

Virtual Reality Exercise Improves Mobility After Stroke

An Inpatient Randomized Controlled Trial

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Background and Purpose—Exercise using virtual reality (VR) has improved balance in adults with traumatic brain injury and community-dwelling older adults. Rigorous randomized studies regarding its efficacy, safety, and applicability with individuals after stroke are lacking. The purpose of this study was to determine whether an adjunct VR therapy improves balance, mobility, and gait in stroke rehabilitation inpatients.

Methods—A blinded randomized controlled trial studying 59 stroke survivors on an inpatient stroke rehabilitation unit was performed. The treatment group (n=30) received standard stroke rehabilitation therapy plus a program of VR exercises that challenged balance (eg, soccer goaltending, snowboarding) performed while standing. The control group (n=29) received standard stroke rehabilitation therapy plus exposure to identical VR environments but whose games did not challenge balance (performed in sitting). VR training consisted of 10 to 12 thirty-minute daily sessions for a 3-week period. Objective outcome measures of balance and mobility were assessed before, immediately after, and 1 month after training.

Results—Confidence intervals and effect sizes favored the treatment group on the Timed Up and Go and the Two-Minute Walk Test, with both groups meeting minimal clinical important differences after training. More individuals in the treatment group than in the control group showed reduced impairment in the lower extremity as measured by the Chedoke McMaster Leg domain ($P=0.04$) immediately after training.

Conclusions—This VR exercise intervention for inpatient stroke rehabilitation improved mobility-related outcomes. Future studies could include nonambulatory participants as well as the implementation strategies for the clinical use of VR.

Clinical Trial Registration—URL: <http://www.ANZCTR.org.au/>. Unique identifier: ACTRN12613000710729. (*Stroke*. 2014;45:1853-1855.)

Key Words: exercise movement techniques ■ gait ■ rehabilitation ■ virtual reality therapy

After a stroke, patients are often left with disabling motor impairments that disrupt balance and mobility, leading to reduced function and quality of life.¹ Virtual reality (VR) exercise programs use computer-simulated interactive environments to promote movement and have been shown to improve clinical measures of functional mobility in adolescents with cerebral palsy,² traumatic brain injury survivors,³ and community-living older adults.⁴ Rigorous studies, including inpatient populations, are lacking to confirm the benefits of VR for poststroke rehabilitation.⁵

The main objective of this randomized controlled trial was to examine the effect of VR exercise, as a supplement to a conventional inpatient stroke rehabilitation program, on outcome measures of balance, mobility, and motor impairment. We hypothesized that an intensive inpatient VR-based exercise program designed to challenge dynamic stability in standing would result in greater improvements in objective

measures of dynamic stability than a similar period of exposure to VR performed while sitting and thus not a challenge to dynamic stability.

A secondary objective included determining whether improvements persisted 1 month after discharge from the inpatient rehabilitation setting. We hypothesized that both groups would maintain gains in dynamic stability, with the treatment group retaining a higher level of improvement compared with the control group.

Methods

The study was a blinded, parallel-group randomized controlled trial with balanced (1:1) randomization considering 2 factors (age and preintervention Berg Balance Scale score) and was conducted on the inpatient stroke rehabilitation unit at the Élisabeth Bruyère Hospital between May 2011 and March 2013. Participants signed informed consent forms approved by the Research Ethics Board of Bruyère Continuing Care.

Received March 4, 2014; accepted March 25, 2014

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The online-only Data Supplement is available with this article at <http://stroke.ahajournals.org/lookup/suppl/doi:10.1161/STROKEAHA.114.005362/-/DC1>.

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Stroke is available at <http://stroke.ahajournals.org>

DOI: 10.1161/STROKEAHA.114.005362

Patients were included in the present study if they: (1) were ≥ 18 years of age; (2) could stand unaided for 1 minute at the time of enrollment; and (3) could provide informed consent. Patients were excluded if they presented with: (1) severe cognitive impairments (unable to follow instructions); (2) an unstable medical condition; (3) vestibular deficits or vertigo; or (4) seizure activity in the previous 6 months.

Of the 330 patients admitted to the stroke rehabilitation unit, 74 were enrolled, and outcome measures were assessed on 59 (30 treatment and 29 control) immediately after the final training session (POST) and on 52 (28 treatment and 24 control) 1 month after the cessation of training (1 MO; see flowchart in Figure 1 in the online-only Data Supplement). The first 30 participants were randomly assigned through coin-toss method to the control or treatment group, with subsequent participants being allocated using age and Berg Balance Scale scores to minimize group differences. Participants in the treatment group interacted with the VR games (eg, soccer goaltending, snowboarding) in a standing position, thereby challenging their balance and weight shifting. In contrast, individuals in the control group were seated and played games that did not require any weight shifting within their base of support. Participants in both groups completed 10 to 12 sessions of 20 minutes of interactive VR exercise using the Interactive Rehabilitation Exercise software (IREX; GestureTek; Toronto, Ontario, Canada; for a detailed description of individual games, see Methods in the online-only Data Supplement)⁶ in addition to their regular inpatient rehabilitation therapy sessions. Exposure time to VR exercise was similar in both groups (treatment group=176.6 minutes \pm 27.8 SD; control=179.1 minutes \pm 14.6 SD; $P=0.584$). Both the research assistant performing the assessments/evaluations and the participants were blinded to group allocation.

