Bilateral movement computer games to improve motor function of upper limb and quality of life in patients with sub-acute stroke: a randomised controlled trial: abridged secondary publication

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KEY MESSAGES

1. Sixteen sessions of bilateral movement computer games training is superior to video-directed conventional training in promoting the recovery of motor control and functional use of a paretic upper limb after a stroke.
2. Bilateral movement computer games training is a useful complement to conventional upper limb rehabilitation for patients with subacute stroke.

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Introduction

In stroke survivors, a paretic upper limb greatly affects their functional independence and quality of life. Neuro-rehabilitation programmes should consist of repetitive, high-intensity, task-specific sensorimotor training in order to promote motor and functional recovery effectively.

Bilateral movement therapy using the non-paretic limb can enhance functional recovery of the paretic limb via the facilitative coupling effects.[1] Bilateral movement training promotes neural plasticity and facilitates control of the paretic limb's movement.[1] Virtual reality refers to interactive simulations with a computer-generated scenario that appears similar to the real world. Virtual reality is a promising rehabilitation intervention for improving upper limb motor control and ability in the activities of daily living after a stroke.[2] It provides a platform for highly repetitive bilateral movement training that is considered engaging, motivating, self-assisted, and task-orientated.

In a study of computer games with a movement-based controller, intervention significantly improved the upper limb motor performance of chronic stroke survivors.[3] However, the study was neither randomised nor controlled; only the immediate effects were studied; and the sample size was small. We therefore tested the hypothesis that those practising bilateral movement computer games training (BMCT) would experience greater improvement in motor control and functional performance than those with conventional training. The objective of this study is to investigate whether the BMCT is more effective than the video-directed conventional training (VDCT), in addition to conventional physiotherapy, in promoting the recovery of motor control and functional use of the paretic upper limb in activities of daily living and quality of life in patients with sub-acute stroke.

Methods

This study was a stratified, single-blinded, controlled clinical trial. It was approved by the Joint Chinese University of Hong Kong - New Territories East Cluster Clinical Research Ethics Committee (reference: CRE-2012.343-T). Informed consent was obtained from each patient.

All patients referred to the geriatric day hospital at Shatin Hospital for stroke rehabilitation were screened by the physiotherapist-in-charge. Subjects were included if they were aged 45 to 85 years, diagnosed with stroke 1 week to 6 months previously, and scored ≤7 out of 10 on the Abbreviated Mental Test. Subjects were excluded if they had receptive dysphasia or any medical, cardiovascular, or orthopaedic condition that would hinder their proper assessment and treatment. Subjects were assigned to either the BMCT or VDCT group using stratified blocked randomisation, in addition to standard physiotherapy training. Interventions were delivered by the two physiotherapists. Assessments and data entry were performed by a research assistant who was blinded to the treatment group.

There were 16 sessions (twice a week for 8 weeks). Each session involved 1.5 hours of conventional physiotherapy and 1.5 hours of multidisciplinary occupational therapy as well as the corresponding intervention. The physiotherapy

TABLE 1. Details of conventional physiotherapy, bilateral movement computer games training, and video-directed conventional training

Conventional physiotherapy	Bilateral movement computer games training	Video-directed conventional training
Upper arm and hand function exercises (30 minutes)	3 different computer games (30 minutes)	Exercise in response to a video (30 minutes)
1. Passive stretching and weight bearing exercise (5 minutes) 2. Assisted or active mobilising exercise (5 minutes) 3. Progressive resisted exercise (10 minutes) 4. Task-orientated exercise (10 minutes)	1. Hitting single stationary targets which required movement in all directions and increasing reaction speed (10 minutes) 2. Hitting multiple moving targets or interacting with multiple moving targets which required directional control, strategy, and timing 3. Interacting with various stationary and moving targets which required strength, endurance, and timing.	Video prescribed the exercise movements of the upper limb that the subject had performed during conventional physiotherapy training (upper arm and hand function exercises)

session involved 60 minutes of lower limb strengthening, balance, and functional training, and 30 minutes of upper arm and hand function training (Table 1).

The BMCT subjects played the video game for 30 minutes. They were instructed to hold the game controller with the paretic hand, and the other end of the controller connected with a handlebar was held by the non-paretic hand. For subjects with severe upper limb motor impairment, the paretic hand was strapped to the game controller with a bandage. The subjects moved the paretic arm in a bilateral, nearly symmetrical and self-assistive pattern. Each subject played three different games for 10 minutes each during each session. A patient care assistant monitored the subject's practice under supervision of a physiotherapist. The games were organised in increasing levels of complexity requiring greater physical movement, skill, and concentration. Progression to more difficult games was directed by the case physiotherapist based on whether the subject could move the paretic arm easily while completing the challenges and whether the subject felt fatigued after each game. The programme was progressed by: (1) moving up the game levels to increase the numbers of targets and moving speed; (2) decreasing mouse sensitivity to increase fine movement control; and (3) adding weight to the handlebar. Training data and progress of each subject were presented in graphs, heat-maps, and scoreboards.

Those in the VDCT group continued to exercise for 30 minutes in response to a video that prescribed the exercise movements of the upper limb that the subject had performed during conventional physiotherapy training (upper arm and hand function training). Participation in video-directed exercise was monitored by the patient care assistant.

The primary outcome was the Fugl-Meyer Assessment - Upper Extremity score. Secondary outcomes were the Action Research Arm Test score, grip strength on the affected and non-affected side as measured with a digital dynamometer, and health-related quality of life measured with the 36-item Short-form Health Survey (SF-36). Subjects were assessed by a blinded assessor before treatment, after 8 sessions, after 16 sessions, and at 4 weeks after treatment.

