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# **Virtual reality for stroke rehabilitation: an abridged version of a Cochrane Review.**

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## Abstract

**Aim:** Virtual reality and interactive video gaming have emerged as new treatment approaches in stroke rehabilitation settings over the last ten years. The primary objective of this review was to determine the effectiveness of virtual reality on upper limb function and activity after stroke. The impact on secondary outcomes including gait, cognitive function and activities of daily living was also assessed.

**Methods:** Randomised and quasi-randomised controlled trials comparing virtual reality with an alternative intervention or no intervention were eligible to be included in the review. The authors searched a number of electronic databases including: the Cochrane Stroke Group Trials Register, the Cochrane Central Register of Controlled Trials, MEDLINE, EMBASE, AMED, CINAHL, PsycINFO, clinical trial registers, reference lists, Dissertation Abstracts and contacted key researchers in the field. Search results were independently examined by two review authors to identify studies meeting the inclusion criteria.

**Results:** A total of 37 randomised or quasi randomised controlled trials with a total of 1019 participants were included in the review. Virtual reality was found to be significantly more effective than conventional therapy in improving upper limb function (standardised mean difference (SMD) 0.28, 95% confidence intervals (CI) 0.08 to 0.49)) based on 12 studies and significantly more effective than no therapy in improving upper limb function (SMD 0.44 (95%CI 0.15 to 0.73)) based on nine studies. The use of virtual reality also significantly improved activities of daily living function when compared to more conventional therapy approaches (SMD 0.43 (95%CI 0.18 to 0.69)) based on eight studies.

**Conclusion:** While there are a large number of studies assessing the efficacy of virtual reality they tend to be small and many are at risk of bias. While there is evidence to support the use of virtual reality intervention as part of upper limb training programs, more research is

required to determine whether it is beneficial in terms of improving lower limb function and gait and cognitive function.

**Key words: rehabilitation, stroke, video games, virtual reality**

Stroke is one of the leading causes of death and disability worldwide <sup>1,2</sup>. A complex combination of sensory, motor, cognitive and visual impairment is common following stroke and impacts on the stroke survivor's ability to perform activities of daily living such as selfcare tasks and participation in work and leisure roles <sup>3</sup>. Evidence suggests that although most recovery is thought to be made in the first few weeks after stroke, people may make improvements on functional tasks many months after the onset of stroke<sup>4</sup>.

Virtual reality has been defined as “an advanced form of human-computer interface that allows the user to 'interact' with and become 'immersed' in a computer-generated environment in a naturalistic fashion”<sup>5</sup>. The use of virtual reality as a rehabilitation intervention was first discussed in the mid 1990's<sup>6</sup>. A number of different virtual reality programs were developed and feasibility studies conducted, yet these programs were predominantly developed and tested in research settings rather than in clinical settings. The release of more sophisticated interactive video games (also referred to as Exergames), such as the Nintendo Wii in 2006 saw the rapid uptake of commercially available gaming consoles in rehabilitation settings.

Virtual reality intervention is thought to be a useful rehabilitation approach for a number of reasons. It enables the clinician to provide patients with a method of repetitive task specific training which is supported by research as being an effective approach in neurological

rehabilitation<sup>7</sup>. Training is conducted in an enriched environment; the stimulating environment is thought to be more effective in training problem solving and performance of functional tasks<sup>8</sup>. Another desirable feature of virtual reality programs is that they may be designed to attempt to simulate real-world activities (such as walking through a park rather than on a treadmill) which may provide enhanced ecological validity when compared with more conventional therapy tasks. In addition, risky activities that are unsafe to practice in therapy sessions (such as crossing the street) can be practised in a safe and regulated environment<sup>9</sup>. Some studies suggest that the programs may be more interesting and enjoyable than traditional therapy tasks ultimately encouraging the rehabilitation participant to engage in longer periods of therapy<sup>10</sup>.

Our initial review, published in 2011, identified 19 studies and a number of ongoing studies. Since then, a large number of studies have been published and an update of our review was warranted. The primary objective of this review was to determine the effect of virtual reality intervention in comparison with an alternative intervention or no intervention on upper limb function and activity. The secondary objective was to examine the effect on outcomes including gait and balance activity, global motor function, cognitive function, activities of daily living limitation, participation restriction and quality of life and neurophysiological changes identified via imaging and adverse events. In addition, we reported on feasibility by examining patient eligibility and recruitment data.

## **Materials and methods**

### *Inclusion/exclusion criteria*

We included randomised or quasi randomised trials that compared virtual reality with an alternative intervention or no intervention. Studies that compared two different types of virtual reality without an alternative group were not included. Study participants had a diagnosis of stroke. We excluded studies where participants had mixed aetiology unless individual data was available for the participants with stroke only.

Interventions that met the following definition were considered to be virtual reality: “an advanced form of human-computer interface that allows the user to ‘interact’ with and become ‘immersed’ in a computer-generated environment in a naturalistic fashion”<sup>11</sup>.

### *Outcomes*

The primary outcome was upper limb function and activity. Secondary outcomes were: gait and balance function and activity, global motor function, cognitive function, activity limitation, participation restriction, quality of life and changes detected in brain imaging. Adverse events and patient eligibility and recruitment were also reviewed.