Clinical assessments of balance and mobility were completed 3 times: before the VR training, at POST, and 1 MO. The primary outcome measure was the Timed Up and Go test (TUG). Secondary outcome measures included the Two-Minute Walk Test (TMWT) and the Chedoke McMaster Stroke Assessment Scale Leg domain.

Table 1. Participant Stroke Information and Demographics

Characteristic	Treatment Group (n=30)	Control Group (n=29)	Overall (n=59)
Mean age \pm SD, y	62.2 \pm 14.1	66.0 \pm 15.8	64.1 \pm 15.0
Sex			
Male	16	16	32
Female	14	13	27
Side of stroke			
Left	12	9	21
Right	15	16	31
Bilateral	3	4	7
Type of stroke			
Ischemic	23	25	48
Hemorrhagic	7	4	11
Location of stroke			
Cortical	21	19	40
Subcortical	12*	20*	32
Mean No. of days between stroke and start of VR training \pm SD	30.1 \pm 18.9	39.6 \pm 17.8	34.8 \pm 18.8
Mean total FIM score on admission \pm SD	88.4 \pm 13.5	81.2 \pm 16.5	84.8 \pm 15.4

Demographics and stroke characteristics. Independent sample t tests and χ^2 tests were used to compare groups. Groups were similar on all characteristics excluding the number of subcortical strokes. FIM indicates functional independence measure; and VR, virtual reality.

* χ^2 ; $P=0.023$.

To test our hypothesis, the differences in improvements between groups are reported with 95% confidence intervals and effect sizes for the TUG and the TMWT. Because scores on the Chedoke McMaster Stroke Assessment Scale Leg domain ranged from 5 to 7, the data were transformed to a count data set in which a participant's score improved (+1), remained the same (0), or decreased (-1) from before the VR training to POST. The Fisher Exact test for count data was used to determine between-group differences in improvements on the Chedoke McMaster Stroke Assessment Scale Leg domain. Analysis focused on those completing the study and was not intention to treat.

Results

Demographic data for the 2 groups before the VR training are presented in Table 1. The VR training sessions did not lead to any falls, seizures, shortness of breath, or fainting. Confidence intervals and the effect sizes for the TUG and the TMWT are shown in the Figure.

Both groups met minimal clinical important difference values at POST for the TUG⁷ and the TMWT⁷ (Table 2). More individuals in the treatment than the control group showed improvements on the Chedoke McMaster Stroke Assessment Scale Leg domain at POST ($P=0.04$) and 1 MO ($P=0.02$).

Discussion

This study is the first randomized controlled trial demonstrating the positive effects on balance and mobility outcomes of a standing VR training program supplementing an inpatient stroke rehabilitation program. As expected from previous work on stroke rehabilitation,⁷ the participants in both groups improved and reached the minimal clinical important

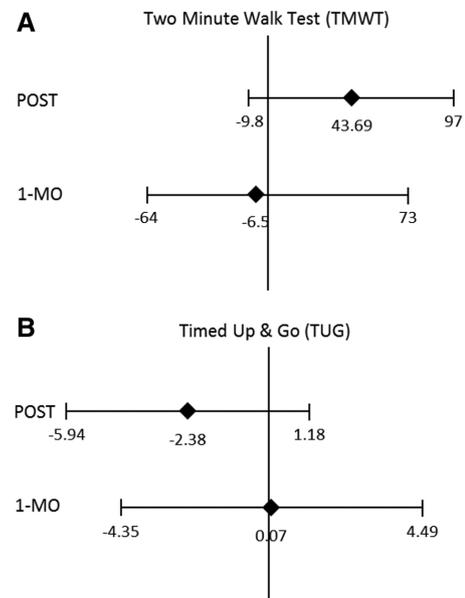


Figure. Ninety-five percent confidence intervals and effect size (black diamonds) for the difference in improvements immediately after the final training session (POST) and 1 month after the cessation of training (1 MO) are shown. For the Two-Minute Walk Test (TMWT; **A**), the effect size to the right of the zero line indicates an improvement, whereas for the Timed Up and Go test (TUG; **B**), the effect size to the left is indicative of improvement in favor of the treatment group.

