Adherence to Technology-Based Exercise Programs in Older Adults: A Systematic Review

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Publication details:
Journal of Geriatric Physical Therapy
v. 41
Chapter No. 1
Medium: Print
pp. 49 - 61
1539-8412 (ISSN); 2152-0895 (ISSN)

Publication Date:
2018-01-01

Publisher DOI:
https://doi.org/10.1519/JPT.0000000000000095

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Adherence to Technology-Based Exercise Programs in Older Adults: A Systematic Review

Trinidad Valenzuela, AEP, MSc\textsuperscript{1,2}; Yoshiro Okubo, PhD\textsuperscript{1,3}; Ashley Woodbury, AEP\textsuperscript{1}; Stephen R. Lord, PhD\textsuperscript{1}; Kim Delbaere, PhD\textsuperscript{1}

ABSTRACT
Background and Purpose: Exercise participation and adherence in older people is often low. The integration of technology-based exercise programs may have a positive effect on adherence as they can overcome perceived barriers to exercise. Previous systematic reviews have shown preliminary evidence that technology-based exercise programs can improve physical functioning. However, there is currently no in-depth description and discussion of the potential this technology offers to improve exercise adherence in older people. This review examines the literature regarding older adults' acceptability and adherence to technology-based exercise interventions.

Methods: A comprehensive systematic database search for randomized controlled trials, clinical controlled trials, and parallel group trials was performed, including MEDLINE, PsycINFO, EMBASE, CINAHL, EMB Reviews, and Cochrane Library, completed in May 2015. Trials reporting adherence to technology-based exercise programs aimed at improving physical function were included. Adherence was defined as the percentage of exercise sessions attended out of the total number of sessions prescribed.

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Trinidad Valenzuela was supported by a UNSW Doctorate scholarship; Stephen R. Lord was supported by NHMRC as a Senior Principal Research Fellow; Kim Delbaere was supported by an NHMRC as a Career Development Fellow; and Yoshiro Okubo was supported by a JSPS Postdoctoral Fellow for Research in Abroad.

The authors declare no conflicts of interest.

Supplemental digital contents are available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.jgptonline.com).

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Richard W. Bohannon was the Decision Editor.

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DOI:10.1519/JPT.0000000000000095

Results: Twenty-two studies were included. The mean cohort age range was 67 to 86 years. Studies were conducted in research facilities, aged care facilities, and people's homes. Ten studies compared outcomes between technology-based and traditional exercise programs. Adherence to both types of interventions was high (median 91.25% and 83.58%, respectively). Adherence was higher for technology-based interventions than traditional interventions independent of study site, level of supervision, and delivery mode. The majority of the studies used commercially available gaming technologies, and both types of exercise interventions were mostly supervised. A lack of detailed reporting of adherence and the pilot nature of most studies did not allow computation of a comprehensive adherence rate.

Discussion: This systematic review provides evidence that technology offers a well-accepted method to provide older adults with engaging exercise opportunities, and adherence rates remain high in both supervised and unsupervised settings at least throughout the first 12 weeks of intervention. The higher adherence rates to technology-based interventions can be largely explained by the high reported levels of enjoyment when using these programs. However, the small sample sizes, short follow-up periods, inclusion of mostly healthy older people, and problems related to the methods used to report exercise adherence limit the generalizability of our findings.

Conclusion: This systematic review indicates that technology-based exercise interventions have good adherence and may provide a sustainable means of promoting physical activity and preventing falls in older people. More research is required to investigate the feasibility, acceptability, and effectiveness of technology-based exercise programs undertaken by older people at home over extended trial periods.

Key Words: adherence, aged, exercise, exergame, technology

(J Geriatr Phys Ther 2018;41:49-61.)

INTRODUCTION

Decline in physical functioning predisposes older adults to loss of independence, poor quality of life, hospitalization, and falls. Older adults who fall often have reduced muscle strength, poor balance, and limited functional ability. These fall risk factors can be improved through properly designed exercise programs and increased physical activity.\textsuperscript{1,2} Despite this evidence and the availability of best-practice clinical guidelines to support exercise interventions for improving function and preventing falls in older adults, exercise participation and adherence in older people is often low.\textsuperscript{3}
Barriers to regular participation in physical activity include lack of time and motivation, boredom, fear of falling, and environmental considerations such as inconvenience, accessibility, safety, and cost. Furthermore, older adults who are new to exercising can often feel intimidated by fitness facilities and group exercise settings.

