intervention and conventional occupational therapy improved UE functioning in the chronic phase of stroke. The VR intervention using real instruments was more effective for improvement in fine motor functioning (MMT p= .039, MAS p=.041, BBT p=.002, FMA-UE p<.001)

	20-85 years old, unilateral paralysis or paresis with a greater score than 18 on FMA-UE scale, and cooperation to complete study		before starting the training, after the 6-week treatment sessions, and 4 weeks after the training was completed.	compared to CT because it provided patients to perform more challenging, yet meaningful tasks. This increased their motivation to perform and resulted in being the most beneficial for UE and cognitive function in patients in the chronic phase of stroke.
Park, M., Ko, MH., Oh, SW, et al., (2019) https://doi.org/10.1186/s12984-019-0595-8	● **Level of Evidence:** 3 ● **N**= 26 ● **M Age:** N/A, excluded 19 years and younger ● **Intervention:** 13 ● **Control:** 13 ● **Inclusion Criteria:** ● Diagnosis of hemispheric stroke resulting in unilateral UE deficits at least 3 months previously, first-ever ischemic or hemorrhagic stroke, ability to understand	**VR Intervention:** Focused on proximal UE rehabilitation, including AROM and coordination exercises across multiple joints. The Smart Board has a 2D moving forearm supported controller with 3 linear guides with an H-shape figuration to enable 2D planar motion. The linear guides have zero friction, so the handlebar moves freely. The Smart Board assessment program (intervention component) has 3 different kinematic programs: free exploration,	**Outcome Measures:** ● Fugl- Meyer Assessment-Upper Extremity (FMA-UE) ● Wolf Motor Function Test (WMFT) ● Stroke Impact Scale (SIS) ● Modified Barthel Index (BI) The outcome measures were administered before intervention, immediately after intervention, and 1 month after the intervention.	**Results:** Key findings in the primary outcomes based on this study's objective were the changes in the FMA-UE scores of both the intervention and control groups. Immediately following the intervention and 1 month post intervention, both groups showed statistically significant improvements in the total and proximal component scores on the FMA assessment. Changes in the WMFT functional ability scale and time, MBI, and shoulder AROM of flexion and abduction significantly improved

	instructions (score 25 or greater on Korean version of the Mini-Mental State Examination; a Medical Research Council scale score of 2 or 3 for the strength of the affected UE; and a Modified Ashworth Scale score greater than 2 for spasticity.)	point-to-point reaching, and circle-drawing. Each different task focuses on functional skills such as UE AROM and vasomotor mapping ability, forward reaching to a given target point, and motor coordination.		in both groups. Total shoulder AROM and shoulder AROM of flexion, abduction, and internal rotation showed better improvements in the smart board intervention group, these findings were immediately following intervention and 1 month post intervention. The stroke impact scale recovery and overall scores demonstrated significant differences between pre-intervention and immediately following intervention only in the smart board intervention group. The emotion and communication components of the SIS assessment showed improvement in scores in the smart board intervention group and deterioration in the control group.
Ain, Q.U., et al., (2021) https://doi.org/10.3390/healthcare9030242	**Level of Evidence:** 1 **N**= 56 **M Age:** 55 years old **Intervention:** 28 **Control:** 28	**VR Intervention:** The participant was 1.5-2 meters away from the Kinect sensor and the sensor was	**Outcome Measures:** ● Modified Ashworth Scale (MAS) ● Fugl- Meyer	**Results:** The FMA-UE assessment showed statistically significant difference between

