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# The Effectiveness of Occupation-based Virtual Reality Intervention on Upper Extremity Functional Improvement in Post-stroke Individuals: A Systematic Review

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## Cover Page Footnote

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**Conflict of interest statement:** The authors declare that they have no conflict of interest with regard to the research conducted in this paper.



***Abstract***

***Purpose***: *Virtual reality (VR)-based therapy is an emerging practice in the clinical setting and still requires research documenting its efficacy. This review analyzed the effectiveness of VR-based therapy on upper extremity (UE) motor recovery in individuals with chronic stroke by analyzing multiple randomized controlled trials.*

***Methods***: *Search limits for this review consisted of articles published between January 2010 and January 2020 and available in English. Search keywords were based on language in individual databases (e.g. stroke or cerebrovascular accident, upper extremity, occupational therapy). Articles were limited to include only randomized control trials consisting of adult patients (18+) with UE impairment due to chronic stroke (onset at least 3 months prior) and occupation-based virtual reality intervention.*

***Results***: *242 articles were screened; eight met the inclusion criteria. Forms of VR within the reviewed articles included traditional gaming systems, mobile-based game devices, and VR combined with real instrument training. These studies showed improved outcomes following VR training such as improvement of UE function, activity participation, and health-related quality of life.*

***Conclusion***: *The results of this review suggest that VR-based therapy has efficacy equal to or greater than conventional therapy for improving function in the upper extremity of adult patients with chronic stroke. As supported by research, practitioners may incorporate virtual reality-based therapy into conventional clinical sessions to assist in improving UE function and interactions within different environments and to help enhance overall participation in daily tasks and occupational performance in their clients.*

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## Introduction

Cerebrovascular accidents, commonly known as strokes, are currently a leading cause of death and/or long-term disability in the United States, with the effects having a long-lasting impact on millions of individuals. Each year, it can be expected that 795,000 individuals within the United States will experience a stroke (CDC, 2020). A stroke is the result of an interruption of blood supply to the brain, resulting in damage to brain tissue. The brain damage that occurs can result in a wide range of potential deficits and/or impairments, including cognitive, physical, emotional, and sensory deficits (Woodson, 2014).

Major impairments often associated with stroke are motor control deficits such as hemiplegia or hemiparesis. These deficits can have substantial impact on upper extremity (UE) function, which ultimately affects an individual's occupational performance in activities of daily living (Woodson, 2014). Conventional rehabilitative occupational therapy (OT) for individuals with chronic stroke often consists of range of motion and strengthening exercises for the affected limb, training for activities of daily living, and tabletop activities. The traditional approach to conventional rehabilitative treatment of motor control impairments, in which the therapist typically performs hands on techniques to facilitate passive movement, is no longer considered best practice as the efficacy of this approach is not highly supported by modern research (Rao, 2016). Many interventions aligning with this traditional model are still commonly used in practice; however, there is insufficient evidence to support their efficacy in improving motor function in post stroke patients. These interventions include: neurodevelopmental treatment (NDT), adjunctive botulinum toxin treatment, adjunctive brain stimulation, positioning, orthoses, stretching, and balance training using visual feedback via devices (American Occupational Therapy Association, 2014). A contemporary model where the patient is encouraged to complete motor movements independently to complete tasks has been shown to be more effective at improving motor control (Mathiowetz & Haugen, 1994). One potential option that follows this contemporary model is VR-based therapy.

VR is an emerging intervention approach in post-stroke rehabilitation that allows for treatment when the "real life" treatment environment may not be possible for individuals. VR is an immersive, artificial environment that is able to sense a person's actions and positions in space, while incorporating multiple senses (i.e., visual, auditory, perceptual). This allows for a reality-based simulation of various activities (i.e., bowling) in environments such as inpatient rehabilitation units, where these activities may not be otherwise possible (Pasco, 2013). The utilization of VR in clinical practice is a logical option, given the accessibility and affordability of various systems.

Various VR systems are currently present within the literature. These systems can be either immersive or non-immersive. Immersive VR provides immediate, first-hand experience of an event or activity (The Association for Educational Communications and Technology, 2001). Non-immersive VR allows an individual to witness and participate in a three-dimensional environment; typically seen through a screen and navigated using a controller or similar device. The systems described within this review are classified as non-immersive VR systems. A summary of the VR systems currently being used for stroke recovery are described in Table 1.

## Virtual Reality Used as Intervention with Stroke

Upper extremity (UE) motor function is a key element of treatment among individuals with chronic stroke who are participating in VR-based OT. OT can incorporate VR into treatment using a variety of methods. A literature search on VR based methods yielded results in two major categories: gaming and smart systems.