### *Search strategy*

The Cochrane Stroke Group Trials Register was searched by the Managing Editor in November 2013. We searched the following databases: the Cochrane Central Register of Controlled Trials, MEDLINE, EMBASE, AMED, CINAHL, PsycINFO, PsycBITE, OTseeker, COMPENDEX and INSPEC in October 2013. Our search strategy was developed with the assistance of the Cochrane Stroke Group Trials Search Co-ordinator.

In an attempt to identify further relevant studies we searched trial registers, scanned the reference lists of systematic reviews, searched Dissertation Abstracts, and contacted key researchers in the area. Full details of the search and search strategy can be found in the full version of the review<sup>12</sup>.

### *Data collection and management*

Two review authors (KL and ST) independently reviewed titles and abstracts retrieved from the search in order to determine whether they met the pre-defined inclusion criteria. All potentially relevant studies were obtained in full text and contact was made with study authors to obtain more information when required. A third review author (JD) moderated any disagreements. Studies published in languages other than English were reviewed by someone fluent in the language as arranged by the Cochrane Stroke Group Trials Search Co-ordinator. Two review authors (KL and ST or SG or JD) independently extracted data from the studies using a pre-designed data extraction form. Disagreements were moderated by a third review author (MC) when necessary. Study authors were contacted by email to gain missing information required for the review. Methodological quality of studies was assessed independently by the same authors (KL and ST or SG or JD) using The Cochrane Collaboration's risk of bias tool. Categories assessed were: sequence generation, allocation concealment, blinding of outcome assessors, incomplete outcome data and selective reporting. Risk of bias was determined to be 'low risk', 'high risk' or 'unclear risk'.

GRADE was used to interpret findings and GRADEpro was used to create a 'Summary of findings' table<sup>13</sup>. The table provides outcome-specific information concerning the overall quality of evidence from studies included in the comparison, the magnitude of effect of the intervention and the sum of available data on the outcomes considered. The overall quality of

evidence was dependent on study limitations (risk of bias), indirectness, inconsistency, imprecision or publication bias.

Outcomes were classified by category (upper limb function, hand function, lower limb and gait activity, global motor function, cognitive function, activity limitation, participation restriction and quality of life, neuroimaging studies). We calculated mean differences (MD) or standardised mean differences (SMD) as appropriate.

We contacted authors for missing data or converted available data where possible (for example, gait speed reported as metres per minute was converted to metres per second). We conducted intention-to-treat analyses to include all randomised participants where possible. Where drop outs were clearly identified we used the actual denominator of participants contributing data.

Results were pooled using a fixed-effect model with 95% CI using RevMan5.0 to present an overall estimate of effect. Results were pooled where there were acceptable levels of heterogeneity. Heterogeneity was assessed by visual inspection of the forest plot and examination of the I<sup>2</sup> statistic<sup>14</sup>. Where heterogeneity prevented pooling, we provided a narrative summary of results.

## **Results**

A total of 8244 studies were identified from the search of which 198 were sought in full text. Further studies were then excluded and reasons for exclusion documented. This resulted in 37 randomised or quasi randomised controlled studies meeting the eligibility criteria and being included in the review <sup>15-51</sup>.

### *Study characteristics*

A total of 1019 participants post stroke were included in the trials. Details of sample size, gender balance, participant age, mean time since stroke and intervention approach are presented in Table 1. Participants in the studies were relatively young with studies reporting mean ages of 46 to 75 years. All included trials took place between 2004 and 2014. Many studies excluded people with aphasia, apraxia and cognitive impairment hence, recruitment data (when reported) revealed that only 26% of patients screened were able to be recruited to the studies.

The most common intervention approach used in studies included in the review was upper limb retraining with 18 studies using this approach. Other interventions included driving retraining (three studies), retraining skills in using the public transport system (one study), lower limb, balance and gait retraining (eight studies), global motor function retraining (seven studies) and visual perceptual retraining (one study). Six of the studies evaluated the effect of commercial gaming consoles; these were that Playstation Eye Toy, Nintendo Wii and Microsoft Kinect. Other virtual reality programs evaluated that are available for purchase include the Armeo, CAREN and the GestureTek.

Virtual reality intervention was most often compared with the same dose of therapy based on a conventional approach. Eleven studies evaluated the efficacy of virtual reality when used alone or as an adjunct to usual rehabilitation.

The risk of bias of included studies is reported in Figure 1. Where detail was lacking in published reports we contacted the study author for additional information or clarification.

### *Primary outcomes*

Twelve studies (with 375 participants) which compared the same dose of virtual reality with conventional therapy reported outcomes for upper limb function and activity post intervention. Results were pooled finding a small significant effect in favour of virtual reality intervention (standardised mean difference (SMD) 0.29 (95% CI 0.09 to 0.49), see Figure 2). Two trials reported outcomes for grip strength. The effect of virtual reality compared with conventional therapy was not significant (mean difference (MD) 3.55 (95% CI -0.2 to 7.30)). Subgroup analyses examined whether results varied based on the dose of treatment, time since onset of stroke, type of system (specialised versus commercial) and severity of upper limb impairment. Results of the analyses suggested that greater benefits were experienced by those who were within six months of stroke at the time of recruitment and those with mild to moderate severity of impairment.