	Inclusion Criteria: Participants' ages ranged from 40-70 years old, scored above a 4 on the Modified Ashworth Scale (MAS), and had their first stroke or are 6 months or more since their last stroke. Participants were required to be able to read and write their name in the local national language, Urdu, and English.	positioned in the appropriate way to ensure maximum motion was captured by the participant. First, the participants were given a demonstration of the games specifically requiring UE movements while lower extremities were only functional for maintaining a standing position and side to side movement. Participants also performed conventional training exercises along with Xbox Kinect training for 20 minutes.	Assessment Scale for Upper Extremity (FMA-UE) ● Box and Block Test ● Montreal Cognitive Assessment (MOCA) The outcomes measured were administered at baseline before the intervention and after 6 weeks of intervention.	baseline and post-intervention measurements for both groups, and the across-group analysis of effect clearly indicates an improvement in the experimental group. The specific components that showed improvement were in volitional movement within synergies, volitional movement mixing synergies, hand, grasp and coordination and speed, favoring the Xbox Kinect training group.
Adams RJ, et al., (2019) doi:10.1177/1539449219829862	● **Level of Evidence:** 4 ● **N=** 14 ● **M Age:** N/A ● **Intervention:** 17 ● **Control:** 0 ● **Inclusion Criteria:** ● History of a stroke with hemiplegia, ongoing stroke-related hand impairment,	**VR Intervention:** The SaeboGlove orthosis was instrumented to enable tracking of finger and thumb movements in each participant. This instrumented glove was equipped with an enhanced version of the Kinect sensor-based SaeboVR software system to enable employment of the hand, elbow, and	**Outcome Measures:** ● Wolf Motor Function Test (WMFT) ● Fugl- Meyer Upper Extremity (FMUE) ● Box and Blocks Test ● Motor Activity Log (VR- produced measures) ● Subtask completion time	**Results:** This study provides strong evidence that performance measures produced by software using motion in a virtual environment can be a valid indicator of UE motor status. The primary outcome measures involving the VR-SCT and the WFMT-time shows a high correlation that is similar to the

	sufficient active finger flexion at the metacarpal phalangeal joint in at least one finger to be detected by visual observation, anti-gravity elbow strength to at least 45 degrees of active flexion, anti-gravity shoulder strength to at least 30 degrees each in active flexion and abduction/adduction, and 15 degrees in active shoulder rotation from an upright seated position.	shoulder in functional interactions with a virtual world. During sessions, patients used their stroke- affected arm to practice virtual IADLs using the orthosis. In the final session, following the completion of the fourth virtual IADL session, a trained study therapist administered a battery of gold-standard tests of UE motor performance.	(VR-SCT) ● Normalized speed (VR-NS) ● Balls and Boxes (VR- BAB) The outcomes were measured during the final study session.	gold-standard measures. There is a high and significant correlation between the software measure and the clinical assessment of hand function, confirming the criterion validity of the primary VR outcome measure. Furthermore, the VR-SCT has a high correlation to both Box and Blocks and FMUE.
Theme 2: Functional Outcomes				
Author/Year	**Level of Evidence/ Study Design/ Participants/ Inclusion Criteria**	**Intervention and Control Group**	**Outcome measures**	**Results**
Lin et al., 2020	**Level of Evidence:**	**Intervention:**	**Outcome Measures:**	**Results:** From baseline to

doi: 10.1111/wvn.12429	Level I: Randomized Control Trial **N**= 152 **Age Range:** 20+ years **Intervention:** n=38 **Control:** n=114 **Inclusion Criteria:** hospitalized with a diagnosis of an acute infarction, admitted within 3 days after onset of stroke, older than 20 years of age, able to communicate with verbal or nonverbal methods and understand Mandarin, had disability that ranged from minimal to moderately severe disability as determined through the Modified Rankin Scale (mRS) as a score of 1-4, and agreed to be randomized.	VR Intervention: The VR intervention was implemented through the use of the Microsoft Kinect Sensor. There were 2 phases to this study. Phase A was a baseline evaluation, which used a coaching style conversation/checklist to assess the participation practice schedule, motivation, and desired ADLs via set outcome measures. This phase also included training sessions, which included training for strength in muscle extremities, cognition, muscle strength for lower extremities, and coordination through four categories. These categories include a reaching, tracking, kicking, and cognitive task. 5 minutes was spent going over each category per training session. Training sessions occurred twice a day, 15 minutes each, for five days in a week.Phase B was the	● Hospital Anxiety and Depression Scale (HADS) ● Manual Muscle Testing (MMT) ● Postural Assessment Scale for Strokes (PASS) ● Barthel Index Outcome measures were performed at baseline and at discharge.	discharge measures, both the EG and the CG groups had significant improvements in the outcome measures. Regarding strength in upper and lower limbs, only the upper extremity strength of the unaffected limb had a significantly greater increase in the intervention group compared to the control group ($ß = 0.34$, $p < .001$). The functional outcome measures for mood state recorded that the intervention group had a greater decrease in depression and anxiety compared to the control group ($ß = -2.31$, $p = .011$; $ß = -1.63$, $p = .047$). The results found no difference in functional status between groups at discharge. Intervention group PASS scores: 21.8 to 26.8; Barthel index: 59.7 to 73.4; Control group: PASS: 23.4 to 26.8; Barthel index: 60.0 to 71.

