

## Effect of Virtual Reality Exercise and Mirror Exercise on Upper Extremity Function in Stroke Patients: A Review Article

WADIDA H. ABD ELKADER, Ph.D.\*; NABIL M. ABDEL-AAL, Ph.D.\*; AMNA K. AQL, M.Sc.\*\* and NABIL H.M. IBRAHIM, M.D.\*\*\*

*The Department of Physical Therapy, Basic Science, Faculty of Physical Therapy, Cairo University\**, *Faculty of Physical Therapy, Misr University for Science & Technology\*\** and *Neurology Department, Faculty of Medicine, Al-Azhar University\*\*\**

### Abstract

**Background:** Virtual reality exercise (VRE) and mirror exercise (ME) are two innovative approaches being explored for improving function of upper extremity in stroke patients. Both exercise types have shown promise in enhancing motor recovery and reducing the risk of complications associated with stroke. While traditional physical therapy methods have been the primary focus for rehabilitation, the integration of VRE and ME offers a new frontier in rehabilitation of stroke patients. This study highlights the importance of exploring these novel interventions to better understand their effects on upper extremity function in stroke patients.

**Aim of Study:** Is to review the effect of the VRE and mirror therapy (MT) on upper limb sensory motor function, gross manual dexterity, hand grip strength, and pinch grip strength of stroke patients.

**Conclusion:** Virtual reality exercises and mirror exercises show promise as a non-harmful, feasible, and effective approach for enhancing upper limb function in stroke patients. However, to fully establish their clinical effectiveness and develop standardized protocols, additional high-quality randomized controlled trials are still required.

**Key Words:** Stroke – Virtual reality exercise – Mirror exercise – Review.

### Introduction

**THE** mortality rate associated with strokes has seen a significant decline, largely due to the increased availability of various acute stroke treatment options [1]. This decline has led to an increased focus on improving functional outcomes for neurologically impaired individuals, particularly in terms of upper limb (UL) function. Previous studies empha-

sized the importance of UL function in daily activities, highlighting the need for effective rehabilitation strategies [2].

Motor rehabilitation for stroke patients involves a combination of spontaneous recovery and motor learning during the rehabilitation process [3]. Effective rehabilitation programs should incorporate repetitive and task-specific practice at high intensity in a multidisciplinary environment to promote neural plasticity and facilitate motor recovery [3].

Recent studies have explored the use of virtual reality exercises (VRE) and mirror therapy (MT) as therapeutic interventions to enhance neuroplasticity [4,5]. These interventions have shown promise in promoting motor recovery, [6,7] but most studies have focused on their effectiveness in isolation without directly comparing them to other rehabilitation methods.

This review aims to provide a comprehensive understanding of the relative effectiveness of VRE, a relatively new and innovative approach, and MT, a traditional method, in the field of stroke rehabilitation. By examining the advantages and limitations of each approach, this review aims to inform the development of more effective rehabilitation strategies and aid in determining the cost-effectiveness and accessibility of VRE and MT.

Virtual reality exercise's clinical effect on functions of upper extremity in stroke patients:

*Mechanism of action of virtual reality exercises:*

*Virtual reality (VR) exercises contribute to improving upper limb sensory-motor function through several mechanisms:*

Cortical reorganization occurs as VR training activates the primary and secondary motor cortex, facilitating adaptation and compensation for motor impairments [8,9]. The interactive and engaging

**Correspondence to:** Dr. Wadida H. Abd Elkader, The Department of Physical Therapy, Basic Science, Faculty of Physical Therapy, Cairo University

nature of VR games increases patient motivation to participate in rehabilitation, which is essential for effective motor recovery. Also, VR allows for high-intensity, repetitive, and task-oriented training, crucial for neuroplasticity and functional recovery [10]. In addition, VR allows for high-intensity, repetitive, and task-oriented training, which is crucial for neuroplasticity and functional recovery. This repetitive practice promotes a shift in activity of sensorimotor cortex from ipsi lateral/bilateral to contra lateral regions [8]. Moreover, VR provides interactive multi-sensory stimulation in real-time, including auditory and visual cues, which enhances the learning process and promotes motor recovery [11]. VR exercises involve a wide range of movements, improving upper limb flexibility and range of motion, enabling more complex, precise movements [9,12]. Furthermore, VR exercises require coordination and timing between different body parts, enhancing the overall coordination and timing of the affected upper limb [13]. The increased repetition and frequency of movement help to strengthen and retrain the affected muscles, leading to improved dexterity.