TABLE 2. Patient characteristics of two groups

Characteristic	Bilateral movement computer games training (n=47)*	Video-directed conventional training (n=46)*
Sex		
Male	27 (57.4)	28 (60.9)
Female	20 (42.6)	18 (39.1)
Age, y	65.1±10.2	66.0±9.0
Body height, cm	162.5±7.6	163.2±8.5
Body weight, kg	58.5±8.1	59.9±9.9
Body mass index, kg/m²	22.1±2.5	22.4±2.7
Post stroke days	57.6±24.7	63.4±39.6
≤8 weeks	29 (61.7)	25 (54.35)
>8 weeks	18 (38.3)	21 (45.65)
Type of stroke		
Infarct	38 (80.9)	38 (82.6)
Haemorrhage	9 (19.1)	8 (17.4)
Hemiplegic side		
Right	21 (44.7)	25 (54.3)
Left	26 (55.3)	21 (45.7)
No. of stroke	1.1±0.4	1.2±0.5
Abbreviated Mental Test	9.5±0.9	9.4±1.1

* Data are presented as mean±standard deviation or No. (%) of participants

The results of a pilot study predicted an effect size of 0.64. The alpha level was set at 0.05 and the design was based on a power of 80%. Assuming the possible drop-out rate of 10%, the sample size required was estimated to be 88 subjects.

Analysis of covariance adjusted with the

TABLE 3. Univariate analysis of changes in outcome measures from baseline to after 16 sessions of treatment

Outcome measure	Mean change (95% confidence interval)		P value (ANCOVA)
	Bilateral movement computer games training	Video-directed conventional training	
Fugl-Meyer Assessment - Upper Extremity	14.84 (12.42-17.26)	6.54 (5.05-8.02)	<0.001
Action Research Arm Test	13.64 (9.65-17.63)	6.61 (3.88-9.33)	0.006
Grip strength (affected)	4.89 (3.21-6.57)	1.72 (0.78-2.67)	0.002
Grip strength (non-affected)	1.38 (0.27-2.49)	1.04 (-0.00-2.08)	0.639
Physical Component Summary	3.85 (1.82-5.88)	3.23 (1.48-4.97)	0.701
Mental Component Summary	4.75 (1.78-7.72)	2.85 (0.01-5.68)	0.455

baseline measurements was used to investigate the significance of any observed differences between groups in changes of scores. The significance level was set at P≤0.05. Analyses were carried out using the SAS software (version 9.4). All subjects were in the intention-to-treat population. Missing values for dropouts were not replaced, and it was assumed that no changes occurred in any outcome measure. All P values were corrected using Bonferroni adjustment to maintain the overall type I error at 5%.

Results

Of 93 subjects, 47 (50.5%) were allocated to the BMCT group. 10 (10.8%) subjects dropped out, owing to hospital re-admission (secondary to re-stroke or other medical problems) or lost to follow-up. The mean days post-stroke at the beginning of the experiment was 57.6±24.7 days in the BMCT group and 63.4±39.6 days in the VDCT group (Table 2).

The mean change in the Fugl-Meyer Assessment - Upper Extremity score, Action Research Arm Test score, and grip strength (affected) from baseline was significantly greater in the BMCT group than in the VDCT group after 16 sessions (all P<0.05, Table 3).

Discussion

Reorganisation of the brain generally occurs in the first 6 months after stroke, determined by the patient's motivation, learning activity, family support, and the quality and intensity of rehabilitation therapies.[2] The BMCT resulted in significantly greater improvements in the mean Fugl-Meyer Assessment - Upper Extremity score, Action Research Arm Test score, and grip strength (affected) than VDCT, regardless of time. BMCT involved exercising the paretic upper limb with support and assistance from the non-paretic limb in a bilateral pattern of movement. The coupling effect of both upper limbs was assumed to facilitate the functional recovery of the paretic limb. It allows the undamaged brain hemisphere to enhance activation of the damaged hemisphere through inter-hemispheric connections.[1] Moreover, the excitation of the intact hemisphere that may be inhibited normally is increased during paretic upper limb movement, resulting in suppression of the output from the damaged hemisphere.[4] However, bilateral movement training can facilitate the generation of identical motor commands in each cerebral hemisphere. This facilitates output from the damaged cerebral hemisphere and from normally inhibited ipsilateral pathways of the undamaged hemisphere in order to augment movement of the paretic upper limb.[4]

The BMCT involved practising repetitive movements in a computer-generated, non-immersive simulated environment. The training tasks were interactive, enriched, and task-orientated, and all movements were shown in real time at real speed as feedback. The virtual reality environment provides the opportunity for active learning, in which immediate feedback and task grading can optimise the motor learning process.[2] Repetitive and intensive task-specific training promotes cortical reorganisation and possibly contributes to functional recovery.[2] The subjects receiving BMCT thus demonstrated significant improvement in their movements, strength, and coordination, and in the functional use of their paretic upper limb.

In this study, there were no significant differences in the mean changes of SF-36 score between the two groups, likely because SF-36 is a generic outcome measure for assessing quality of life in stroke patients and the improvement may not be truly reflected in the changes of SF-36 score.

The findings of this study can only be generalised to stroke survivors fulfilling the study's inclusion criteria. Multicentre randomised trials are needed to confirm our findings. Moreover, patients' feedback, concentration, and motivation are all important aspects that require further investigation. The treatment effectiveness was assessed only up to 1 month after the treatment ended; the long-term effects and benefits remain unknown.

Conclusions

Sixteen sessions of 30-minute BMCT is superior to VDCT in improving motor control and functional use of the paretic upper limb after stroke. BMCT is a useful complement to conventional upper limb rehabilitation programmes for patients with subacute stroke.

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