		intervention phase, in which participants first practiced using the Kinect system at home. Once a week the researcher would assess each participant's grip/pinch, wrist extension, and had a general progression conversation about ADLs and function. These check-ins were important in modifying goals and grading the VR system to meet the patient's needs. A 60-minute re-evaluation was then conducted by the researcher and the OT at the end of the intervention, using listed outcome measures to monitor data. **Control:** Therapy that consisted of standard care after a stroke via early rehabilitation. Techniques administered here include postural training, facilitation techniques, and stretching exercises. All of these therapy		

		sessions took place in the neurological care unit in the medical center in Taiwan. OT, PT, and SLP were all included in the rehabilitative plan of care within each individual. Timing of intervention differed per participant due to schedules and timing referrals from physicians, but it spanned from 3-6 days after admission. It included five, 60-minute sessions per week during the duration of the trial.		
Zanona et al., 2019. doi: 10.1159/000488581	**Level of Evidence:** Level II: observational cohort pre-post study **N** = 10 **Age Range:** 62-79 **Inclusion Criteria:** Participants of this study were volunteers who had experienced a stroke 2-10 years prior.	**Intervention:** A VR intervention, which consisted of the Nintendo Wii Sports resorts was given to each individual. The protocol created chose the sports that favored symmetrical and bilateral movement, as well as weight shifting. This included snowboarding, boxing, bowling, tennis, and	**Outcome Measures:** ● Assessment of Body Symmetry ● Berg Balance Scale ● Functional Independence Measure Outcome measures used at baseline and at discharge.	**Results:** All 10 participants were active through the duration of the trial and completed all assessments. Body temperature, compared from pre-intervention to post-intervention, was found to be reduced in some areas of the body, but not all. The areas of a significant decrease include: the right arm,

		swimming games. Before each intervention, the participant was told which of the games they would be performing, so they had some time to strategize how they wanted to play. Each session was 60 minutes long, and the time was split in half so that the participant had 30 minutes playing 2 sports of the administrator's choice. The participant played the game until the administrator observed required actions for the participant to be successful in the game, for example displaying proper weight shifting and balance techniques. Aids were given to promote these actions, such as mirrors, parallel bars, and balancing boards.		the left and right thigh, and the right hand. Comparative results from the Berg assessment revealed an average increase of 6.5 points among individuals, which is deemed as a significant improvement and correlates with a decreased risk in falls for individuals. The FIM scores were also assessed, and this evaluation resulted in increased functional independence, with an average increase of 14.25 when comparing the later results to the earlier.
Lee et al., 2015. doi: 10.1589/jpts.27.2285	**Level of Evidence:** Level I: Randomized controlled trial **N** = 18	**Intervention:** The intervention group consisted of 10 patients who participated in VR based bilateral upper	**Outcome Measures:** ● QUEEG-8 (Brain activity measurements)	Brain wave scans that measure the amount of brain activation were compared at baseline to the end of the six week

	M Age: 73 **Intervention:** n=10 **Control:** n=10 (2 drop out) **Inclusion Criteria:** Participants of this study were hemi-paralytic, able to follow verbal commands, had a diagnosis of a stroke from a physician, were at least 6 months post-stroke, able to communicate (determined from the Mini Mental state language section), and scored less than 2 on the Modified Ashworth Scale (MAS) for upper extremities.	extremity training (VRBT). This occurred in 30 minute sessions, three times a week, for a total of six weeks. The VR intervention created through a webcam and monitor consisted of visual training animations that required the use of the bilateral upper extremities. Each task was performed for four minutes, with a one minute rest break between tasks. Depending on grip strength, handle controls for the VR system were either held or strapped to the participants hand. After each intervention, a brain scan assessing amounts of brain activity was given to each participant. This was in a separate, undisturbed place to not affect the results of the scans. Additional, conventional physical therapy was also offered to participants in 30 minute sessions five days a week. Unclear on participation in this	Outcome measure administered at baseline, after each intervention, and at discharge of trial.	trial. EEG results found an increase in concentration within different parts of the wave, at one section increasing by 9.8 points and another by 5, both found to be significant through the calculation of p values. There was also a significant increase in Hz from the EEG scans. These numbers were mostly equal, if not more than, the control group scans. The results of this trial found that after 6 weeks of VR upper extremity intervention, increased brain activation in stroke patients