Interactive exercise-based video games (also known as “exergames”) were initially designed to provide enjoyable exercise opportunities for children and young adults. In recent years, exergames have been used to promote physical activity and improve program adherence in individuals undergoing rehabilitation, who have an acute or chronic illness, or have a physical or developmental impairment. The adoption of these technologies in older people may increase exercise uptake and long-term adherence as they can overcome many perceived barriers to exercise as they are engaging, provide immediate feedback, and can be individually tailored and progressed.

Previous systematic reviews have shown preliminary evidence that technology-based exercise programs can improve physical functioning. There is also promising new evidence that interactive cognitive-motor interventions can improve both physical and cognitive fall risk factors in older adults. The aim of this systematic review is to examine the literature regarding the use of technology-based exercise interventions to improve physical functioning in older adults, and explore older adults’ acceptability and adherence to such programs.

**METHODS**

**Registry of This Systematic Review Protocol**
The protocol for this review (which complies with the Preferred Reporting Items for Systematic review and Meta-analysis guidelines) was prospectively registered with the International Prospective Register of Systematic Reviews (PROSPERO) (registration number CRD42015019896).

**Search Strategy**
Electronic database searches were performed in MEDLINE, PsycINFO, EMBASE, CINAHL, EMB Reviews, and Cochrane Library from the earliest available year of publication to May 2015. Permutations of keyword combinations for the following categories were used: (i) population: aged, elder, geriatric, senior, older, and (ii) technology: “computer gam*”, “video gam*”, “computer assisted gam*”, exergame*, “virtual reality”, and (iii) exercise: exercise exercise therapy, “physical activit*”, “physical train*”. The following additional criteria were then applied: not (stroke or Parkinson* or multiple sclerosis or cerebral palsy or brain injury or child* or adolescent*). References for all eligible articles and systematic reviews identified from electronic database searches were manually searched for any articles missed by the database searches. No language restrictions were applied.

**Inclusion and Exclusion Criteria**
Randomized controlled trials, controlled clinical trials, and parallel group trials that used technology as a means to deliver an exercise intervention to older people were included. Exercises could be delivered using a number of technologies, for example, gaming consoles, stepping systems, virtual reality systems, and other custom design software. Trials that used technology alone, or in combination with other forms of training, such as conventional physiotherapy, were included. Trials in which participants assigned to the control group participated in usual daily activities, usual care or other forms of exercise were included. Studies that used technology solely to provide feedback or encouragement to participants, but not to provide the exercise intervention, were excluded. To be included, trials had to report at least 1 physical function outcome (such as balance, strength, reaction time, or gait speed) and measures of exercise adherence to the technology-based exercise intervention had to be identifiable. Adherence was defined as percentage of exercise sessions attended out of the total number of sessions prescribed.

The target population was older adults with a minimum age of 60 years and a mean age of 65 years and over, independent in activities of daily living and living in community settings. This included private homes, independent living units, retirement villages, and low-care residential care facilities. Studies including participants with an underlying condition, but not recruited specifically because of the condition, were included. Studies investigating disease-specific samples (eg, dementia, Parkinson’s disease, multiple sclerosis, stroke, knee osteoarthritis) were excluded. Study protocols, abstracts, conference proceedings, and articles published in languages other than English were excluded.

**Selection and Quality Assessment**
Titles and abstracts of studies were screened by 1 reviewer to identify studies that potentially met the inclusion criteria. The full texts of these studies were retrieved and independently assessed for eligibility by 2 reviewers. Any disagreement was resolved through discussion with a third reviewer. Articles that did not meet all the criteria were excluded (Figure 1). Two reviewers independently assessed the quality of included studies using the PEDro scale (see Table, Supplemental Digital Content 1, http://links.lww.com/JGPT/A6, which summarizes the quality assessment of the included studies). Disagreements were resolved by discussion and with the involvement of a third reviewer.