Nine studies (with 190 participants) examined the effect of virtual reality when it was used alone (i.e. the control group did not receive any therapy) or as a way of augmenting usual rehabilitation (i.e. to increase the total dose of therapy). Results showed a small to moderate significant effect in favour of virtual reality (SMD 0.44 (95% CI 0.15 to 0.73)), see Figure 3.

### *Secondary outcomes*

Seven studies reported on outcomes of gait and balance however, only the results from three of these studies could be pooled. Pooling revealed no significant effect on gait speed (MD 0.07 (95% CI -0.09 to 0.23)).

Three studies reported outcomes related to global motor function . Two of these studies (with 27 participants) which examined the effect of virtual reality intervention compared with no intervention were pooled. Results did not reveal a significant improvement in global motor function (SMD 0.14 (95% CI -0.63 to 0.90)).

Eight studies, comparing virtual reality intervention with conventional therapy, reported outcomes for activities of daily living function. Virtual reality intervention was found to be significantly more effective (SMD 0.43 (95% CI 0.18 to 0.69)). Heterogeneity was negligible ( $I^2=2\%$ ). The effect of virtual reality on ADL function when used as a method of increasing therapy dose was similar (SMD 0.44 (95% CI 0.11 to 0.76)).

Two studies examined the effect of virtual reality on the Stroke Impact Scale; neither identified significant differences in outcomes between those in the intervention and control groups.

There were few adverse events reported across studies and those reported were mild (i.e. dizziness, headache).

There were insufficient trials to examine effect on cognitive function.

## Discussion

This review included 37 randomised controlled trials comparing virtual reality with an alternative intervention or no intervention in patients after stroke. Intervention approaches, outcome measures and control groups varied limiting the extent to which we could pool studies and conduct meta-analyses. We were able to conduct meta-analysis to examine the effect of virtual reality on upper limb function, grip strength, gait speed, and activities of daily living function.

Virtual reality intervention was found to be a more effective approach than conventional therapy in retraining upper limb function. However, this was considered to be low quality evidence when graded using GRADE methodology due to risk of bias and inconsistent findings across trials. There was insufficient evidence to provide information about the most effective dose of therapy, type of virtual reality program however results suggested most benefit for those within six months of stroke and with mild to moderate severity arm impairment. Our analysis shows that using virtual reality as a method of increasing therapy dose is an effective method of improving arm function. There was insufficient evidence to draw conclusions on the effectiveness of virtual reality compared with conventional therapy in improving gait speed. Although the interventions in these studies did not specifically target activities of daily living function, there was a significant effect demonstrated when using a virtual reality approach (GRADE: very low quality). Few adverse events were reported suggesting that the virtual reality interventions described in the studies were relatively safe when administered by health professionals with appropriate patients.

### *Limitations of the review*

The use of meta-analysis can be controversial where there is heterogeneity present between studies. Although there was clinical heterogeneity between studies included in the review we were careful only to pool studies where participants, interventions and outcome measures were comparable. While we were able to include 37 studies in this review, sample sizes of the included studies were generally small and few of the studies examined whether effects were sustained. Some of the papers reporting on the included studies lacked detail therefore we were unable to ascertain the risk of bias within some studies. In addition, although many authors responded to queries regarding study details, some did not, therefore, we were unable to gather all requested information. Despite our comprehensive search strategy it is possible that relevant studies were not identified. This may include studies where there is no abstract published in English.

### *Implications for practice*

There is low quality evidence that virtual reality is a safe and effective method of improving arm function and activities of daily living function following stroke. Patients in the acute and subacute phases with milder severity strokes appear to be most likely to benefit. However, there is a lack of information regarding the most effective types of programs and even whether programs specifically designed for rehabilitation settings are more effective than commercial gaming consoles. Studies that compare different forms of virtual reality intervention will provide information regarding the most important characteristics of the environment and interaction methods. The lack of adverse events reported in research studies suggests that intervention is safe although clinicians need to monitor this closely in busy clinical settings. Studies included in the review tended to include younger stroke survivors

without significant cognitive impairment or aphasia therefore the results do not appear to be applicable to all stroke survivors.

### *Implications for research*

While this review included a further 18 studies, the findings and conclusions are not vastly different from the previous review. The more recent studies were not necessarily larger or higher in quality. Adequately powered trials of high quality are still required to provide more definitive information regarding efficacy.

Most of the studies examined motor retraining interventions. In particular upper limb retraining was the focus of half of the studies included in the review. In contrast, there is less research into activity retraining tasks (such as driving simulators) despite promising results from existing studies. More research is required to determine whether the effects of task practice in the virtual environment translate to task performance in real world tasks. The use of independent practice of virtual reality tasks is consistently identified as a possible method of increasing therapy dose. Yet, research to date has assessed the efficacy when provided with direct 1:1 supervision. Further studies are needed to determine feasibility and efficacy of virtual reality when used without direct clinician supervision.

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