		additional therapy. **Control:** The intervention group consisted of 10 patients who participated in bilateral upper limb training (BT). Of these ten, 2 were excluded from the final results as they had poor participation in the trial. This occurred in 30 minute sessions, three times a week, for a total of six weeks. The article did not get very detailed into the specifics of the control group's therapy. Readers do know that the therapy consisted of tasks that targeted upper extremities. After each intervention, a brain scan assessing amounts of brain activity was given to each participant. This was in a separate, undisturbed place to not affect the results of the scans. Additional, conventional physical therapy was also offered to participants in 30 minute sessions five		

		days a week. Unclear on participation in this additional therapy.		
Ho et al., 2019. doi: 10.1007/s00415-018-09171-2	**Level of Evidence:** Level I: Retrospective Case-Matched Study **N** = 200 **M Age:** 67 **Intervention:** n=100 **Control:** n=100 **Inclusion Criteria:** Patients were able to participate in this study if all of the following applied: diagnosed with acute ischemic stroke within the last seven days, minor-moderate stroke severity defined by the National Institutes of Health Stroke Scale (NIHSS) (score 16 or less), able to maintain posture unaided while sitting EOB or in wheelchair, clear consciousness with ability to understand instructions, limited	**Intervention:** CT consisted of range of motion (ROM) exercises, fine motor activities, strengthening exercises for the limbs, and cognitive rehab. ROM and coordination exercises were administered via an overhead pulley system, a ROM arc, and a horizontal bar that participants had to insert rings into. Fine motor training was done through the use of a peg board, finger taps, and turning coins. Weight pulley exercises and upper body exercises were used to work on strengthening. Weight shifting exercises were implemented to work on balance. Each exercise/task was administered for five minutes. VR intervention was	**Outcome Measures**: ● National Institute of Health Stroke Scale (NIHSS) ● Modified Rankin Scale Outcome measures given at baseline and at discharge.	The intervention group scored statistically significant improvements in their NIHSS and mRS scores ($p < 0.001$). However, compared to the control group, the intervention group had no difference in improvements regarding the NIHSS scores ($p > 0.05$), but there were statistically significant improvements in the mRS scores for the intervention group compared to the control group. The intervention group had a greater percentage of change for stroke severity improvement: 20.18% compared to 4.59% ($p < 0.005$); and a greater increase in functional outcome progress via the mRS: -0.58 compared to -0.23 ($p < 0.001$). However, there was no difference in length of hospital

	effort against gravity in limb's motor performance as defined by NIHSS with subitem score of motor for arms and legs equal or less than 2.	done using the XBox Kinect sensor: which uses an infrared sensor, a TV monitor, and different VR programs. This took place in a 20 meters squared room solely for VR, so there were no outside disturbances. Full body images were captured, allowing for participants to feel an immersive VR effect. One program selected was a reaching task, which targeted ROM and coordination as it required participants to reach for objects at different heights and depths. The second program was a tracing task, which consisted of participants having to point to a moving, virtual airplane. This aimed to increase upper extremity strength and ROM. Another program was kung-fu soccer, which worked on strengthening of lower extremities, balance, and trunk stabilization. During this task,		stay. The intervention group received a significantly higher proportion of better mRS outcome scores (68%) compared to the control group (60%), which is related to functional independence in ADLs ($p<0.05$).

		participants were required to raise their leg at various heights to kick an oncoming soccer ball. The last program selected was cognition training, which included mathematical calculations, number arrangements, vocabulary comprehension, and color arrangement tasks. Each task had an option to be performed either seated or standing. They were performed for a duration of 5 minutes each with a 1 minute break in between. As the duration of the trial continued, level of difficulty increased during interventions to match an individual's progression in the form of complexity, amount of cues, amplitude, speed, and frequency. **Control:** CT consisted of range of motion (ROM) exercises, fine motor activities, strengthening		

		exercises for the limbs, and cognitive rehab. ROM and coordination exercises were administered via an overhead pulley system, a ROM arc, and a horizontal bar that participants had to insert rings into. Fine motor training was done through the use of a peg board, finger taps, and turning coins. Weight pulley exercises and upper body exercises were used to work on strengthening. Weight shifting exercises were implemented to work on balance. Each exercise/task was administered for five minutes.		
Rogers et al., Wilson PH, 2019. doi: 10.1186/s12984-019-0531-y.	**Level of Evidence:** Level I: Randomized Control Trial **N** = 21 **Age Range:** 42-94 **Intervention:** n=10 **Control:** n=11	**Intervention:** The experimental group received three hours of standard therapy from both occupational and physical therapist every day. In addition to that, this group also received 12 VR interventions within four weeks that lasted a total of 30-40	**Outcome Measures** ● Box and Blocks Task ● Montreal Cognitive Assessment ● The Groton Maze Learning Tasks ● Set Shift Task ● The	**Results** Conventional occupational and physiotherapy proved significant results in functional and cognitive progress for stroke survivors. However, three months of CT paired with 12 VR therapy sessions showed