**Data Extraction and Procedure**
Data were extracted into tables using the following headings: Cohort and Intervention Characteristics (Table 1), Adherence and Dropout Rates (see Table, Supplemental Digital Content 2, http://links.lww.com/JGPT/A7, which summarizes the adherence and dropout rates for the technology-based and traditional exercise groups), and
Enjoyment and Acceptability of Technology-Based Exercise Interventions (see Table, Supplemental Digital Content 3, http://links.lww.com/JGPT/A8, which presents outcomes related to participant’s enjoyment and program acceptability). Two reviewers independently vetted the articles regarding the data extraction measures. Adherence and dropout rates were calculated in percentages if not already provided. For adherence, the average number of attended sessions (by participants who completed the intervention) out of the total number of sessions prescribed was used. If needed, authors of included articles were contacted to provide missing data. Descriptive statistics were performed on adherence rates for each intervention component (technology-based and traditional exercise) by generating a percentage of exercise sessions completed for each intervention program, and then calculating the median and ranges from all the intervention programs (Table 2).

RESULTS
A total of 22 studies were eligible for review. The flow of retrieved articles to final inclusion and reasons for exclusion are displayed in Figure 1.

Study Characteristics

Quality assessment
The quality of the reviewed studies varied largely (minimum score 1, maximum score 7), with most studies (64%) being of moderate quality (PEDro score between 4 and 6). Sixteen studies (73%) were randomized controlled trials and 6 studies (27%) were nonrandomized controlled trials. In general, most studies reported eligibility criteria (86%), had similar groups at baseline regarding the most important prognostic indicators (91%), conducted between-group analysis (77%), and reported measures of variability for the primary outcome (100%). Only 8 studies (36%) had blinded assessors. No studies had blinding of participants or therapists who administered the therapy.

Cohort characteristics
An overview of the cohort characteristics is provided in Table 1. Samples were categorized as either “independent” if participants lived in their own homes or “residential age care” if participants lived in an aged care facility. Participants were further categorized as “healthy” or “high-risk” if frailty, muscle weakness, balance and gait impairment or residing in an aged care facility were study inclusion criteria. Nine studies (41%) included healthy participants; 6 studies (27%) included independent-living high-risk participants; 6 studies (27%) included high-risk participants living in residential age care facilities (RACF); and 1 study included high-risk participants living either independently or in RACF. The number of participants included in the studies ranged from 12 to 82 (median 34.5) and the

Figure 1. Flow chart of study selection process.
Table 1. Cohort and Intervention Characteristics

<table>
<thead>
<tr>
<th>Study Author</th>
<th>Study Design; Period; Sample Size; PEDro Score</th>
<th>Sample</th>
<th>Technology; Games (Exercises); Additional Components</th>
<th>Technology Based Exercise Intervention</th>
<th>Control Exercise Intervention</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bierlyla and Doid</td>
<td>RCT; 3 wk; n = 12; score: 3</td>
<td>81.3 ± 5.6; 83% independent; healthy</td>
<td>Wii Fit-balance board; yoga (half-moon, chair, warrior), soccer heading; ski jump, torso twists</td>
<td>Balance, endurance†</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Chiao et al</td>
<td>CT; 4 wk; n = 32; score: 4</td>
<td>85.2 ± 6.4; 72% RACF; high-risk</td>
<td>Wii-balance board; balance, run, lunge, penguin slide, table tilt; chair and deep breathing (yoga)</td>
<td>Balance, strength, endurance†</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Daniel</td>
<td>RCT; 15 wk; n = 23; score: 4</td>
<td>77.1 ± 4.6; 61% independent and RACF; high-risk</td>
<td>Wii Fit; bowling, tennis, boxing with a weighted vest</td>
<td>Balance, strength†</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>de Bruin et al</td>
<td>CT; 12 wk; n = 35; score: 3</td>
<td>86.2 ± 7.2; 70% RACF; high-risk</td>
<td>Dance pad; PC; projector; step mania</td>
<td>Stepping Game levels ↑</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Duque et al</td>
<td>RCT; 6 wk; n = 70; score: 4</td>
<td>76.8 ± 8.9; 62% independent; high-risk</td>
<td>Balance rehabilitation unit; mazes, breakfast, surfing</td>
<td>Balance Game levels ↑</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Franco et al</td>
<td>RCT; 3 wk; n = 38; score: 5</td>
<td>78.3 ± 6.4; 79% independent; healthy</td>
<td>Wii Fit-balance board; soccer heading, ski jumping, ski slalom, tightrope game, table tilt, balance bubble</td>
<td>Balance Game levels ↑</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Hagedorn and Hdm</td>
<td>RCT; 12 wk; n = 35; score: 4</td>
<td>81.3 ± 5.7; 67% independent; high-risk</td>
<td>Computer feedback system with infrared sensors to register body position; building tower (standing on the spot), bursting balloons (toe-raises), water and fruit catch (right-left weight shift)</td>
<td>Balance Game levels ↑</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