### Gaming Systems

A well-known method found in the literature is the use of gaming systems such as the Nintendo Wii TM and the Xbox Kinect TM to improve motor performance (Hung et al., 2019; Park & Park, 2016; Sin & Lee, 2013). These systems have become popular in research and clinical settings due to the availability of the systems as well as affordability,

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**Table 1.** *Virtual Reality Systems*

| Authors | System Description and Programs Used |
|---|---|
| Choi, Ku, Lim, Kim & Paik (2016) | A combination of a tablet PC and smartphone were utilized to promote UE motor patterns. Grip of the mobile device is required.<br>4 games- Honey Pot Guard, Protect the Bunny, Put Out Fire, and Flower Splash |
| Hung et al. (2019) | Kinect2Scratch maps the participant's body and creates an avatar within the program. No hand controller is required.<br>8 games included (4)- just for fun: whack-a-mole, alien attack, hungry shark, hungry ant and (4)- occupation-based: harvest carrots, picking apples, bowling, boxing |
| Oh et al. (2019) | Joystim is a self-contained unit consisting of a screen and a rotary disk of implements to encourage ADL participations through occupation-based activities including: thumb pinch, doorknob turning, button pushing, and steering wheel turning. |
| Park et al. (2019) | Smart Board -distal UE is placed in a supportive brace and tracks along the board provide stability for UE movement. The system encourages free exploration of the board including point-to-point and circle-drawing. |
| Park & Park (2016) | Wii TM Sport & Wii TM Sports Resort gaming console and controller used occupation-based leisure activities including: bowling, table tennis, canoeing to encourage UE movement. Gaming system requires the ability to grip the controller. |
| Rogers, Duckworth, Middleton, Steenbergen & Wilson (2019) | Elements training- targeted movement of four hand-held objects or "elements" (circle, pentagon, triangle, rectangle) in the virtual world. Patient moves blocks to match with projected images on the tabletop screen or uses the shapes in order to draw and create. |
| Shin et al. (2016) | The Smart Glove system maps the client’s hand while they are tasked to complete simulated occupation-based ADLs including: catching butterflies or balls, squeezing oranges, fishing, cooking, cleaning the floor, pouring wine, painting fences, and turning pages in a book. The Smart Glove provides no support to the affected limb. |
| Sin & Lee (2013) | Xbox Kinect TM scans and recognizes patient movements. Focus is placed on gross and not fine movements through games that are occupation-based including: bowling, boxing, Rally Ball, 20,000 Leaks and Space Pop. |

as compared to other brands of VR systems. Researchers have also found that the effects of the Nintendo Wii TM as a rehabilitation technique may increase when combined with mental health practices (Park & Park, 2016). Similar effects were also observed regarding the feasibility and effectiveness of the Xbox Kinect TM. Researchers from several previously published studies have examined the effects of Xbox Kinect TM games that involve simulated activities such as boxing, bowling, or picking apples. Researchers from one study observed that the effects of the Kinect2Scratch intervention were similar to effects of traditional intervention and suggested Xbox Kinect TM as an intervention may be more beneficial when combined with conventional therapy services (Hung et al., 2019). Another study using the Xbox Kinect TM as a VR-based intervention also noted improvements among the Xbox Kinect TM group. However, improvements in upper extremity function, as measured by the FMA-prox, were not significantly greater than the therapist-based group. Therefore, these researchers also hypothesized that Xbox games may be more effective when used in conjunction with traditional OT services (Sin & Lee, 2013).

**Smart Systems**

Another VR-based intervention approach commonly used includes the use of Smart Boards, Smart Gloves, and other various tablet PCs and smartphones. Researchers using a newly developed SmartBoard technology as an intervention found that SmartBoard activities combined with conventional therapy result in greater improvements in goniometric measurements of active range of motion (AROM) than conventional therapy alone (Park et al., 2019; Shin et al., 2016). Additionally, health-related quality of life (HrQoL), as measured by the Stroke Impact Scale or EuroQoL-5Dimension, was improved to a greater extent when VR was incorporated into occupational therapy (Park et al., 2019; Shin et al., 2016). Specifically, findings from this study found the experimental SmartBoard group to show greater improvements in shoulder AROM and HrQoL, as compared to the control group receiving only conventional OT (Park et al., 2019). Further, researchers investigating the effects of using a Smart Glove for various simulated activities (i.e., pouring a glass of wine, squeezing oranges) found substantial improvements in UE functioning, specifically for distal functioning (Shin et al., 2016). The use of these SmartBoard systems as a novel rehabilitation approach for stroke patients has limited research available and further studies are warranted to examine the effects of this approach to VR-based interventions on UE function.

Among studies with various VR-based approaches, the evaluation of health-related quality of life (HRQoL) was a common secondary outcome measure (Choi et al., 2016; Park et al., 2019; Shin et al., 2016). Researchers using Smart devices (i.e., Smart Gloves, Smart Boards) observed greater improvement in HRQoL among the groups using Smart devices, as compared to control groups (Park et al., 2019; Shin et al., 2016). Oftentimes the improvement was accredited to the increased ability of participants to independently complete tasks (Park et al., 2019; Shin et al., 2016). Researchers using other VR-based devices (i.e., tablet PCs, Smartphones) also found evidence that VR-based therapy is effective in improving overall HRQoL. However, more research is suggested in this area as within-group differences were observed, while between-group differences were not (Choi et al., 2016).