	Inclusion Criteria: Inclusion criteria included needing to be able to communicate in English, being able to sit independently, and those who consented.	minute each session **Control:** The control group only received three hours of standard therapy from both occupational and physical therapists every day.	Neurobehavioral Functioning Inventory Outcome measures used at baseline and at discharge of the trials.	greater improvement regarding functional and cognitive progress in stroke survivors compared to CT alone. Because of these benefits, these participants had a higher success rate maintaining cognitive and motor skills as well as reintegrating into their desired roles and responsibilities.
Theme 3: Quality of Life				
Author/Year	**Level of Evidence/ Study Design/ Participants/ Inclusion Criteria**	**Intervention and Control Group**	**Outcome measures**	**Results**
Shin, J. H., Park, S. B., & Jang, S. H. (2015) https://doi.org/10.1016/j.compbiomed.2015.03.011	**Level of Evidence:** 1 **Study Design:** randomized, single-blind, parallel-group study **N** = 35 **Age Range:** 18+ **Intervention:** 16 **Control:** 16 **Inclusion Criteria:** **-**on the Medical Research Council Scale they scored of greater than or = to 2	**VR Intervention:** The VR rehab using the RehabMaster system consisted of 10 minutes of rehab training and 20 minutes of therapist selected rehab games. The patients participated in training/games while sitting in a chair that activated their arm and trunk movements. The	**Outcome Measures:** **-**Korean version of the Short Form Health Survey (SF-36) -Korean version of Hamilton Depression Rating Scale (HAMD) -Fugl-Meyer Assessment (FMA)	**Results:** Within the VR + OT group, there was a significant improvement in role limitation due to emotional problems (compared to baseline), and in role limitation due to physical problems, compared to just OT. Both groups exhibited significant improvements

	-less than or = to 4 -a Brunnstrom motor recovery stage for the proximal upper extremity of greater than or = to 2 and less than or = to 5	difficulty of the rehab was manipulated for each patient.		in HAMD and FMA scores compared to the baseline scores, however there were no inter-group differences observed.
Rodríguez-Hernández, M, et al. (2021) **https://doi.org/10.3390/ijerph18062810**	**Level of Evidence:** 1 **Study Design:** randomized control trial **N** = 46 **Age Range:** 18-85 **Intervention:** 23 **Control:** 23 **Inclusion Criteria:** -after the stroke, they had to have a maximum evolution time of six months and they had to have some kind of upper limb motor involvement -dependent in their ADLs following the Stroke Impact Scale version 3.0 -have a life expectancy greater than six months, absent of life-threatening diagnoses, and absent of other serious and disabling pathologies	**VR Intervention:** There were several VR systems used for motor training, HandTutor glove for hand rehab and 3DTutor for the upper extremity. To improve the upper limbs, trunk, and lower body, the Rehametrics software was used to stimulate ADLs and mobility while ambulating within the community. These systems were based on intensive, repetitive practice through movement and feedback instructions provided by the software with virtual environments and tasks that simulate movements that are required within the stroke survivors'	**Outcome Measures:** **-**HRQoL with applied EQ-5D-5L instrument -EQ-VAS The outcome measures were completed by both sample groups before starting the treatment (baseline), three weeks after the start (post-intervention), and three months after its completion (follow-up).	**Results:** When observing the evolution of pain between both groups, there were significant changes compared to at baseline. It was decreased considerably in the experimental group after the interventions were performed. The EQ-VAS score increased in both groups; however, it was significantly higher within the experimental group as the mean score at baseline was 29.1 to post-intervention was 86.5. The results show that the use of VR + CT shows significant changes in HQRoL in the subacute phase of the