Table continues...
<table>
<thead>
<tr>
<th>Study Author</th>
<th>Study Design; Period; Sample Size; PEDro Score</th>
<th>Sample Technology-Based Exercise Intervention</th>
<th>Control Exercise Intervention</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Janssen et al.34</td>
<td>CT; 12 wk; n = 29; score: 6</td>
<td>81.7 ± 9.2; 69%: RACF; high-risk</td>
<td>IG1 and IG2: Nintendo Wii Fit Plus-balance board; “Table Tilt Plus” and 2 other games. Note: G1: Participants had previous experience using Wii Fit Plus; G2 did not have previous experience using Wii Fit Plus</td>
<td>Balance; Game levels ↑</td>
</tr>
<tr>
<td>Jorgensen et al.16</td>
<td>RCT; 10 wk; n = 58; score: 7</td>
<td>74.8 ± 5.9; 69%: independent; high-risk</td>
<td>Wii Fit-balance board; Table tilt, slalom ski, perfect 10, tight rope tension, penguin slide</td>
<td>Balance; Game levels ↑</td>
</tr>
<tr>
<td>Keogh et al.35</td>
<td>CT; 8 wk; n = 34; score: 5</td>
<td>82.8 ± 7.0; 86%: independent; high-risk</td>
<td>Wii Sport; baseball, boxing, golf, tennis, and 10-pin bowling</td>
<td>Balance; Game levels ↑</td>
</tr>
<tr>
<td>Kim et al.17</td>
<td>RCT; 8 wk; n = 36; score: 7</td>
<td>67.4 ± 3.8; 86%; independent; healthy</td>
<td>Xbox 360 KINECT; Tai Chi and yoga exercises following avatar (4 major motions)</td>
<td>Balance; strength</td>
</tr>
<tr>
<td>Lai et al.25</td>
<td>RCT/C; 6 wk; n = 30; score: 4</td>
<td>72.7 ± 4.1; 57%: independent; healthy</td>
<td>Step mat, console, television; walking in virtual environment</td>
<td>Stepping;</td>
</tr>
<tr>
<td>Lee et al.26</td>
<td>RCT; 10 wk; n = 82; score: 5</td>
<td>75.2 ± 6.6; 71%: independent; healthy</td>
<td>Wii Fit-remote and balance board; boxing, tennis, bowling, table tilt, slalom ski, perfect 10, penguin slide, tight rope, obstacle course</td>
<td>Balance; Game levels ↑</td>
</tr>
<tr>
<td>Malott et al.27</td>
<td>RCT; 12 wk; n = 32; score: 5</td>
<td>73.5 ± 3.6; 84%: independent; healthy</td>
<td>Wii Fit; sports-remote and balance board; tennis, boxing, bowling, soccer headers, ski jump, marbles, ski slalom, hula hoop, trampoline, and tennis return of serve</td>
<td>Balance; general fitness</td>
</tr>
</tbody>
</table>