Though systematic reviews of VR exist, they do not examine the use of VR for individuals with chronic stroke and the impact (positive or negative) on UE motor performance. Several systematic reviews relating to VR with stroke patients address other areas of function such as gait or cognition (Derooji et al., 2016; Li et al., 2016, Moreira et al., 2013; Ogourtsova et al., 2017). One systematic review specifically focused on the use of the Xbox Kinect TM as an intervention tool and assessed the impact on balance and activities of daily living (Xavier-Rocha, et al., 2020). The evidence showed that increased use of the Xbox Kinect TM is effective in the improvement of balance and motor function (Xavier-Rocha, et al., 2020). This review did not specifically assess the effects of UE function for patients with chronic stroke or evaluate multiple types of VR devices. While one systematic review did focus on the effects of virtual reality systems on upper extremity function, function was not measured in terms of occupational performance (Lee et al., 2019).

Many interventions of previously published literature simulated various everyday activities (i.e., pouring liquid into a glass, bowling) which may have the potential to impact patients' HRQoL, sense of inclusion or perception of happiness. Considering these potential implications, the research question was developed to reflect the OT scope of practice which includes a holistic approach to treatment. A holistic approach includes not just the physical, but the mental and emotional needs of an individual. HRQoL and depression are often linked to a person's motor function and ability to perform everyday activities (Woodson, 2014). Therefore, HRQoL and depression have the potential to show improvements among individuals who have experienced stroke, as a result of VR-based therapy that is directed at motor function.

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The purpose of this review is to examine the effectiveness of VR-based interventions on UE motor function in individuals with chronic stroke, as well as the potential secondary effects associated with recovery (i.e., HRQoL).

## Methods

### Literature Search

Researchers conducted an initial search in order to obtain articles from various databases related to VR therapy for upper extremity function among individuals with chronic stroke. Search terms for the review were developed by the researchers with assistance from a research librarian with experience conducting searches for systematic reviews. Relevant search terms included cerebral vascular accident, stroke, upper extremity function, virtual reality and OT. Table 2 outlines the complete list of search terms utilized for this review.

### Screening and Selection

Articles were selected by first searching a variety of databases including CINAHL, OTseeker, PubMed, and ScienceDirect. All articles retrieved during the search were saved on RefWorks, an online reference management software tool. Duplicate articles were removed.

The authors completed an initial screening by titles, and then abstracts in order to determine if the articles were relevant for review. Articles were deemed relevant when they met all inclusion criteria. Based on the initial screening, full-text articles were then obtained and further screened for potential inclusion in the review. The research librarian was consulted in order to obtain full'-text papers of potential articles that were not readily available.

Each researcher reviewed articles independently, then discussed the screening results with one other researcher in order to come to a consensus regarding whether the article fit the criteria. This was done to reduce bias in the screening process. Inclusion criteria for articles included in this systematic review included the following: randomized controlled trial, participants age 18+, diagnosis of stroke with onset at least three months prior to start of study, UE impairment as a result of stroke, and an occupation-based, VR therapy regimen. General inclusion criteria for the systematic review consisted of peer-reviewed literature, available in English language, and publication within the last 10 years (2010-2020). These criteria were chosen in order to provide a high level of evidence and to prevent the risk of co-intervention or contamination bias. Studies were excluded from this review if participants had a diagnosis other than stroke or upper extremity motor impairment as a result of a comorbidity.

### Data Extraction

A summary of each article was compiled, and the data extracted included the purpose, setting, sample, findings, and limitations of each study. For each article, the same categories of data were extracted recorded in tabular from. This data included setting of the study, intervention, outcome measures, results and conclusions. Table 3 outlines the study characteristics of all articles included in the final review.

Data extraction was done in pairs and each pair came to a consensus on what data could be gathered from individual articles before recording it in the table. If pair consensus was not achieved, the group at large came together for discussion until an agreement was made.

### Quality Appraisal

Each article was evaluated by pairs of researchers regarding its quality. The researchers individually completed McMaster's Quantitative Critical Review Forms (Law et al., 1998). This form is a respected screening for quality assessment of quantitative research. By following the guidelines set out in this form, the researchers were able to determine what biases were present in each article. The pairs then compared their responses, ultimately coming to an agreement about the quality in terms of selection bias, measurement biases, intervention biases, or other limitations as outlined by Table 4. If the researchers agreed that the study resulted in a great degree of bias (more than 2 areas of bias), the article was excluded from the rest of the review

