

Kertas Asli/Original Article

A Pilot Study of the Efficacy of Interactive Virtual Reality Sports on Balance Performance among Older Women
[Kajian Amalan Keberkesanan Sukan Realiti Maya Interaktif ke Atas Pencapaian Keseimbangan di Kalangan Wanita Berusia]

BALA S. RAJARATNAM, HO WEI FANG, VANESSA GOH YOCK JUN, STELLA HONG YAN CHAI & DORIS LIM YAN SHAN

ABSTRAK

Pengenalan perawakan terkawal yang menilai peranan latihan sukan interaktif realiti maya adalah terhad. Kajian awalan ini mengukur efikasi latihan golf interactive virtual reality terhadap keupayaan keseimbangan di kalangan komuniti warga tua yang boleh bergerak. Lapan orang warga tua perempuan (52.5 ± 1.5 tahun) melakukan Multi-Directional Test (MDRT), Step Up Test (SUT), Double Leg Static Balance di dalam keadaan mata buka dan tutup serta perubahan pusat tekanan sway diukur menggunakan force plate. Pemilihan subjek dilakukan secara rawak kepada kumpulan kawalan (conventional mat exercise) dan eksperimentasi (interactive virtual reality golf). Seorang subjek keluar dari kumpulan eksperimentasi dan 3 orang dari kumpulan kawalan. Tiada perbezaan yang signifikan pada pengukuran data awalan keseimbangan di antara kumpulan. Kumpulan yang menjalani golf interaktif realiti maya tidak menunjukkan peningkatan keseimbangan yang signifikan berbanding kumpulan kawalan. Peningkatan pada pusat tekanan selepas golf interaktif realiti maya memberi petunjuk kepada peningkatan kawalan postur. Kajian lanjutan dengan populasi yang lebih besar perlu dijalankan dengan menggunakan off-the shelf interactive virtual reality golf untuk melatih keseimbangan. Teknologi nobel ini boleh menambahkan program rehabilitasi untuk mempercepatkan penyembuhan dan kekerapan senaman terutamanya dalam kondisi kronik anggota bawah.

Kata kunci: Realiti maya; golf; postural sway; keseimbangan, wanita berusia

ABSTRACT

This randomized control pilot study quantified the efficacy of interactive virtual reality golf training on balance performance among community mobile older person. Eight older women were assigned randomly to a conventional mat exercises program group ($n = 4$, mean age = 51 ± 1.6 years old) or an experimental group that participated in interactive virtual reality golf ($n = 4$, mean age = 53.5 ± 1.4 years old). Balance assessments of all participants included Multi-Directional Reach Test (MDRT), Step Up Test (SUT), Double Leg Static Balance (DLSB) with eyes open and closed and excursion of centre of pressure (COP) sway quantified with a force plate. One subject dropped out from the experimental group and three subjects from the conventional mat exercise group due to work commitments to complete the once a week study for four weeks. No significant differences in base-line balance abilities were found between groups. The experiment group did not have significant improvements in balance capability compared with control subjects (MDRT $p = 0.16-0.66$; SUT $p = 0.05$; COP during DLSB $p = 0.18-0.66$). However, virtual reality golf intervention improved medial-lateral sway by 57.24% during DLSB compared to 14.99% after floor-mat exercises. The improvement in COP during DLSB after interactive virtual reality golf hints towards improved postural control. Further studies with a larger population should explore using off-the shelf interactive virtual reality sports for balance training. This novel technology can complement rehabilitation programs.

Keywords: Virtual reality; golf; postural sway; balance; older women

INTRODUCTION

Proprioception sensitivity decreases with increasing age, resulting in greater postural sway, poorer balance and increase the risk of falls (Baloh et al. 1994; Era & Heikkinen 1985; Gabell & Nayak 1984; Maki et al. 1994; Lord et al. 1999; Ribeiro & Oliveria 2007). Furthermore, muscle spindles are less sensitive to detect joint position and movement senses with increase age (Verdue et al. 2000; Dinse 2006; Heimstra et al. 2001).