These factors collectively explain the improvements observed in upper limb gross manual dexterity, grip strength, and overall upper extremity function in stroke patients after VRE [14].

#### *Previous Studies about the effect of Virtual Reality Exercises on Upper Limb Function:*

Several studies have investigated the effects of VR exercises on upper limb function in stroke patients. Previous study reported that after a six-week intervention, the Fugl-Meyer Assessment Scale for Upper Extremity (FMA-UE) score of the Xbox Kinect training group (XKGT) significantly higher than the score of exercise training group (ETG) [9]. Another study showed that Kinect-based virtual reality game training combined with traditional therapy resulted in statistically significant improvements in FMA-UE and Box and Block Test (BBT) scores [15]. Not only, It was reported that Kinect technology improved shoulder flexion range of motion (ROM) and stability, allowing for better manual hand dexterity, [16] but also it was reported significant improvements in hand grip strength after Kinect-based VR training, indicating upper limb function improvements [17]. In another way Arman et al., found that Kinect games increased pinch grip strength in children and adolescents with juvenile idiopathic arthritis (JIA) [18]. Another previous study demonstrated significant improvements in pinch grip strength using a virtual reality system combined with robot-assisted haptics [19].

However, some studies did not find significant differences between VR and conventional therapy groups. A previous study revealed that patients who received VRE and those who received conventional therapy showed similar improvements in upper limb function as measured by FMA-UE, Manual

Function Test, and Korean version of the Modified Barthel Index. This discrepancy could be attributed to stroke stage (acute stage), small sample size (26 patients), and the specific VR system used was not described [20]. The study by Shin et al., found that both VRE combined with occupational therapy (OT), and OT alone led to significant improvements in function of upper limb, however, no significant intergroup differences were observed. This could be due to differences in study designs, sample sizes, and populations [21]. Another study did not find a statistically significant difference in FMA-UL scores between the groups. This may be attributed to the upper limb impairment severity of participants (82.8% with severe impairment) and the very acute stage of stroke (less than 6 weeks after stroke) [22]. The study by Brunner et al., revealed that the VRE group and the control group exhibited comparable results in BBT scores, both immediately after the intervention and during the follow-up period, indicating no statistically significant differences between the two groups. The study was conducted on sub-acute stage stroke patients, which may have influenced the results. Additionally, approximately 40% of patients had severe impairment in the wrist and hand [23].

In summary, VRE offer a safe training method and engaging environment for patients to improve upper limb function. The feasibility and cost-effectiveness of VR tools suggest their potential use in stroke rehabilitation centers and outpatient clinics to enhance upper limb function in chronic stage stroke patients.

Mirror exercise's clinical effect of on functions of upper extremity in stroke patients:

#### *Mechanism of action of mirror exercises:*

*Mirror exercises (ME) contribute to improving upper limb function through several mechanisms:*

Mirror therapy creates the illusion that the paralyzed limb is moving in synchronization with the non-paralyzed limb. This interlimb transfer helps stimulate the motor cortex and promote motor recovery by reorganizing the neural connections between the two limbs [24,25]. The ME trick the brain into perceiving movement in the affected limb, even though it is not actually moving. This illusion stimulates the central nervous system, leading to increased neural activity and improved motor function [26]. Also, Providing a visual representation of movement can help reduce the non-use phenomenon, where patients tend to avoid using the paralyzed limb [27]. In addition, the use of mirror therapy in stroke patients has been shown to alter the initially unbalanced pattern of brain activation observed during bimanual tasks, leading to a more symmetrical pattern of activation [28]. Moreover, Mirror therapy can involve exercises that target key muscle groups for hand and grip function, such as the wrist extensors, finger flexors/extensors, and forearm supina-

tors. By practicing these movements while observing the mirrored reflection, patients can re-activate and strengthen these impaired muscle groups [29].

