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Effects of balance-focused interactive games compared to therapeutic balance classes for older women

D. K. A. Singh, B. S. Rajaratnam*, V. Palaniswamy, V. P. Raman, P. S. Bong and H. Pearson†

Universiti Kebangsaan Malaysia, Faculty of Health Sciences, Kuala Lumpur, Malaysia; *Nanyang Polytechnic, Singapore; †Pantai Integrated Rehab Services Sdn Bhd, Pandan Indah, Kuala Lumpur, Malaysia

Key words: VIRTUAL REALITY, BALANCE, AGILITY, FUNCTIONAL MOBILITY, COMMUNITY-Dwelling older women

ABSTRACT

Objective The prospective pre–post control study was designed to evaluate the effect of introducing balance-focused interactive virtual-reality games to community-dwelling older women to improve their agility, balance and functional mobility.

Method The study was set in a senior citizens’ club in Cheras, Kuala Lumpur, Malaysia. The participants were 36 community-dwelling older women. Participants were randomly divided into either a group undertaking balance-focused virtual-reality games or a group doing therapeutic balance exercises. The program lasted 6 weeks and was conducted twice a week for 40 min during each session. As the main outcome measures, the results of the Ten Step Test (TST), postural sway (overall performance index, OPI) and the Timed Up and Go test (TUG) were measured pre- and post-intervention to evaluate agility, balance and functional mobility, respectively.

Results Although both groups improved in OPI ($F=4.63, p<0.001$), TST ($F=46.15, p<0.001$) and TUG ($F=52.57, p=0.03$), combined time and group interaction only improved in the TUG ($F=4.54, p<0.05$). No significant differences between the two groups were found in terms of TST ($F=0.02, p=0.86$), OPI ($F=0.66, p=0.42$), and TUG ($F=0.11, p=0.74$).

Conclusion Older people could improve their agility, balance and functional mobility by complementing therapeutic balance exercises with active participation in interactive virtual-reality games at home or in the community.

INTRODUCTION

By 2050, the world is expected to have 2 billion older adults aged 60 years or more and 54% of them will be residing in Asia. The older adult who adopts a sedentary lifestyle has poorer agility, balance and impairment in mobility compared to the aged-matched individual who exercises regularly at moderate intensity for 30 min at least 5 days a week. Thus, a regular exercise program for older adults should include balance and agility training components.

Balance training is important as the sensorimotor system starts to decline early in the fourth decade of life. Tai-Chi and golf are exercises that activate the sensorimotor system to improve balance, knee joint proprioception and limits of stability in the stance of older adults. Older adults are more likely to comply and adhere to physical activities that are engaging, interesting, motivating, and easy to perform compared to activities such as jogging, cycling and strength training. Performing exercises indoors may also be preferred so as to avoid the impact of outdoor weather.

Interactive virtual-reality games performed in the comfort of one’s own home and in the community present an opportunity for the older adult to keep agile and physically fit independently. The Wii Fit™ is a new-generation, interactive, virtual-reality game tool that immerses the user in a stimulating ‘real exercises’ environment. It is worth noting that 25% of today’s gamers are above the age of 60 years. Interactive virtual-reality games have varied levels of challenges and...
provide real-time visual feedback to improve older adults’ balance and lower limb muscle strength\(^{15,17}\). Interactive virtual-reality games can be performed at any time and at any location and are known to increase practice volume and attention span\(^{18-21}\). Interactive virtual-reality games and robot-assisted movement training have been shown to improve upper limb motor function after stroke\(^{22-23}\). Community-dwelling older women who participated in interactive virtual-reality games improved their balance\(^{15,18,24-26}\) and attention span, hand–eye coordination, motor skills, short-term memory, problem solving and reaction time\(^{27}\).

The current study evaluated the effect of introducing balance-focused, interactive, virtual-reality games compared to therapeutic balance exercise classes among community-dwelling older women to study the effect on their agility, balance and functional mobility. This study also investigated covariates of the pre-intervention physical status of older adults as confounding or interacting factors. If interactive virtual-reality games are found to improve the agility, balance and functional mobility of older adults, health-care professionals can introduce these games to be undertaken as exercises within the home as well as in rehabilitation units for older adults with dysfunction. Computer-literate older adults who are capable of exercising safely and in an unsupervised environment could also keep physically active within the comfort of their homes and in the community. A physically fit, older adult requires less medical services and places less strain on medical and long-term care facilities\(^{28}\).

**METHODS**

Forty-six women aged 56 years and above, who could ambulate without a walking aid and were willing to attend twice-a-week exercise programs, were recruited from a senior citizens’ club in Kuala Lumpur, Malaysia. Participants were excluded if they had severe cognitive impairments (Mini Mental State Examination score <23), vestibular and visual impairments that were not corrected, an ear infection 2 weeks before the intervention, were currently enrolled in a structured physical activity program. Lower OPI scores reflect better ability to regulate postural sway. An intelligent balance board, with perturbation features and attached to a computer screen that has an intra-class correlation coefficient of \(r = 0.916\) (Probalance, Lab Rehab Pte Ltd., Singapore), quantified each participant’s postural sway\(^{30}\).