**Table 2**. *Literature search syntax*

| Database | Keywords |
|---|---|
| CINAHL | Stroke OR Chronic Stroke OR Cerebrovascular accident OR CVA; AND Upper extremity function OR Upper limb function OR motor function OR UE function; AND Hemiplegia OR hemiparesis; Virtual reality OR VR OR Virtual reality therapy OR augmented reality; AND OT OR OT OR occupational therapist OR occupational therapists |
| MEDLINE | Stroke OR Chronic Stroke OR CVA OR Cerebrovascular Accident; AND Virtual Reality OR Virtual Reality Therapy OR VR; AND Upper extremity impairment OR Upper extremity function OR hemiplegia OR Upper Limb Function; AND OT OR OT |
| OTSeeker | Stroke OR CVA OR Cerebrovascular accident) AND (Virtual Reality OR VR) AND (Upper Extremity or Upper Limb) AND Randomised Controlled Trial |
| PubMed | (OT) AND (VR OR virtual reality OR virtual reality therapy) AND (Stroke OR Chronic stroke OR Cerebrovascular accident OR CVA) AND (Upper extremity function OR UE function OR Upper limb function OR motor function OR hemiplegia) |
| ScienceDirect | (stroke OR chronic stroke) AND (upper extremity function OR upper limb function OR motor function OR UE function) AND (virtual reality OR VR) AND (OT) |

**Study Selection**

The literature search yielded a total of 242 articles. After the removal of duplicate articles and an initial screening for inclusion/exclusion criteria 210 articles were excluded. After quality appraisal was done on the remaining 32 articles, eight articles were found to have met the inclusion and quality criteria (Figure 1).

## Results

### Study Characteristics

All eight articles included in the final review were randomized controlled trials; seven were single-blinded RCTs (Hung et al., 2019; Oh et al., 2019; Park et al., 2019; Park & Park, 2016; Rogers et al., 2019; Shin et al., 2016, Sin & Lee, 2013), and one article was a double-blinded RCT (Choi et al., 2016). All studies were conducted and published between September 2013 and October 2019. The location of the studies varied slightly, with the majority being conducted in Korea (Choi et al., 2016; Oh et al., 2019; Park et al., 2019; Park & Park, 2016; Shin et al., 2016, Sin & Lee, 2013), one in Taiwan (Hung et al., 2019), and one conducted in Australia (Rogers et al., 2019).

Sample sizes for the studies were similar with a range of 20 to 40 participants in each study. The drop-out rate for all studies ranged from 0% to 28.26%. Most studies included were conducted within an inpatient rehabilitation setting (Choi et al., 2016; Oh et al., 2019; Park et al., 2019; Park & Park, 2016; Rogers et al., 2019; Shin et al., 2016, Sin & Lee, 2013) and only one study was conducted in an outpatient rehabilitation setting (Hung et al., 2019).

There was variation among the studies in the intervention duration, ranging from two to twelve weeks. Effect of the interventions were determined by using baseline measurements and post-intervention measurements. Six out of the eight studies also included evaluated after a follow-up period. 1-month follow up assessments were completed by five studies (Choi et al., 2016; Oh et al., 2019; Park et al., 2019; Rogers et al., 2019; Shin et al., 2016), and 3-month follow up assessments were completed by one study (Hung et al., 2019), while researchers in two studies, Sin & Lee (2013) and Park & Park (2016), did not include a follow-up evaluation. Duration of intervention should be considered when interpreting results of these studies, as interventions that took place over the course of a longer period of time were more likely to have higher changes in outcomes.

The included studies encompassed a wide range of VR systems, including: the Xbox Kinect TM (Sin & Lee, 2013), the Nintendo Wii TM (Park & Park, 2016), mobile game-based devices with Smart Glove (Shin et al., 2016), MoU-Rehab (Choi et al., 2016), the Kinect2Scratch (Hung et al., 2019), VR combined with real instrument training (Oh et al., 2019), Rapael Smart Board (Park et al., 2019), and the Elements system (Rogers et al., 2019).