*Previous Studies about the effect of mirror exercises on Upper Limb Function:*

A comprehensive analysis revealed that mirror therapy is an effective intervention for enhancing motor function, as assessed by FMA-UL. Furthermore, it was found to have a positive impact on ADL and pain perception among the studied population [30]. Champaiboon et al., compared MT to a sham group and found that the group receiving MT demonstrated significant improvements in their Motor Assessment Scale scores and lateral pinch strength, though the 10-session duration may have been insufficient for sustained effects [31]. The effectiveness of task-based mirror therapy in improving upper limb motor function and activities of daily living (ADL) was explored in individuals with subacute stroke. The researchers conducted a study involving 30 patients and found that task-based mirror therapy was more effective than sham therapy in enhancing upper limb motor function and ADL performance. However, further research with larger sample sizes and longer-term follow-up is needed to confirm and expand upon these findings [32]. Another study also found better upper limb motor improvement with MT compared to control, though they did not include neurophysiological measures to elucidate the underlying mechanisms [33].

A research aimed to compare MT and traditional therapy and found no substantial differences between the two groups on FMA-UL and Modified Ashworth Scale at the end of the four-week intervention period. The small sample size (34 patients) and short intervention duration may have contributed to the lack of significant findings. The study also did not control for factors like stroke severity, patient age, or pre-intervention motor function levels [34]. Similarly, another research studied the effectiveness of self-administered MT on upper extremity function in acute stroke patients. They randomly assigned 36 patients to control and experimental groups and assessed outcomes using the FMA-UL, Wolf Motor Function Test, and Modified Barthel Index. However, there were no significant differences between groups at the end of the 4-week intervention. The small sample size of 36 patients at a single center may have limited the ability to detect significant differences and the generalizability of the results [35]. A recent study Arfianti et al., investigated MT's effectiveness in enhancing upper limb motor recovery and independence in stroke patients. While the mirror therapy group exhibited advancements in Brunnstrom and Functional Independence Measure (FIM) scores compared to the control group, the differences were not statistically significant ( $p > 0.05$ ). The small sample size of 18 patients may explain the lack of significant findings [36].

*Conclusion:*

Virtual reality exercises and mirror exercises demonstrate potential as safe, practical, and beneficial approaches for improving upper limb function in individuals who have experienced a stroke. These interventions appear to have a positive physiological impact. To confirm the clinical efficacy and establish standardized protocols, further well-designed randomized controlled trials with a high level of quality are necessary.