When participants stood on the Probalance, they were instructed to keep their center of body mass within a circle shown on the computer screen for 30 s. Their anterior–posterior and medial–lateral sway scores were converted to an overall performance index (OPI) by the Probalance software program. Lower OPI scores reflect better ability to regulate postural sway.

Functional mobility was quantified by performing the Timed Up and Go (TUG) test. Participants were required to stand up from an arm chair (46 cm seat height and 65 cm arm height), walk 3 m as fast as possible, turn around and walk back to sit on the chair; the time they took was recorded\(^{31}\). The test–retest intra-class correlation coefficient of the TUG is \(r = 0.97^{31,32}\). The assessor who measured TST, OPI and TUG in weeks 1 and 7 was blinded to the type of intervention that each participant experienced (Figure 1).

**Procedure**

Thirty-eight participants were randomly allocated to the group undertaking the balance-focused, interactive, virtual-reality games (experimental) or to the therapeutic balance exercise group (control). One participant from each group withdrew after the first session. Thirty-six participants completed the 6-week intervention. Table 1 lists the demographic data of the 36 participants.

Both programs consisted of 5 min of warming-up exercises followed by 30 min of either the experimental or the control programs. The programs concluded with 5 min of cooling-down exercises. Sessions for both groups were conducted twice weekly for six continuous weeks.

Participants in the experimental group performed the exercises using the Nintendo\(^{\text{®}}\) Wii balance board. The virtual-reality games selected for this study were Ski Slalom, Table Tilt, Penguin Slide, Soccer Heading, Tight Rope Walk, Perfect 10 and Tilt City. Participants progressed within each game at their own pace from the beginner level to the advanced level, and then to the expert level.

Participants in the control group performed five balance tasks adapted from the protocol of Seidler and Martin\(^{33}\). The tasks were ‘one leg standing’, ‘free leg swinging’, ‘moving objects forward, backwards and sideways’, and ‘walking in place, sideways and backwards’. Participants progressed by increasing their speed of performance and the complexity of each task. For example, the complexity of ‘one leg standing’ progressed from standing with the eyes opened, to standing with the eyes closed and finally standing on foam with eyes opened.

Data was analyzed with a two-way repeated measure (ANOVA) with time and group as the within- and between-subject variables. SPSS software version 19 was utilized during the analysis.
RESULTS

The demographic data of the participants are shown in Table 1. There were no significant differences in age and body mass index between the groups.

The results indicated significant within-group improvement in TST, OPI and TUG due to the intervention (TST, $F = 46.15$, $p < 0.001$; TUG, $F = 52.57$, $p < 0.001$; OPI, $F = 4.63$, $p = 0.03$). The between-group effect showed no significant difference in TST ($F = 0.02$, $p = 0.86$), OPI ($F = 0.66$, $p = 0.42$) and TUG ($F = 0.11$, $p = 0.74$). Analysis of time and group interaction showed significant effect in TUG ($F = 4.54$, $p = 0.04$) (Table 2). No significant effects were demonstrated for TST ($F = 1.17$, $p = 0.29$) and OPI ($F = 1.32$, $p = 0.26$) (Table 2). Figure 2 depicts the percentage improvement in the virtual-reality game group and the therapeutic balance exercise group post-intervention.

DISCUSSION

This study demonstrated that community-dwelling older women who participated in regular, interactive, virtual-reality games could improve their agility, balance and functional mobility. The improvements were similar to the outcomes of older women who participated in a therapeutic balance exercise program. Thus, therapists working in community settings can introduce interactive virtual-reality games to community-dwelling older adults to improve their balance and minimize their risk of falls.

Table 1  Demographic data of participants. Data are given as mean ± standard deviation

<table>
<thead>
<tr>
<th></th>
<th>Experimental group $(n = 18)$</th>
<th>Control group $(n = 18)$</th>
<th>Analysis of covariance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>$61.12 ± 3.72$</td>
<td>$64.00 ± 5.88$</td>
<td>0.08</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>$29.54 ± 5.01$</td>
<td>$27.31 ± 4.31$</td>
<td>0.10</td>
</tr>
</tbody>
</table>
Agility is the ability to change positions and directions quickly, with accuracy and without loss of balance. Regular participation in virtual-reality games requires repetitive performance of visual neuromotor actions that are quick and precise to respond effectively to disturbances of body equilibrium during activities. Our results indicated an 18% improvement in agility after participating in the balance-focused, interactive, virtual-reality games for 6 weeks compared with therapeutic balance exercises. To the best of our knowledge, this is the first study that has quantified agility improvement among community-dwelling older women after they participated in a regular, interactive, virtual-reality games-based program.