**Figure 1.** *Flow diagram for studies included in the systematic review* (Format adapted from Moher et al., 2009)

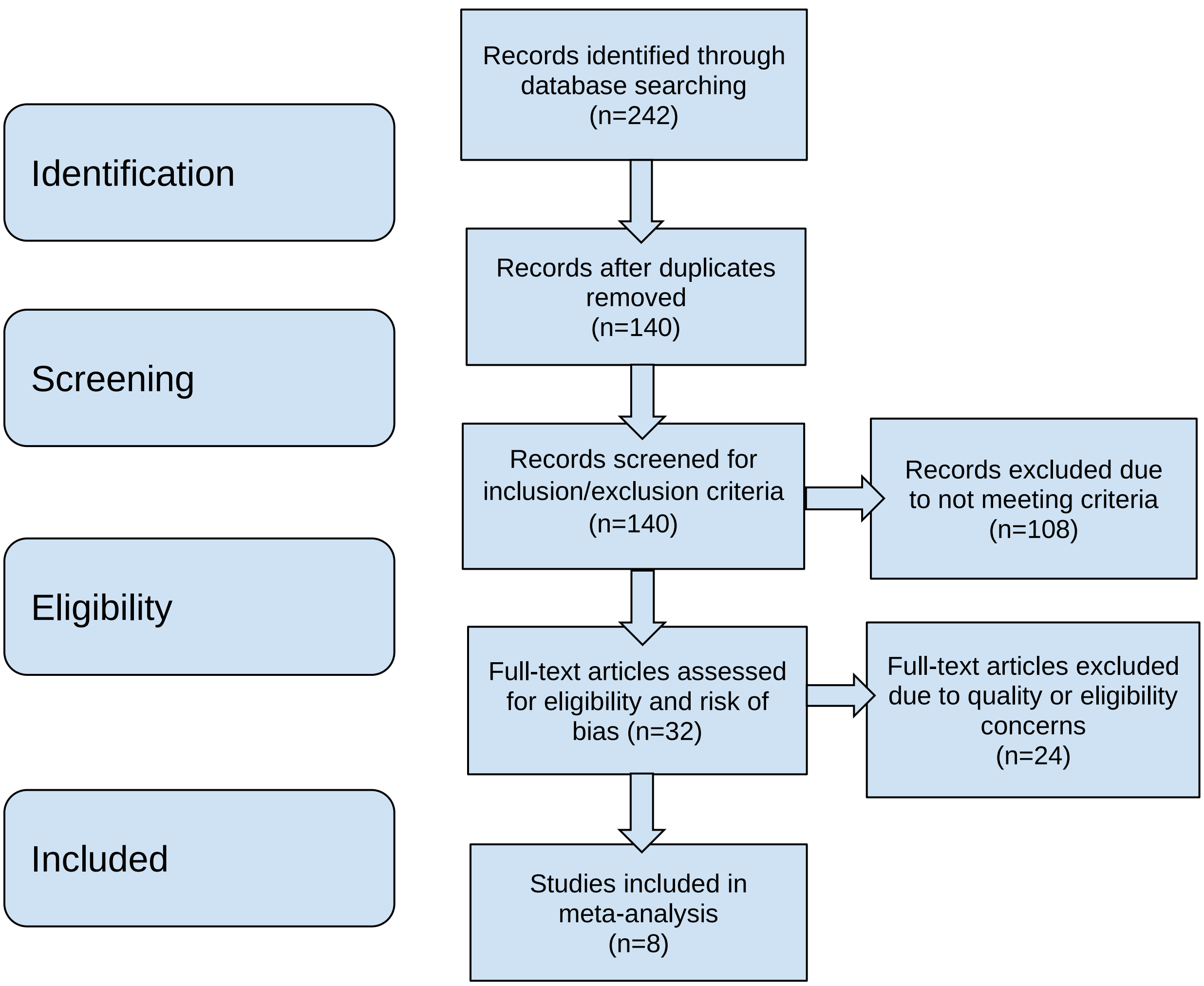

**Table 3**. *Sample Evidence Matrix*

| Author/ Year | Focus of Study | Level of Evidence/ Study Design/ Inclusion Criteria | Context/ Setting/ Sample | Intervention and Control/ Dose | Outcome Measures | Results | Conclusions |
|---|---|---|---|---|---|---|---|
| **Choi et al. (2016)** | Develop a mobile game-based UE VR program for patients who have experienced stroke & evaluate the feasibility and effectiveness | Level 1<br><br>Double-blind RCT<br><br>*Inclusion criteria:* ischemic stroke, able to follow one-step commands, clinical stability,& UE impairment (Brunnstrom stage between 1 -5), | *N* = 24 patients with stroke<br><br>*MoU-Rehab Group* = 12 patients<br><br>*Control group* = 12 patients<br><br>Recruited from Department of Rehabilitation Medici ne between Sept. 2013- Oct. 2014 | *Intervention*: The MoU-Rehab group completed 30 minutes of MoU-Rehab and 30 minutes of conventional occupation therapy. MoU-Rehab consisted of pt. Playing various games on a hands-free mobile device, while attached to a sensor. All games promote various UE motor patterns or exercises.<br><br>*Control:* The control group completed 1 hour of conventional therapy during each session; consisting of ROM exercises, strengthening exercises, and functional tasks.<br><br>Total dose = 10 sessions, 5 days per week, for 2 weeks. | FMA *(Motor impairment)*<br><br>MMT *(UE function)*<br><br>MBI *(activity limitations)*<br><br>EQ-5D *(participant restrictions and QOL)*<br><br>BDI *(psychological aspects)*<br><br>Brunnstrom Stages *( UE recovery)* | For between-group differences, there was greater improvement in the experimental group than in the control group for upper extremity motor performance in the FMA-UE, Brunnstrom stages, and MMT; which persisted at the 1-month follow-up.<br><br>There were no significant between-group differences for activity limitations, participant restrictions and QOL, or psychological aspects. | While off-the shelf games have been effective in VRBT, more systems that are specifically designed for clients with stroke are needed. Focus on ADL activities during training sessions increases the level of engagement as clients can see the carry-over into their daily life. |

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### Risk of Bias

Quality assessment was completed using a method developed by Greenhalgh and Brown (2017). The quality assessment method was designed specifically to assess the risk of bias of randomized controlled trials by qualifying an article as either biased, uncertain or free of bias in a variety of subtypes of bias. Though articles were excluded if a high degree of bias (more than 2 areas of bias) was noted, it is still important to note any bias that may be present in the included articles when considering the results. No studies were able to eliminate all potential biases, but each of the included studies were evaluated to meet the defined bias criteria (no more than 2 areas of bias).