Table 2. Minimal Clinical Important Differences

	TMWT, ft	CMSA-Leg	TUG, s
MCID	62	N/A	-4.8
Control			
Pre	279.1 (86.4)	5.9 (0.3)	22.5 (8.9)
Post	349.6 (103.5)	6.0 (0.3)	16.8 (5.2)
Post-pre	70.5*	0.1	-5.7*
Treatment			
Pre	327.3 (146.2)	5.9 (0.5)	21.4 (9.6)
Post	438.5 (153.6)	6.3 (0.5)	13.6 (6.0)
Post-pre	111.2*	0.4	-7.8*

Group averages (SD) are shown for both groups. CMSA-Leg indicates Chedoke McMaster Stroke Assessment Leg domain; MCID, minimal clinical important difference; N/A, not available; TMWT, Two-Minute Walk Test; and TUG, Timed Up and Go test.

*Changes that meet MCID for that measure.

differences for the TUG and the TMWT. However, there was a greater improvement in the treatment group with the addition of the standing VR intervention that the authors think is clinically meaningful. Such difference in improvements between groups was not significant for the TUG and the TMWT. This is likely because the study was underpowered. Post hoc power analysis suggests that 20 additional subjects per group would be needed to achieve statistical significance.

The results occurred in a group of higher functioning stroke patients (high score on the functional independence measure and ambulatory with or without the use of aids) who were also receiving intensive inpatient rehabilitation therapies. Therefore, the results here cannot necessarily be generalized to all stroke subgroup populations.

The improvement between before the VR training and 1 MO was relatively similar between both groups, indicating that the control group continued to make gains on balance and mobility outcome measures, reaching similar performance levels as the treatment group. We did not control or document activity levels (eg, additional physiotherapy or other exercise programs) of participants between POST and 1

MO, and therefore, we are unable to explain the difference in recovery rate after POST.

This study has shown that VR balance and mobility exercise are positive additions to inpatient stroke rehabilitation. Future studies will include nonambulatory inpatient participants, as well as explore administrative/scheduling challenges of an inpatient-based VR program for inpatient rehabilitation.

Acknowledgments

We sincerely thank the participants, the inpatient stroke rehabilitation staff, and Paddi O’Hara and Gloria Baker.

Sources of Funding

This study was supported by the Dr Tony Hakim Innovative Stroke Research Award, Heart and Stroke Foundation Centre for Stroke Recovery, and a personal donation from Tony and Elizabeth Graham. D. McEwen holds a Queen Elizabeth II Graduate Scholarship in Science and Technology and a University of Ottawa Excellence Scholarship.

Disclosures

None.

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Stroke. 2014;45:1853-1855; originally published online April 24, 2014;
doi: 10.1161/STROKEAHA.114.005362

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Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the World Wide Web at:

<http://stroke.ahajournals.org/content/45/6/1853>

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ONLINE SUPPLEMENT

Virtual reality exercise improves mobility after stroke: an in-patient, randomized control trial.

Supplemental Methods:

IREX Games used in the intervention:

VR games which trained mobility, lateral weight shifting and reaching were chosen for the intervention. The parameters of the games were modified according to group allocation. The game parameters for the treatment group were programmed to require the participants to reach for virtual objects located at extreme locations on the screen (up in the corners at the top, for example) which required the participant to laterally weight shift and reach to the limits of their standing balance. These participants were instructed to step and reach as far as they could. No such weight shifting or reaching movements were required by the control group because the virtual objects were programmed to appear in the center midline area of the screen and the instructions to these participants were to contact the virtual object only when it was in front of their body. The following games were played by both the treatment and the control groups:

1) Soccer goaltending: the participant stood in front of a “virtual soccer net” and attempted to prevent any goals being scored by blocking the ball with any part of his/her body. The treatment group was required to weight-shift, step and reach laterally towards the extreme areas of the net while the control group’s soccer balls required no body movements because their “virtual soccer balls” were being directed towards the midline of the body. ;

2) Birds & Balls: the participant was required to reach with their paretic hand and gently touch a variety of floating, coloured balls which caused them to weight shift and gauge the force with which they contacted the ball and transform it into a bird. The treatment group was instructed to reach for the balls as soon as they appeared in any area of the screen while the control group was instructed to not reach for the balls but rather touch them when the balls were positioned in front of their trunk;

3) Juggler: the participant was in a circus environment with balls floating down from the top of the screen and was required to “juggle” (keep the balls in the air) for as many consecutive hits as possible. The standing group had a wide play area requiring lateral stepping and reaching while the juggled balls in the control group were specifically programmed to fall within the centre (midline) area of the screen ;

4) Conveyor: the participant was in a factory setting located between two conveyor belts and was required to move boxes using the paretic arm from the non-affected to the affected side. The treatment group was required to lean and reach from a variety of heights and distances while the control group was limited to horizontal movements within the body area;

5) Sharkbait: the participant was immersed ‘underwater’ and needed to collect stars while avoiding sharks and eels. The treatment group was required to lean, squat and extend upwards to move around the water while the control group were able to move through the immersed “underwater “areas by moving one hand in front of their waist.