Our findings are in agreement with other studies that also found improvement using virtual-reality games among participants with impaired balance, neurological impairment, healthy older adults, and young adults. Balance-focused, virtual-reality games require one to decrease one’s postural sway to move safely and repeatedly in all directions. The percentage of improvement in body sway among those who participated in balance-focused, interactive, virtual-reality games compared to therapeutic balance exercises was 21% higher (Figure 2). The results suggest that older women, who can exercise safely alone and are unable to attend rehabilitation, can participate in regular, interactive, virtual-reality games in their homes or in community settings.

Functional mobility to rise from sitting to standing, walk a distance and turn around and return to sit also improved after participation in balance-focused, interactive, virtual-reality games. Our results concur with similar findings among patients after stroke and the elderly who used the Wii Fit system. However, TUG scores of those in the therapeutic balance exercise group improved 9.54% more than those in the interactive, virtual-reality games group. One explanation would be that balance-focused, interactive, virtual-reality games confine one’s body sway within the Wii balance board whereas therapeutic balance exercises allow one to move around freely during exercise and thus the performance more.

### Table 2: Comparison of time and group interaction effects on TST, OPI and TUG in the balance-focused, interactive, virtual-reality games group (experimental) and therapeutic balance exercise group (control). Data are given as mean ± standard deviation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Experimental group (n = 18)</th>
<th>Control group (n = 18)</th>
<th>Analysis of covariance</th>
</tr>
</thead>
<tbody>
<tr>
<td>TST pre-intervention (s)</td>
<td>19.96 ± 4.20</td>
<td>20.86 ± 5.37</td>
<td>1.17  0.29</td>
</tr>
<tr>
<td>TST post-intervention (s)</td>
<td>16.35 ± 4.37</td>
<td>15.89 ± 2.88</td>
<td></td>
</tr>
<tr>
<td>OPI pre-intervention (score)</td>
<td>1.43 ± 0.36</td>
<td>1.40 ± 0.79</td>
<td>1.32  0.26</td>
</tr>
<tr>
<td>OPI post-intervention (score)</td>
<td>0.99 ± 0.42</td>
<td>1.27 ± 0.64</td>
<td></td>
</tr>
<tr>
<td>TUG pre-intervention (s)</td>
<td>9.55 ± 1.48</td>
<td>10.24 ± 1.88</td>
<td>4.54  0.04*</td>
</tr>
<tr>
<td>TUG post-intervention (s)</td>
<td>8.27 ± 1.64</td>
<td>7.90 ± 1.30</td>
<td></td>
</tr>
</tbody>
</table>

†, Time and group interaction effect; *, p < 0.05

TST, Ten Step Test; OPI, overall performance index; TUG, Timed Up and Go

![Figure 2](image) Percentage improvement after training on agility, balance and functional mobility. *, p < 0.05 in comparison with change between virtual-reality balance games and therapeutic balance exercise group post-training. TST, Ten Step Test; OPI, overall performance index; TUG, Timed Up and Go
closely resembles the functional mobility required in activities of daily living. Developers of interactive virtual games should include safe functional mobility activities in their design of future games for the older adult. Nevertheless, older adults who regularly participate in balance-focused, interactive, virtual-reality games can improve their functional mobility.

Health-care professionals could work with interactive digital media developers to design rehabilitation-focused games to keep the growing number of older adults physically active and disability-free. Rehabilitation-focused games must also have features to measure therapeutic outcomes besides providing the older adult with immediate feedback to monitor their own progress at home and in the community. The outcomes can be transmitted remotely to a virtual rehabilitation therapist for analysis and progression of treatment. Besides promoting physical activity and better therapeutic outcomes among community-dwelling older adults, their collaborative work can go one step further to design safe and beneficial rehabilitation-focused fall-prevention games for the growing number of older adults at risk of falls. The collaboration may result in commercially available rehabilitation-focused, interactive, virtual-reality games in the future that would be included within therapy sessions to reduce clinicians’ time in implementing rehabilitation programs. In addition, rehabilitation-focused games may empower older adults to take responsibility for their own physical and mental fitness and well-being.

One of the limitations of this study is the therapeutic balance program adapted from the study of Seidler and Martin which was modified to mimic the exercises in the balance-focused, interactive, virtual-reality games-based group. This may explain why no significant differences were demonstrated between the groups. Second, as the study was performed in community-dwelling older women, the results of this study may not be applied to institutionalized older adults.

CONCLUSIONS

Participation in regular, balance-focused, interactive, virtual-reality games improved the agility, balance and functional mobility of community-dwelling older women. Collaboration between health-care professionals and virtual-reality game developers should result in the development of simple yet effective rehabilitation-focused, interactive, virtual-reality games than can measure therapeutic outcomes for use in the community, in rehabilitation centers and at home. Participation in rehabilitation-focused, interactive, virtual-reality games could also be part of the overall preventative management strategy to keep the mobility of older adults in the community, and at lesser risk of falls and disability.

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Conflict of interest We certify that we have no affiliation with or financial involvement (e.g. employment, consultancies, honoraria, stock ownership or options, expert testimony, grants and patents received or pending, royalties) with any organization or entity with a financial interest in, or financial conflict with, the subject matter or materials discussed in the manuscript and all such affiliations and involvements are disclosed in the manuscript.

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