The most common bias among all studies was the non-blinding of participants, with only researchers Choi et al., being able to successfully blind participants. This bias may have inadvertently affected the withdrawal rate, as well as various biases such as contamination or co-intervention. All eight studies showed a low risk of a selective reporting bias. Allocation concealment and random sequence generation were used for all studies, except that conducted by researchers Choi et al., were strong, presenting with a low risk of bias.

### Outcome Measures

Three outcome measures were identified within the studies included in the systematic review These include upper extremity function, activity limitations/participation, and health related quality of life. Many of the studies further subdivided their research to include proximal and distal functioning. Several of the studies addressed multiple outcomes within their research, therefore those studies will be included in multiple sections and may not be exclusive to a specific category.

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**Measures of Upper Extremity Function**

All eight studies included measurement of UE function as a primary outcome measure. Among these eight studies, seven used the Fugl-Meyer Assessment (FMA) as the primary measurement tool. Rogers et al. (2019) utilized the Box and Block Test (BBT) as the primary assessment tool. Evidence from all eight of the Level 1 studies (RCTs) found that VR therapy is able to improve UE motor function among chronic stroke patients. Of the seven studies using the FMA, four suggested that UE motor function improvement was a result of the virtual reality-based interventions (Table 5). Additionally, Rogers et al., (2019) found improvements in UE function both within and between the experimental VR and control groups with changes to BBT scores reported as 17.3 (+/-8.6) and 8.4 (+/-5.3) respectively (Rogers et al., 2019, p.6).

***Measures of Proximal UE Function***

Three studies provided the results of proximal functioning. To assess proximal motor performance of the UE, the studies utilized a subscale of the Fugl-Meyer Assessment (FMA-PROX). The FMA-PROX evaluates the shoulder, elbow, and forearm. Two of the three studies found no between-group differences in proximal UE functioning at any stage using the FMA-PROX. It was further described that both groups in each study showed improvement at follow-up with FMA-PROX score changes recorded as 2.00 (2.00-4.00) and 1.3 (0.8-3.4) respectively (Hung et al., 2019; Park et al., 2019). Additionally, Park et al., (2019) used a secondary measure, the Wolf Function Motor Test (WFMT) to further evaluate shoulder AROM and found significant improvement in the Smart Board group as compared to conventional OT. Of these two studies, participants were not blinded to group allocation, which may have led to a potential detection bias. One study was able to find a significant difference in the VR-based group as compared to the control group, using the FMA-PROX during Smart Glove-based intervention and at follow-up. It is important to consider that this study presents a possible detection bias and high

**Table 4.** *Risk of Bias*

| Author (year) | Choi et al. (2016) | Hung et al. (2019) | Oh et al. (2019) | Park et al. (2016) | Park et al. (2019) | Rogers et al. (2019) | Shin et al. (2016) | Sin et al. (2013) |
|---|---|---|---|---|---|---|---|---|
| Random Sequence Generation | ? | Low | Low | Low | Low | Low | Low | Low |
| Allocation Concealment | ? | Low | Low | Low | Low | Low | Low | Low |
| Comparability (confounding) | High | Low | Low | Low | Low | Low | Low | Low |
| Eligibility (Selection bias) | Low | ? | Low | Low | Low | ? | Low | Low |
| Blinding of Participants | Low | High | High | High | High | High | High | High |
| Blinding of outcome assessment | Low | Low | Low | Low | Low | High | Low | Low |
| Incomplete outcome data (attrition bias) | Low | Low | ? | ? | Low | Low | High | Low |
| Selective Reporting | Low | Low | Low | Low | Low | Low | Low | Low |

| Key | | |
|---|---|---|
| Low risk of bias | Unclear risk of bias (?) | High risk of bias |

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risk of attrition bias as over 80% of participants withdrew from the study (Shin et al., 2016). However, since the research did not have a high risk of bias in more than 2 areas, it still met the quality review criteria for this review.

***Measures of Distal UE Function***

Two of the studies assessed distal UE functioning as a primary outcome using a subscale of the Fugl-Meyer Assessment (FMA-DIST), in addition to proximal measurements (Hung et al., 2019; Shin et al., 2016). The subscale of the FMA that measures distal functioning assesses the wrist and hand. Findings from these two studies varied slightly. Hung et al. (2019), found strong evidence that the Kinect2Scratch group had significant improvements in distal functioning compared to the control group immediately following intervention ($p = 0.017$), however these findings were not sustained at the follow-up. Shin et al., (2016) found that the Smart Glove group had significantly higher scores at the follow-up assessment, as compared to the control group ($p = 0.024$). As noted previously, Shin et al., (2016) presents with a possible risk of detection bias and high risk of attrition bias.