The older person who regularly participate in exercise, hydrotherapy and Tai Chi improved their proprioception and balance performance Brauer et al. 2000; Tsang & Hui-Chan 2003, 2004a & 2004b; DiBrezza et al. 2005; Marigold et al. 2005). For instance, participation in golf maintains one's coordination of the trunk and arm movements, and facilitates controlled weight shifting in single or double leg stance. Elderly golfers and individuals who participated in Tai Chi had significant better balance abilities compared to

young non-golfers and their age-matched counterparts who do not play golf (Tsang & Hui-Chan 2004a).

Despite knowing the benefit of exercise, sedentary older individuals' compliance to regular physical activity is difficult to achieve. Interactive virtual games may provide visual feedback, promote physical activity anytime and at any location and facilitate compliance (Health Games Research 2009).

Fun and self-directed interactive activities that provide knowledge of results feedback may improve exercise compliance among the older person. Participation in interactive virtual reality and videogames improved cancer-related knowledge (Beale et al. 2006), promoted physical activity among obese children (Carson et al. 2006), facilitated better management of chronic pediatric diseases (Lieberman 2001) and expedited upper limb motor recovery after stroke (University of South Carolina 2008).

The benefit of interactive virtual reality games such as golf is lacking. This pilot study evaluated if virtual reality training golf improved clinical and laboratory measures of balance among healthy older persons. The randomized controlled study hypothesized that interactive virtual reality golf can improve balance among older persons.

METHOD

Eight female community-dwelling volunteers (52.5 ± 1.5 years old) were conveniently selected from a local women's welfare organization to participate in this study. The investigators explained the purpose and risk of the study to all participants. On agreement to participate in the study, they signed an informed consent. The Ethics Committee of a local tertiary institution approved the study.

SUBJECTS

All eight subjects were community ambulant, lived independently and had no major neurological or musculoskeletal impairments or joint replacements and were cognitively alert.

Subjects who had visual or vestibular deficits, had experienced an ear infection within 2 weeks prior to program, had reported a fall within the last 6 months, or scored less than 19 on the Tinetti balance score were excluded.

OUTCOME MEASURES

The balance abilities of subjects were assessed before and after the experimental protocol using Multi-Directional Reach Test, Step Up Test and Double Leg Static Balance Protocol.

Multi-Directional Reach Test The Multi-Directional Reach Test (MDRT) has a high inter-rater reliability of ICC = 0.91-0.98, and moderate to good test-retest reliability of ICC = 0.66-0.83 (Newton 2001; Holbein-Jenny et al. 2005). It also has a high internal consistency (Cronbach's Alpha =

0.89) and moderate to good correlation with the Berg Balance Scale. Subjects were asked to stand next to a wall that had a measuring tape placed horizontally at the level of their acromion process of their dominant hand. They reached as far as possible, firstly in the forward and backward directions, and later in the left and right directions without moving their feet. Each direction was tested twice and the average reading recorded.

Step Up Test Step Up Test (SUT) required subjects to step on and off a 15 cm high step as many times as possible in 15 seconds with their dominant foot. The test simulated dynamic components of balance during daily activity. The test has a high test-retest reliability (Kappa coefficients = 0.97) and a good correlation of $r = 0.66$ with the Rivermead Mobility Index (Tyson & DeSouza 2004).

Double Leg Static Balance Protocol Double leg static balance (DLSB) required subjects to stand for 30 seconds on a force-plate platform with their eyes open (DLSB/EO). The amplitude of their body sway in the anterior-posterior direction (COPy) and medial-lateral (COPx) direction were recorded (Figure 1). The test was repeated with eyes closed (DLSB/EC). DLSB has a linearly correlated with Bergs Balance Scale (Era & Heikkinen 1985; Gabell & Nayak 1984; Maki et al. 1994, 49:72-84). Data was collection at 100 Hz. A low pass 15 Hz filter removed signals of noise.