Additional games were played by the treatment group only as these games required full body movements which could not be adapted to a sitting posture. These games included the following:

Snowboarding, in which the participant was going down a ski hill and had to go over as many jumps as possible while avoiding other objects (i.e. rocks, trees, snowmen) by leaning side to side;

Formula Racer, where the participant was in a formula-1 race car and was required to navigate a track using lateral weight shifting while avoiding other racers as well as the sides of the track.

Supplemental Figures:

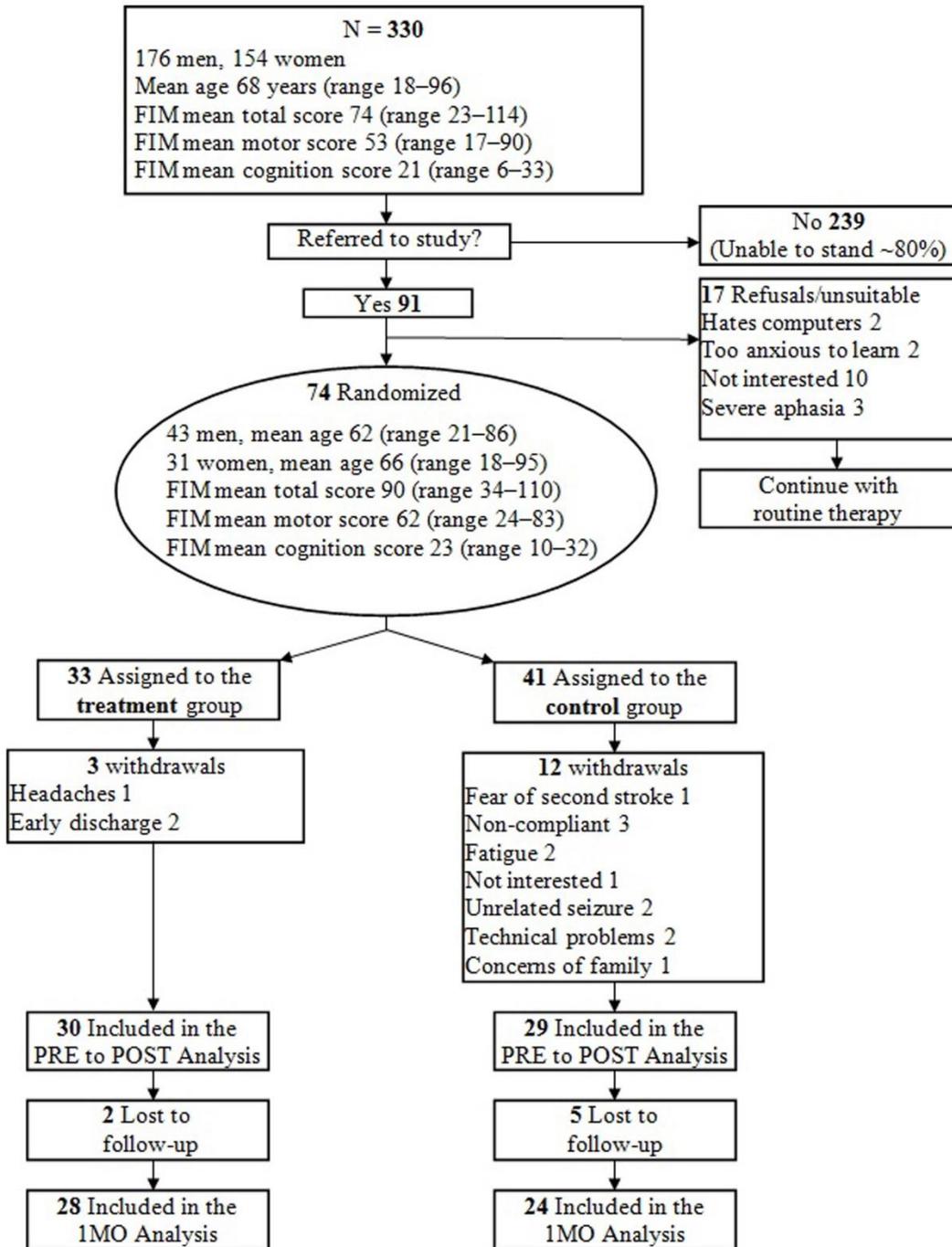


Figure I: Flow of participants through the study.



Figure II: VRRASS participant playing the soccer application. *LEFT:* Participants stood in front of a green screen with a physio belt around their waist while being monitored by a researcher (behind the participant). *RIGHT:* The participant sees himself immersed in a soccer net. Above the TV is the camera that captures the image of the participant. Photo used with permission of the participant.