## References

- 1- DA SILVA PAIVA L., OLIVEIRA F.R., DE ALCANTARA SOUSA L.V., DOS SANTOS FIGUEIREDO F.W., DE SÁ T.H. and ADAMI F.: Decline in Stroke Mortality Between 1997 and 2012 by Sex: Ecological Study in Brazilians Aged 15 to 49 Years. *Sci. Rep.*, Feb 27; 9 (1): 2962, 2019. DOI: 10.1038/s41598-019-39443-3.
- 2- MEKBIB D.B., HAN J., ZHANG L., FANG S., JIANG H., ZHU J., et al.: Virtual reality therapy for upper limb rehabilitation in patients with stroke: A meta-analysis of randomized clinical trials. *Brain Inj.*, Mar 20; 34 (4): 456-465, 2020.
- 3- LI S.: Spasticity, Motor Recovery, and Neural Plasticity after Stroke. *Front Neurol.*, Apr 3; 8: 120, 2017. DOI:10.3389/fneur.2017.00120.
- 4- HAO J., XIE H., HARP K., CHEN Z. and SIU K.C.: Effects of Virtual Reality Intervention on Neural Plasticity in Stroke Rehabilitation: A Systematic Review. *Arch. Phys. Med. Rehabil.*, Mar. 103 (3): 523-541, 2022.
- 5- CHINNAVAN E., RAGUPATHY R. and WAH Y.C.: Effectiveness of mirror therapy on upper limb motor functions among hemiplegic patients. *Bangladesh J. Med. Sci.*, 19 (2): 208-213, 2020. DOI:10.3329/bjms.v19i2.45863.
- 6- WU J., ZENG A., CHEN Z., WEI Y., HUANG K., CHEN J., et al.: Effects of Virtual Reality Training on Upper Limb Function and Balance in Stroke Patients: Systematic Review and Meta-Meta-Analysis. *J Med Internet Res [Internet]*. Oct 12; 23 (10): e31051, 2021. DOI: 10.2196/31051.
- 7- NOGUEIRA NGHM, PARMA JO, LEÃO SESA, SALES I.S., MACEDO L.C., GALVÃO ACDR, et al.: Ferreira BP. Mirror therapy in upper limb motor recovery and activities of daily living, and its neural correlates in stroke individuals: A systematic review and meta-analysis. *Brain Res. Bull*, Dec. 177: 217-238, 2021.
- 8- IKBALI AFSAR S., MIRZAYEV I., UMIT YEMISCI O., COSAR SARACGIL S.N.: Virtual Reality in Upper Extremity Rehabilitation of Stroke Patients: A Randomized Controlled Trial. *J. Stroke Cerebrovasc. Dis.*, Dec. 27 (12): 3473-3478, 2018.
- 9- AIN QU, KHAN S, ILYAS S, YASEEN A, TARIQ I., LIU T., et al.: Additional Effects of Xbox Kinect Training on Upper Limb Function in Chronic Stroke Patients: A Randomized Control Trial. *Healthcare (Basel)*. Feb. 24; 9 (3): 242, 2021. DOI:10.3390/healthcare9030242