		daily lives. The HRQoL was used at baseline, post interventional assessments, and the 3-month follow-up were conducted by the same researcher in both groups		stroke survivors. The HQRoL also indicates that the combination of conventional treatment + virtual semi-immersive approach reduces the severity of problems in the dimensions of the EQ-5D-5L and in improving subjective health statuses (EQ-VAS).
Unibaso-Markaida, I., & Iraurgi, I. (2021) https://doi.org/10.1155/2021/6635298	**Level of Evidence:** 3 **Study Design:** Pre-Post Design **N** = 30 **Age Range:** 50-80yo **Intervention:** 15 **Control:** 15 **Inclusion Criteria:** - be of legal age (+18) -been diagnosed as having suffered a moderate stroke using the Oxfordshire Community Stroke Project (OCSP) instrument -score of between 60 to 90 on the Barthel Scale -Mini-Mental (MMSE) with a cut-off of 23 or higher	**VR Intervention:** The intervention group used the Nintendo Wii video game to carry out the VR portion of the session. The participants completed these sessions individually and in pairs for some cases (from session 20).	**Outcome Measures:** -The Timed "Up and Go" Test (TUG) -SF-36 V2 Health Questionnaire The outcome measures were completed at the pre- and post-test.	**Results:** Within the Nintendo Wii group, it was observed that there was a greater improvement in mobility with all participants. The intervention group using the Nintendo Wii achieved a significant reduction in the execution time of the TUG (-11 sec) which was greater than that obtained by the control group which was a change in −6 seconds. According to this, also, using VR in rehabilitation improves

	-having suffered a stroke at least one month ago but not more than one year ago -preservation of the dominant hand in order to conduct the assessment tasks.			patients' balance and gait ability. Similar results were presented in physical function and social function, where the intervention group performed better at physical and social levels compared to the control group. However, the control group had the greatest change in mental health.
Shin, JH., Ryu, H. & Jang, S.H (2014) https://doi.org/10.1186/1743-0003-11-32	**Level of Evidence:** 3 **Study Design:** Participatory Design **N = 22** **Age Range:** 18+ **Intervention:** 6 **Control:** 16 **Inclusion Criteria:** -exhibited mild-to-severe deficits of the paretic upper extremity -scored ≥2 and ≤4 on the Medical Research Council Scale, and ≥2 and ≤5 on the Brunnstrom stage of motor recovery for the proximal part of the upper extremity	**VR Intervention:** An observation study was performed to assess the feasibility of use and adverse effects of the RehabMaster-based training and games in patients with stroke. All the patients used the RehabMaster training for UE. Four different types of games were suggested for the patients: Underwater fire (train forearm movement and hand-eye coordination), Goalkeeper & Bug hunter (train UE control, endurance,	**Outcome Measures:** -Fugl-Meyer Assessment (FMA) -modified Barthel Index (MBI) -Passive range of motion (PROM) Fugl-Meyer and modified Barthel Index assessments were administered at baseline, during the 5th session, during the last session, and two weeks after the intervention. PROM was administered at Baseline, during the 1st session, and during the	**Results** The tests improved the participant's attention, the immersive flow experience, and individualized intervention. Within the first clinical trial, the RehabMaster intervention improved both the FMA (P = .03) and MBI (P = .04) scores across the evaluation times. The second trial showed that the use of adding the RehabMaster intervention enhanced the improvement in the FMA (P = .07) but did

		speed, accuracy, and range of motion), and *Rollercoaster* (increase the control, speed, and accuracy of UE and trunk movements). The patient's movements were recorded during the entire gaming session and was played back to them at the end of the session to provide them feedback. Using the RehabMaster, the patients performed 10 30- minute sessions (one session per day, five days per week for two weeks) for a total of 300 minutes. The Fugl-Meyer and modified Barthel Index assessments were administered all throughout the study	last session.	not improve the MBI.
Şimşek, T. T., & Çekok, K. (2016) https://doi.org/10.3109/00207454.2015.1115993	**Level of Evidence:** 1 **Study Design:** randomized control trial **N** = 44 **Age Range:** Intervention- 54.15 ± 20.29 Control- 54.15 ± 20.29 **Intervention:** 22 (20) **Control:** 22	**VR Intervention:** This group used five games selected from the Wii sports and Wii Fit packages for upper limbs (tennis and punch out) and balance training (tightrope tension, tilt table and heading). Each	**Outcome Measures:** -Functional Independence Measure (FIM) -Nottingham Health Profile (NHP) The outcome measures were completed before	**Results:** The main findings within this study were that Nintendo Wii and Bobath NDT approaches, which are applied in similar durations, have no difference in effects on gaining independence in

	Inclusion Criteria: -first diagnosed with hemiplegia -no conventional physical therapy treatment received in the early period after stroke -medically stable to participate in active rehabilitation - above 18 years old -Mini-Mental State Examination (MMSE) score above 23 -functional level below 4 according to modified Rankin Scale (mRS) and upper extremity spasticity was below 3 according to Modified Ashworth Scale (MAS) -Patients who could stand and walk independently were tried to be selected for participation since the N-Wii games would be played and as they could lead to balance problems and falls.	game was performed as 3 sets of 5-minute intervals between each. Before and after the intervention, the participants were measured for performance of ADLs and health-related quality of life.	and after the intervention to assess the participants.	ADLs and improving QOL.
Theme 4: Functional Performance				
Author/Year	**Level of Evidence/ Study Design/**	**Intervention and Control Group**	**Outcome measures**	**Results**