**Activity Limitations/Participation**

Activity limitations and participation were evaluated in three studies. Researchers evaluated the potential effects that increased motor performance may contribute to engagement in activities of daily living and other potential activities of interest. Two of the studies evaluated these possible effects using the Modified Barthel Index (MBI) (Choi et al., 2016; Park et al., 2019). Park and Park (2016) utilized a quality of movement subscale within the Motor Activity Log (MAL-QOL). MAL-QOL allows researchers to confirm the transfer of motor improvements directly related to participation in therapy to activities of daily living. The experimental groups of Choi et al., (2016) and Park et al., (2019) utilized MoU-Rehab and SmartBoard intervention, respectively. These two studies found that both the experimental and control groups showed improvements in activity participation, but no significant between-group differences were observed (Choi et al., 2016; Park et al., 2019). Park et al., (2019) presented with a possible detection bias, due to the lack of blinding of participants to group allocation. Researchers Choi et al., (2016) presented with a possible confounding bias due to the difference in baseline comparability for age, as previously mentioned. However, Park and Park (2016) were able to observe improvements in scores for MAL-QOL in the Nintendo Wii TM group, as compared to the control group, both post treatment and at the 1-month follow-up. Park and Park (2016) presented with a possible detection bias due to the lack of blinding of participants.

Both of these studies present a moderate risk of detection bias, as participants were blinded neither to allocation nor to the purpose of the study; and HRQoL was evaluated using a patient-reported outcome measure. Further, Shin et al., (2016) had a high risk of attrition bias due to 13 participants (28% of sample) withdrawing from the study, resulting in over 80% of the dataset being excluded. Choi et al., (2016) utilized the EQ-5D and found significant within-group differences which were maintained through follow-up; however, they found no significant between group differences at any other stage. Choi et al., (2016) may have a possible confounding bias present, as baseline comparability was not achieved between groups at the beginning of the study. Age was found to have a statistically significant difference between the MoU-Rehab group and control group, with the control group being older (Choi et al., 2016).

**Health Related Quality of Life (HRQoL)**

Three out of eight studies examined health-related quality of life (HRQoL) in addition to UE functioning. Three studies considered HRQoL as a secondary outcome measure (Choi et al., 2016; Park et al., 2019; Shin et al., 2016). Two of the studies utilized the Stroke Impact Scale (SIS) (Park et al., 2019; Shin et al., 2016), and one study utilized the EuroQoL-5Dimension (EQ-5D) (Choi et al., 2016) to assess HRQoL. Park et al. (2019) and Shin et al. (2016) found significant between-group differences between the experimental group and the control group, with the experimental group

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**Table 5.** Fugl-Meyer Assessment Scores

| Researchers | FMA-UE baseline Scores | FMA-UE Post-Test Scores |
|---|---|---|
| Choi et al. (2016) | C: 21.5 (4-57)<br>E: 24.5 (4-63) | C: 31.4 (21.50-34.67)<br>E: 43.6 (24.50-53.75) |
| Hung et al., (2019) | C: 33.5 (23.75-43)<br>E: 35 (28-44) | C: 36.00 (25.50-52.25) p = 0.014<br>E: 37.00 (29.50-51.00) p = 0.001 |
| Oh et al., (2019) | C: 36.5 (18.7-54.3)<br>E: 37.6 (23.2-52) | C: 38.6 (20.1-57.1) p < 0.01<br>E: 39.5 (24.4-54.6) p < 0.05 |
| Park et al., (2019) | C: 19.9 (10-29.8)<br>E: 16.8 (9.5-24.1) | C: 22.0 (12.3-32.3) p = 0.018<br>E: 19.0 (11.5-26.5) p = 0.036 |
| Park & Park (2016) | C: 48.9 (44.7-47.5)<br>E: 49.3 (48.1-50.5) | C: 53.1 (51.7-54.5) p < 0.001<br>E: 54.4 (53.5-55.3) p < 0.001 |
| Shin et al., (2016) | C: 48.2 (45.6-50.8)<br>E: 53.4 (51.6-55.2) | C: 49.6 (46.5-51.9) p = 0.512<br>E: 58.3 (56.6-60) p < 0.001 |
| Sin & Lee (2013) | C: 32.29 (11.86-52.72)<br>E: 26.06 (10.26-41.88) | C: 34.59 (13.87-55.31) p < 0.001<br>E: 47.72 (32.38-63.06) p < 0.001 |

C=control group, E=experimental VR group

displaying greater improvements in HRQoL. Shin et al. (2016) had the experimental group utilize the Smart Glove and detected a significant difference in this group, as compared to the control group. Park et al., (2019) used the Smart Board intervention in their study and found that the Smart Board group had a significantly greater (p=0.038) increase than the control group in HRQoL. The Smart Board group had greater improvements in the areas of emotion and communication, whereas the control group saw a deterioration in these areas.

## Discussion

VR is an emerging therapy technique and therefore has a growing amount of research documenting its various effects. While studies have focused on specific forms of VR therapy in comparison to conventional therapy; this study aimed to review the effectiveness of VR therapy on UE function for adult patients with chronic stroke. Eight randomized controlled trials that examined the effectiveness of VR on UE function in individuals with chronic stroke (3+ months post stroke) were assessed in this review. Each of these studies found that virtual reality was as or more effective than conventional occupational therapy treatment at improving UE motor function.