- 10- BAO X., MAO Y., LIN Q., QIU Y., CHEN S, LI L., et al.: Mechanism of Kinect-based virtual reality training for motor functional recovery of upper limbs after subacute stroke. *Neural Regen Res.*, Nov 5; 8 (31): 2904-13, 2013.
- 11- JOHANSSON B.B.: Multisensory stimulation in stroke rehabilitation. *Front Hum Neurosci.*, Apr 9; 6: 60, 2012. DOI:10.3389/fnhum.2012.00060.
- 12- SIN H. and LEE G.: Additional virtual reality training using Xbox Kinect in stroke survivors with hemiplegia. *Am. J. Phys. Med. Rehabil.*, Oct. 92 (10): 871-80, 2013.
- 13- MEIRELES C.V., OLIVEIRA L.M., GOMES L.M., FIGUEIREDO E.M. and FARIA CDCM.: Effects of virtual reality training in the upper limb motor coordination of individuals post-stroke: a systematic review with meta-analysis. *Fisioterapia e Pesquisa.*, 29: 11-21, 2022.
- 14- CUESTA-GÓMEZ A., SÁNCHEZ-HERRERA-BAEZA P., OÑA-SIMBAÑA E.D., MARTÍNEZ-MEDINA A., ORTIZ-COMINO C., BALAGUER-BERNALDO-DE-QUIRÓS C., et al.: Effects of virtual reality associated with serious games for upper limb rehabilitation inpatients with multiple sclerosis: Randomized controlled trial. *J. Neuroeng Rehabil.* Jul 13; 17 (1): 90, 2020. DOI:10.1186/s12984-020-00718-x.
- 15- AŞKIN A., ATAR E., KOÇYIĞIT H. and TOSUN A.: Effects of Kinect-based virtual reality game training on upper extremity motor recovery in chronic stroke. *Somatosens Mot. Res.*, Mar. 35 (1): 25-32, 2018.
- 16- YEH S.C., WU Y.L., KUO M.Y., KUO C.H., TSAI Y.C. and TSAI P.Y.: A kinect-based system for stroke rehabilitation. In: 2019 Twelfth International Conference on Ubi-Media Computing (Ubi-Media). IEEE, p. 192-198, 2019. DOI:10.1109/Ubi-Media.2019.00-21.
- 17- ADOMAVIČIENĖ A., DAUNORAVIČIENĖ K., KUBILIUS R., VARŽAITYTĖ L. and RAISTENSKIS J.: Influence of New Technologies on Post-Stroke Rehabilitation: A Comparison of Arneo Spring to the Kinect System. *Medicina (Kaunas)*, Apr. 9; 55 (4): 98, 2019. DOI:10.3390/medicina55040098
- 18- ARMAN N., TARAKCI E., TARAKCI D. and KASAP-COPUR O.: Effects of Video Games-Based Task-Oriented Activity Training (Xbox 360 Kinect) on Activity Performance and Participation in Patients With Juvenile Idiopathic Arthritis: A Randomized Clinical Trial. *Am. J. Phys. Med. Rehabil.*, Mar. 98 (3): 174-181, 2019.
- 19- YEH S.C., LEE S.H., CHAN R.C., CHEN S. and RIZZO A.: A virtual reality system integrated with robot-assisted haptics to simulate pinch-grip task: Motor ingredients for the assessment in chronic stroke. *NeuroRehabilitation*, 35 (3): 435-49, 2014.
- 20- KWON J.S., PARK M.J., YOON I.J. and PARK S.H.: Effects of virtual reality on upper extremity function and activities of daily living performance in acute stroke: A double-blind randomized clinical trial. *NeuroRehabilitation*, 31 (4): 379-85, 2012.
- 21- SHIN J.H., BOG PARK S. and HO JANG S.: Effects of game-based virtual reality on health-related quality of life in chronic stroke patients: A randomized, controlled study. *Comput Biol Med.*, Aug. 63: 92-8, 2015.
- 22- KONG K.H., LOH Y.J., THIA E., CHAI A., NG C.Y., SOH Y.M., et al.: Efficacy of a Virtual Reality Commercial Gaming Device in Upper Limb Recovery after Stroke: A Randomized, Controlled Study. *Top Stroke Rehabil.*, Oct. 23 (5): 333-40, 2016.
- 23- BRUNNER I., SKOUEN J.S., HOFSTAD H., ASSMUS J., BECKER F., SANDERS A.M., et al.: Virtual Reality Training for Upper Extremity in Subacute Stroke (VIRTUES): A multicenter RCT. *Neurology*, Dec. 12; 89 (24): 2413-2421, 2017.
- 24- WANG D., DING L., WANG X., ZHANG K., TONG S., JIA J., et al.: The Effect of Mirror Visual Feedback Therapy on the Hand Mental Rotation in Stroke Patients: An ERP study. *Annu. Int. Conf IEEE Eng. Med. Biol. Soc.*, Jul. 2023: 1-4, 2023.
- 25- GURBUZ N., AFSAR S.I., AYAŞ S. and COSAR S.N.: Effect of mirror therapy on upper extremity motor function in stroke patients: A randomized controlled trial. *J. Phys. Ther. Sci.*, Sep. 28 (9): 2501-2506, 2016.
- 26- LIU H., XU Y., JIANG W., HU F., ZHOU Y., PAN L., et al.: Effects of task-based mirror therapy on upper limb motor function in hemiplegia: Study protocol for a randomized controlled clinical trial. *Trials*, Apr. 11; 25 (1): 254, 2024. DOI:10.1186/s13063-024-08081-1
- 27- SANG-HOON LEE, JUNG WAN CHOE, YOUNG KOOG CHEON, MIYOUNG CHOI, MIN KYU JUNG, DONG KEE JANG, et al.: Improving upper extremity motor function in stroke patients using a complex task with multi-joint-based mirror therapy: A randomized controlled trial. *Neurology Asia*, 25 (3): 425-434, 2020.
- 28- MIRELA CRISTINA L., MATEI D., IGNAT B. and POPESCU C.D.: Mirror therapy enhances upper extremity motor recovery in stroke patients. *Acta. Neurol. Belg.*, Dec. 115 (4): 597-603, 2015.
- 29- SHAKER H., ELSHEHABY W., ELBAKRY R. and EL-WISHY A.A.: Effect of mirror therapy on hand functions in Egyptian chronic stroke patients. *Egypt J. Neurol. Psychiatr Neurosurg.*, 56 (1): 1-6, 2020.
- 30- YANG Y., ZHAO Q., ZHANG Y., WU Q., JIANG X. and CHENG G.: Effect of Mirror Therapy on Recovery of Stroke Survivors: A Systematic Review and Network Meta-analysis. *Neuroscience*, Oct. 15; 390: 318-336, 2018.
- 31- CHAMPAIBOON J., SONTIM W., RUENGYOO R. and PIRAVEJ K.: Effects of mirror therapy in recovering strength and function of the upper limbs in chronic stroke patients: A randomized controlled trial. *Chulalongkorn Med. J.*, 61 (2): 165-181, 2017.
- 32- LEKSHMY D., NAIR RR, NAIR M.K.C. and NAIR S.S.: Effectiveness of Conventional Mirror Therapy on Functional Improvement of Upper Extremities in Patients with Stroke: A Prospective Interventional Study. *Nursing and Midwifery Research Journal*, 18 (1): 26-34, 2022.
- 33- PARK J.Y., CHANG M., KIM K.M. and KIM H.J.: The effect of mirror therapy on upper-extremity function and