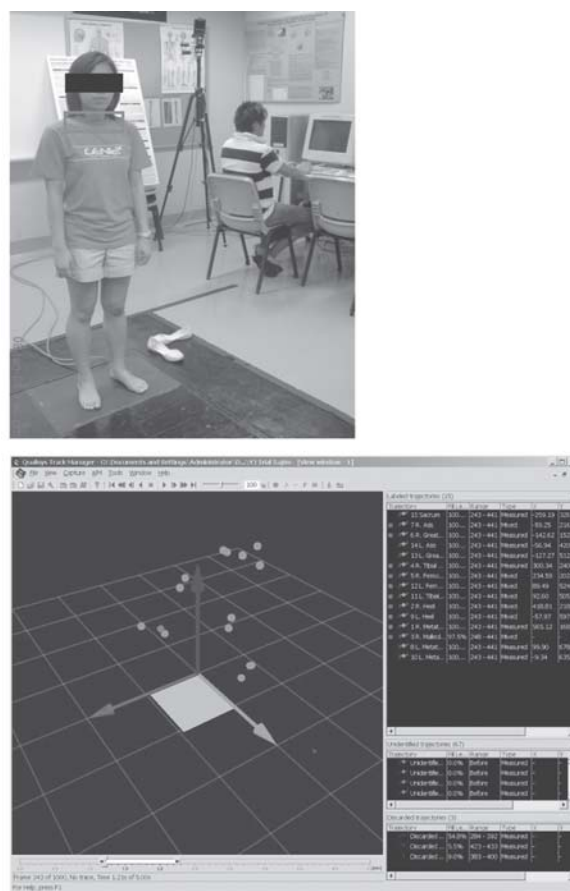


FIGURE 1. Subject standing on force plates to perform the Double Leg Static Balance (DLSB) protocol with eyes open and closed

After obtaining baseline data of their balance abilities, subjects were randomly assigned to either a control (conventional mat exercises program; $n = 4$, mean age = 51 ± 1.6 years old) or an experimental group (interactive virtual reality golf; $n = 4$, mean age = 53.5 ± 1.4 years old) (Figure 2). Both groups participated in assigned activities held once a week for 4 weeks. Each week the program commenced with a 5-minute warm-up segment follow by 20 minutes of low impact dance-like aerobics program synchronized to music (Figure 3a). Thereafter, the experimental group performed 30 minutes of virtual reality golf swings (Figure 3c) while subjects in the control group performed 30 minutes of floor-mat exercise focus on the musculature of their abdominal, buttocks and thighs in a separate room (Figure 3b). Both groups terminated each weekly session with a 5-minute cool down. After completion of the 4-week study, a blinded research assessed their balance performance. Three subjects in the control group and one from the experimental dropped out during the course of the study due to their inability to attend sessions because of work commitments.

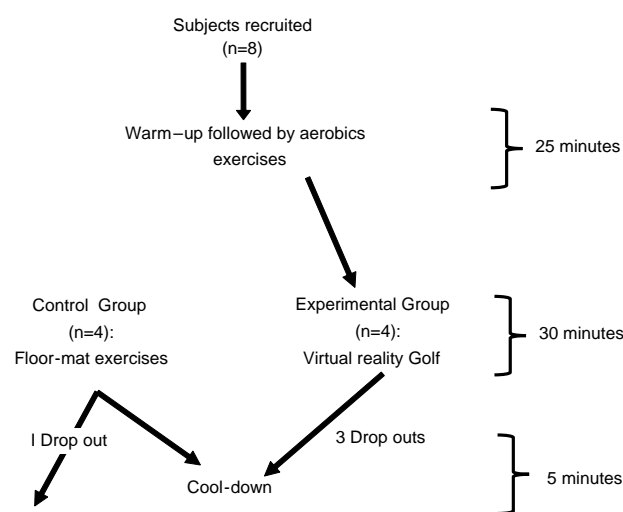


FIGURE 2. Flow-chart of exercise program for both control and experimental groups