In addition to measures of UE function, many of these studies also examined differences in activity participation and HRQoL. Three studies measured activity participation as seen through assessments of engagement in activities of daily living such as the Modified Barthel Index and Motor Activity Log (Choi et al., 2016; Park et al., 2016; Park et al.,

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2019). These studies all found equal or greater degree of improvement in activity participation following VR intervention. Three studies also measured HRQoL as a secondary outcome through the Stroke Impact Scale or EuroQoL-5 Dimension assessment and all found improvement at follow up in both the experimental and control groups (Choi et al., 2016; Park et al., 2019; Shin et al., 2016). The findings of these studies suggest that VR therapy is at least as effective and may be more effective than conventional therapy for improving UE function, activity participation and HRQoL for adults with chronic stroke.

## Limitations

The limitations of this systematic review should be taken into consideration. While the studies were all considered high levels of evidence and screened for quality, they do have some potential bias that may impact the generalizability of the results. These biases are outlined in the risk of bias table (Table 4). None of the studies except that done by researchers Choi et al. (2019) blinded the participants as to which group they were a part of possibly resulting in some performance and contamination bias (Hung et al., 2019; Oh et al., 2019; Park et al., 2019; Park & Park, 2016; Rogers et al., 2019; Shin et al., 2016, Sin & Lee, 2013).

Other limitations such as with comparability and attrition bias were present in some studies but were not as prevalent. Additionally, due to the fact that VR is a relatively new treatment approach, the studies reviewed for this systematic review included a wide scope of ages (18+) and period of onset after stroke (3+ months) to allow for a sufficient number of articles to review. This onset period was chosen in place of a longer onset (such as 6+ month) in order to gather the largest amount of relevant articles about the use of VR in rehabilitation. The wide scope of this review may impact the degree to which it can be applied to particular VR technologies or to specific individuals or populations. As a corpus of research builds, future studies will be able to narrow down the age and onset period in order to gather more specific results.

While this review focused on VR in its many forms, more research is needed on each of the specific forms of VR seen throughout these studies. Initial research indicates the effectiveness of these devices on upper extremity function for chronic stroke patients in the outpatient setting. However, more research involving these devices in a variety of settings and contexts would be useful. Additionally, these devices could be helpful for other populations or for other outcomes (such as balance or cognition). The versatility of these devices should be further explored.

The evidence showed that VR was an effective form of therapy for adults 18+; however, there was no analysis of levels of effectiveness in smaller age groups. Further research would be necessary to determine the effectiveness of this form of therapy for smaller more specific age groups, for example the geriatric population. Additionally, there could be further investigation of under what circumstances VR is most effective for each age group and population.

Reducing biases in research of VR is inherently challenging due to the nature of the intervention. While participants may be randomly assigned to the control or experimental group, they will likely immediately know that they are part of the experimental group as soon as intervention involving VR systems begin. This makes double blinding the participants difficult to impossible thus leaving open the possibility of performance or contamination bias.

## Implications for Practice, Education and Research

This review holds a variety of implications for practice, education and research in the field of OT.

VR therapy, particularly fully immersive VR, is as effective or more than conventional OT in the treatment of UE function in adults with chronic stroke. Therefore, it may be an effective alternative or supplemental treatment for this population especially for individuals who have an interest in VR or gaming.

There is a wide variety of VR devices and systems available. These range in cost with some being very expensive, but others such as the Kinect 2 Scratch game (Hung et al., 2019) being fairly low cost. Low-cost VR devices may be a reasonable alternative for practitioners or organizations that would like to follow best practice while also keeping costs low. Further research is necessary to determine if cost is related to effectiveness of the VR system.

The evidence supports the efficacy of this intervention; OT students and practitioners may benefit from learning about this intervention to potentially augment the treatment of present or future clients.

Many of the forms of VR may also be used at home. Further research is needed to determine whether use of these treatments without the facilitation of a therapist is also effective, safe and feasible for improving UE function in adult patients with chronic stroke.

Although this review focused on how VR can improve UE function, evidence also suggested the efficacy of VR as a treatment for psychosocial deficits (Park et al., 2019; Shin et al. 2016). Further research is needed to explore VR as a treatment option in the field of mental health.

## Conclusion

The research conducted for this review demonstrates that specific interventions that include VR and simulated environments are an effective form of OT for treating UE impairments and function in adults with chronic stroke. The many forms of VR support improvements in UE function and interactions within different environments to help enhance overall participation in daily tasks and occupational performance. The occupational therapists that conduct this supplemental form of treatment possess the skills and training needed to produce effective, engaging, and occupation-based treatments. Evidence indicates that there are a wide variety of VR systems available, ranging from low -cost to clinic-specific models, which are sometimes viewed as cost prohibited for certain organizations' budgets. VR and simulated environments are intervention approaches that OT practitioners should consider for improving UE motor impairments for those individuals with chronic stroke. The evidence supports the effectiveness of VR as a form of OT for treating UE. However, more occupation-based research is required to demonstrate the role VR has on OT treatments.

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