	Participants/ Inclusion Criteria			
Lee, K. (2015) https://doi.org/10.1589/jpts.27.1637	**Level of Evidence:** Level II Cohort Study N = 10 M Age: 63.3 years old Intervention: N = 10 Control: No control group Inclusion Criteria: ● Stroke diagnosis ● Able to maintain posture for approximately 30 minutes while sitting in a wheelchair ● Able to follow level 1 instructions ● Able to contract the muscles of any part of the upper extremities, such as the shoulder, elbow, and wrist ● Not participating in any similar studies	**Intervention:** Patients participated in the VReP (VR exercise program) called the Interactive Rehabilitation and Exercise System (IREX) which included the following VR programs: Airborne Rangers, Birds and Balls, Coconut Conveyer, Drums, Juggler, and Soccer. Participants completed 30 min. of VR, 3x/week, for 4 weeks.	**Outcome Measures**: Korea-Mini Mental Status Evaluation (K-MMSE), Fugl-Meyer Assessment (FMA) Outcome measures were administered at baseline and the conclusion of the intervention	**Results**: The participants who received the VReP intervention demonstrated improved total cognitive functioning, improved overall ADL performance, and upper extremity motor function.
Yi Long, R., Zhang, J. (2020) https://doi.org/10.1186/s12984-020-00783-2	**Level of Evidence:** Level I Randomized Controlled Trial N = 52	**Intervention**: The intervention for the VR group consisted of a VR system called "Doctor	**Outcome Measures**: COPM, Stroke Self-Efficacy Questionnaire (SSEQ)	**Results:** The authors found that a period of 3-week VR training could improve

	M Age: 53.28±15.30 years old (intervention) 54.11±14.81 years old (control) Intervention: N = 34 Control: N = 18 Inclusion Criteria: ● Diagnosis of first ever stroke with an onset time < 1 year ● Ability to follow verbal instructions (Mini-Mental State Evaluation score of >24 points) ○ Note: an adjusted cut-off value of 17 for the MMSE was used for participants with less than 6 years of formal education ● Modified Ashworth Scale score for UL of at least 2	Kinetic" which is a VR-based game system with a touch-controlled computer screen. While completing the games, participants could see a human-shaped model on the screen demonstrating the tasks and game actions. Participants received VR training for 45 min. 5x/week for 3 weeks. **Control:** The participants received CT, including occupational therapy, physical therapy, and acupuncture for 5x/day for 45 minutes over a period of 3 weeks	Outcome measures were administered at baseline and the conclusion of the intervention	self-efficacy and ADL performance among individuals post-stroke. Occupational performance scores showed a positive change, as they were more than 2 points over baseline, indicating a clinically significant improvement in occupational performance, but there was no difference between the intervention/control groups.

	● Proximal UL manual muscle testing score equal to or greater than 2 ● No visual field deficit or hemianopia			
Chen, C. et al. (2022) https://doi.org/10.3233/SHTI220330	**Level of Evidence:** Level II Cohort Study N = 48 M Age: No age mentioned Intervention: N = 48 Control: No control group Inclusion Criteria: ● Musculoskeletal disorders (shoulder pain, limited ROM) ● Unstable cardiovascular status ● Any cognitive or emotional disorder ● Other systemic disease such as epilepsy, diabetes, or hypertension ● Receiving conventional mirror therapy or	**Intervention:** The intervention consisted of using the Rehago software on HMD Pico Neo 2 headsets and controllers. In the study, the simulated mirror (therapy) mode was implemented in Rehago. Rehago is a CE marked software with 10 gamified trainings targeting different body parts for the purpose of UL rehabilitation for stroke patients. Mirror mode, which was used in the study, involved participants with L side hemiplegia holding the controller in their R hand, and movement of the R hand was mirrored to the L hand, and vice versa for R side hemiplegia. Participants completed	**Outcome Measures**: FIM, EQ5D-5L The outcome measures were administered at baseline, and every 14 days during the study; day 1, day 14, day 28, and day 42 (the conclusion of the intervention)	**Results:** The study found an observable improvement of patients' functional performance, based on significant differences in baseline to 42 day scores of FIM and QoL assessment scores.