FIGURE 3. All subjects performed aerobic exercise protocol (a). Control group performed floor-mat exercises (b) and experimental group virtual reality golf (c)

STATISTICAL ANALYSIS

Student Version of SPSS 12.0 for Windows evaluated differences in balances scores between groups. Non-parametric unrelated (Mann-Whitney U) and related (Wilcoxon W) tests compared significant differences in perimeters between the experimental and control groups. Both tests also compare pre and post data within each group, respectively. The significance level was $p < 0.05$.

RESULTS

Base-line evaluation of sway in medial-lateral (ML) direction in the x plane and anterior-posterior (AP) direction in the y plane during DLSB with eyes closed and open, MDRT and SUT had similar baseline values for both groups of subjects (Table 1). No significant effects of intervention were also found in balance ability.

The experimental group has a 16.10% and 25.0% improvement in forward (anterior) and backward (posterior) directions of MDRT respectively. The control group showed no improvement. Pre-post tests AP and ML sways during DLSB were not statistically significant in both groups (Table 1). The experimental group had a 57.24% positive improvement in mean amplitude of sway in ML direction during DLSB/EO and 51.84% improvement during DLSB/EC. The mean amplitude sway in the ML direction decreased after floor-mat exercises (14.99% during DLSB/EO, 11.67% during DLSB/EC). Subjects who participated in virtual reality golf showed more consistency in improvement in the patterns of postural sway especially in the ML direction after the intervention. (Table 1)

DISCUSSION

PRE-POST INTERVENTION BALANCE OUTCOMES

Although four weeks of interactive virtual reality golf did not statistically improve balance among older women compared with aerobic exercises in this pilot randomized control study, the experimental group showed improvements in balance measures in the medial-lateral directions. Medial-lateral sway is regulated by the load-unloading strategy where the left hip abductor moment and the contralateral right hip adductor moment act simultaneously on the pelvis segment to transfer load towards the contralateral limb while simultaneously decreasing the load on the ipsilateral limb and vice-versa (Karlsson & Frykberg 2000; Rietdyk et al. 1999). The load-unloading strategy is pivotal for postural stability during walking. Elderly rely more on hip movements during walking while young adults adopt the ankle strategy to control postural stability (Okada et al. 2001).

Based on this study's finding of a primary improvement in balance in medial-lateral direction between both groups of older subjects, virtual golf activities replicated the load-unloading strategy experienced during walking. Interactive

TABLE 1. Results of Multi-directional reach tests, Step-up test and Double leg stance balance (expressed as means & standard deviation)

Group & test session	MDRT Front (cm)	MDRT Back (cm)	MDRT Right (cm)	MDRT Left (cm)	SUT (no of times)	DLSB/EC COPx	DLSB/EC COPy	DLSB/EO COPx	DLSB/EO COPy
Pre test Experimental (n = 3)	29.5 ± 9.97	14.25 ± 8.17	22.58 ± 13.02	23.33 ± 7.95	14.67 ± 2.40	172.95 ± 84.68	141.51 ± 5.08	149.14 ± 76.67	153.60 ± 8.00
Pre test Control (n = 1)	33.75	23.50	23.00	31.00	17	98.16	148.95	87.06	74.59
Baseline significance	p = 0.180	p = 0.346	p = 0.180	p = 0.180	p = 0.052	p = 0.655	p = 0.655	p = 0.180	p = 0.655
Post test Experimental (n = 3)	31.58 ± 2.50	15.25 ± 4.82	19.42 ± 3.88	19.33 ± 2.63	14.67 ± 0.88	73.95 ± 36.02	159.16 ± 9.31	72.86 ± 41.01	383.78 ± 22.93
Post test Control (n = 1)	31.00	31.00	21.00	24.50	17	109.62	156.28	100.11	167.88
Pre-post-test significance	p = 0.157	p = 0.180	p = 0.655	p = 0.180	p = 0.051	p = 0.655	p = 0.180	p = 0.180	p = 0.655