- activities of daily living in stroke patients. J. Phys. Ther. Sci., Jun. 27 (6): 1681-3, 2015.
- 34- MEDEIROS C.S., CACHO R.O., BORGES G., OLIVEIRA R., FERREIRA N.M. and LAURENTINO G.E.: Effects of mirror therapy through functional activities and motor standards in motor function of the upper limb after stroke. Fisioter Pesqui., 21: 264-270, 2014.
- 35- RAJENDRAN V., JEEVANANTHAM D., LARIVIÈRE C., SINGH R.J., ZEMAN L. and PAPURI P.: Effectiveness of self-administered mirror therapy on upper extremity impairments and function of acute stroke patients: Study protocol. Trials, Jul 9; 22 (1): 439, 2021. DOI:10.1186/s13063-021-05380-9.
- 36- ARFIANTI L., ROCHMAN F., HIDAYATI H.B. and SUBADI I.: The addition of mirror therapy improved upper limb motor recovery and level of independence after stroke: A randomized controlled trial. Cad Bras Ter Ocup., 30: e3218, 2022. DOI:10.1590/2526-8910.ctoAO245932182.

## تأثير تمارين الواقع الافتراضي وتمارين المرأة على وظيفة الطرف العلوي لدى مرضى السكتة الدماغية: مقالة مرجعية

الخلفية: تمارين الواقع الافتراضي وتمارين المرأة هما نهجان مبتكران يتم استكشافهما لتحسين وظيفة الطرف العلوي لدى مرضى السكتة الدماغية. أظهرت كلتا الطريقتين وعداً في تعزيز التعافي الحركي والحد من مخاطر المضاعفات المرتبطة بالسكتة الدماغية. في حين كانت طرق العلاج الطبيعي التقليدية هي البؤرة الرئيسية للتأهيل، فإن دمج تمارين الواقع الافتراضي وتمارين المرأة يقدم أفقاً جديداً في تأهيل مرضى السكتة الدماغية. تسلط هذه الدراسة الضوء على أهمية استكشاف هذه التدخلات الجديدة لفهم آثارها على وظيفة الطرف العلوي لدى مرضى السكتة الدماغية بشكل أفضل.

الهدف من الدراسة: هو مراجعة تأثير تمارين الواقع الافتراضي وعلاج المرأة على وظيفة الحس الحركي للطرف العلوي، والمهارة اليدوية الإجمالية، وقوة قبضة اليد، وقوة قبضة الإبهام لدى مرضى السكتة الدماغية.

الخلاصة: تُظهر تمارين الواقع الافتراضي وتمارين المرأة إمكانات واعدة كنهج غير ضار وقابل للتنفيذ وفعال لتعزيز وظيفة الطرف العلوي لدى مرضى السكتة الدماغية. ومع ذلك، لإثبات فعاليتها السريرية بشكل كامل وتطوير بروتوكولات قياسية، لا تزال هناك حاجة إلى مزيد من التجارب العشوائية المضبوطة عالية الجودة.