	other therapy using VR	the intervention for 30 minutes each day over a span of 42 days total.		
Faria, A., et al. (2016) https://doi.org/10.1186/s12984-016-0204-z	**Level of Evidence:** Level I Randomized Controlled Trial N= 18 M Age= 58 years old (intervention group), 53 years old (control group) Intervention: N = 9 Control: N = 9 Inclusion Criteria: ● No hemi-spatial neglect as assessed by clinicians with the Line Bisection Test ● Capacity to be seated ● Ability to read and write ● Minimum cognitive function (as assessed by the Mini-Mental State Examination [MMSE] ● Motivated to participate in the	**Intervention:** Participants in the intervention/experimental group used a VR-based simulation of ADLs called 'The Reh@City". This VR program features a 3-D environment with buildings, parks, moving cars, streets, and sidewalks. The system was controlled with a joystick handle and only two buttons – one for selection and one for "help" to ensure stroke patients with motor difficulties could still use the system. Participants must accomplish ADLs in four common places: a supermarket, a post office, a bank, and a pharmacy. The intervention's real-life applicability focused on having the participants use problem resolution,	**Outcome Measures**: Adenbrooke Cognitive Examination (ACE), Picture Arrangement Test from Wechsler Adult Intelligence Scale III (WAIS III), Stroke Impact Scale 3.0 (SIS 3.0) Outcome measures were administered at baseline and the conclusion of the intervention	**Results:** The intervention group showed improvements in global cognitive functioning, improvements in attention, memory, and visuospatial abilities, problem resolution, and overall processing speed. Based on the SIS 3.0 scores, the VR group improved significantly in the physical domain, specifically in strength and mobility, memory, emotion, social participation, and overall recovery, while the control group decreased in the physical domain and only improved in social participation, memory, and mobility. Both groups had clinically important improvements in ADLs and mobility.

	study	planning, and reasoning skills. Participants received twelve 20-min. sessions distributed over 4-6 weeks. **Control**: Participants in the control group received CT which consisted of time-matched cognitive training. Participants performed puzzles, shape sorting, problem resolution, and calculus. These activities required visuo-spatial abilities, attention and memory, and executive functioning. Participants received twelve 20-min. sessions distributed over 4-6 weeks.		
Shin, J., et al. (2016) https://doi.org/10.1186/s12984-016-0125-x	**Level of Evidence:** Level I Randomized Controlled Trial N = 46 M Age: 57.2 ± 10.3 years old (intervention group) 59.8 ± 13.0 years old (control group) Intervention: N = 24 (5 dropped out) Control: N = 22 Inclusion Criteria:	**Intervention**: Participants used the RAPAEL Smart Glove, which has a sensor tracking functional movements and is designed for distal upper extremity rehabilitation. The motion and posture of the hand is displayed through virtual hands in	**Outcomes**: Fugl-Meyer Assessment, Jebsen-Taylor Hand Function Test (JTT), Purdue Pegboard Test (PTT), Stroke Impact Scale 3.0 Outcome measures were administered before the intervention (T0), in the	**Results**: The study found improved distal UE function for participants in the VR intervention group, based on their increased FM scores, and improved HRQoL based on their SIS scores. The study also found improvements in the SIS ADLs/IADLs

	• First-ever ischemic or hemorrhagic stroke • Complaints of unilateral upper extremity functional deficits after stroke • Presence of a score of at least 2 points on the medical research council scale for wrist flexion/extension or forearm pronation/supination	virtual games. The training games were categorized by functional movement and the participant must perform a simulated ADL task such as catching butterflies / balls, squeezing oranges, fishing, cooking, cleaning the floor, pouring wine, painting fences, and turning over pages. The participants completed the movements in the games to achieve task-based goals with visual feedback in real time. Participants received 30-minute intervention sessions for 5 days a week over 4 weeks, plus standard OT daily for 30 minutes. **Control**: The control group's conventional OT interventions consisted of focus on the distal upper extremity. The standard OT sessions (for both groups) involved range of motion and	middle of the intervention, after the 10th session (T1), immediately after the intervention (T2), and 1 month after the intervention (T3).	scores beyond the minimum clinically important difference in the intervention group as well.

		strengthening exercises for the affected limb, table-top activities, and training for ADLs, administered by OTs who were not involved in the study. Participants received 30-minute intervention sessions for 5 days a week over 4 weeks, plus standard OT daily for 30 minutes.		