MDRT = Multi-Directional Reach Test, SUT = Step-Up Test, DLSB/EC = Double Leg Static Balance with eyes closed, DLSB/EO = Double Leg Static Balance with eyes opened, COPx = centre of pressure in the ML direction, COPy = centre of pressure in the AP direction.

virtual reality golf is, thus a safe physical activity to perform anytime and at any location. Regular participation may improve balance during walking. To the best of our knowledge, this is the first randomized control study using off-the-shelf virtual reality games highlighting potential ability to improve balance among the older person.

This study also indicated a non-significant improvement in double leg static balance with eyes-closed and open in the y-direction in both groups of subjects. With the eyes closed, spatial clues of body position and changes are solely by the somatosensory system. Tsang & Hui-Chan (2004a & b) and Proske's (2005) expressed that repeated stimulation of muscle spindles induces plastic changes that synchronize neural recruitment of the motor neurons. Off-the-shelf virtual reality games seem to provide another therapeutic exercise approach to improve motor control to respond to sudden perturbations.

SUBJECTS COMPLIANCE TO INTERVENTION PROGRAM

An unexpected finding in our study was the high compliance amongst the subjects exposed to interactive virtual reality golf. Kessler and colleagues (2007) found that a short-term Pilates-inspired balance-training program improved postural stability among older adults. Bogaerts et al (2007) reported that new and interesting training methods might improve compliance by the older generation (5% dropout rate). Many of the subjects in the experimental group expressed their willingness to continue with the training despite having to travel to our institution each week to participate in the program without obtaining remunerations.

Interactive virtual reality sport-based exercises provide a novel, customized and challenging environment to increase practice volume and attention span in the comforts of their home (Betker et al. 2006). Repetitive practice of conventional exercises, inconvenience of frequently visit to rehabilitation centers and lack of customization especially

when conducted in group settings are factors that cause patients to lose interest of the rehabilitation program. Therapists should embrace off-the shelf technology to make therapy fun and exciting. Emerging technologies can motivate and improve patients' compliance to perform home exercise programs anytime and anywhere (Nichols 1997; Kaesler et al. 2007; Goh et al. 2008; Fagan 2008).

LIMITATIONS OF STUDY

Subjects who participate in this study had high postural balance scores recorded by the Tinetti screening test. On reflection, the experimental intervention may not have been sufficiently challenging. Moreover, due to the low power of this pilot study, results could be due to chance. These factors may explain the non-significant results of the balance tests results by both groups of older persons.

Secondly, we did not measure compliance using a well-designed outcome measure. Measuring compliance is an important factor that may improve outcome.

Lastly, the contribution of visual feedback in virtual reality game was not studied. Visual biofeedback may result in increased motivation level among the experimental subjects, leading to a better performance in balance more than the activity of in-door golf.

CONCLUSION

This pilot study supports further evaluation of the effectiveness of interactive virtual reality sports to improve outcome of rehabilitation programs. Virtual reality sports are safe and can attract older persons to adopt an active lifestyle to improve their balance. Further research with decreased balance ability subjects is required to conclusive establish this view. Exercises using interactive virtual reality devices could be combined with therapy.

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Bala S. Rajaratnam,
Ho Wei Fang
Vanessa Goh Yock Jun
Stella Hong Yan Chai
Doris Lim Yan Shan
School of Health Sciences
Nanyang Polytechnic

Corresponding author: Bala S. Rajaratnam
Email address: Bala_S_RAJARATNAM@nyp.gov.sg
Tel: 65501349

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