(continues)
<table>
<thead>
<tr>
<th>Study Author</th>
<th>Study Design; Period; Sample Size; PEDro Score</th>
<th>Sample Characteristics</th>
<th>Technology-Based Exercise Intervention</th>
<th>Control Exercise Intervention</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pichierri et al 28</td>
<td>RCT; 12 wk; n = 25; score: 4</td>
<td>Age: 84.6 ± 4.9; % Female: 60%; high-risk</td>
<td>Custom step system mat; dance game</td>
<td>Stepping Game levels ↑</td>
<td>RACF; supervised; group</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ Balance, strength</td>
<td>Balance, strength</td>
<td>Base of support ↓; weight ↑</td>
<td>20 min; 2 d/wk</td>
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<tr>
<td>Pichierri et al 29</td>
<td>RCT; 12 wk; n = 31; score: 4</td>
<td>Age: 86.3 ± 4.7; % Female: 82%; high-risk</td>
<td>Custom step system mat; dance game</td>
<td>Stepping Game levels ↑ (number of distracting visual cues ↑)</td>
<td>RACF; supervised; individual</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>+ Balance, strength</td>
<td>Balance, strength</td>
<td>Base of support ↓; speed ↑</td>
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<tr>
<td>Rendon et al 30</td>
<td>RCT; 6 wk; n = 40; score: 6</td>
<td>Age: 84.5 ± 5.3; % Female: 65%; independent; high-risk</td>
<td>Wii Fit-balance board; lunges, single-leg extensions and twists following onscreen visual displays</td>
<td>Balance</td>
<td>Dance pad, TV, console; adapted step mania game</td>
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<tr>
<td>Schoene et al 18</td>
<td>RCT; 8 wk; n = 37; score: 7</td>
<td>Age: 78 ± 4.9; % Female: NR; independent; healthy</td>
<td>Dance pad, TV, console; adapted step mania game</td>
<td>Stepping Game levels ↑</td>
<td>Home; unsupervised; individual</td>
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<td></td>
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</tr>
<tr>
<td>Silveira et al 36</td>
<td>CT; 12 wk; n = 44; score: 2</td>
<td>Age: 75.1 ± 10.3; % Female: 64%; independent; healthy</td>
<td>Tablet-computer application; strength and balance exercises following avatar. Two versions of the app: individual and social</td>
<td>Balance</td>
<td>Tablet-computer application; strength and balance exercises following avatar. Two versions of the app: individual and social</td>
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<tr>
<td>Szurm et al 20</td>
<td>RCT; 8 wk; n = 30; score: 7</td>
<td>Age: 80.8 ± 6.5; % Female: 63%; independent; high-risk</td>
<td>Pressure mat, PC; under pressure, memory match and balloon burst</td>
<td>Balance</td>
<td>Pressure mat, PC; under pressure, memory match and balloon burst</td>
</tr>
<tr>
<td></td>
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</tbody>
</table>

(continues)
### Table 1. Cohort and Intervention Characteristics (Continued)

<table>
<thead>
<tr>
<th>Study Author</th>
<th>Study Design; Period; Sample Size; PEDro Score</th>
<th>Sample Characteristics</th>
<th>Technology-Based Exercise Intervention</th>
<th>Control Exercise Intervention</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Touliote et al.</td>
<td>RCT; 20 wk; n = 36; score: 5</td>
<td>Age: 77.6 ± 7.3 yrs; % Female: 61%; Living Status: independent; healthy</td>
<td>IG1: Wii Fit; soccer, ski jumping, yoga, downhill skiing, game balls and tightrope walker. IG2: Wii fit (as above)</td>
<td>IG1: 60 min; 1 d/wk IG2: 30 min; 1 d/wk</td>
<td>Yes Center (gymnasium); supervised; individual</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>IG2: + balance, strength, gait, proprioception, flexibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>IG2: + balance, strength, gait, proprioception, flexibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Williams et al.</td>
<td>CT; 12 wk; n = 21; score: 1</td>
<td>Age: 76.7 ± 5 yrs; % Female: independent; high-risk</td>
<td>Wii Fit; (jumping, tilt table, steps basic, ski, salmon, yoga, heading, ski jump, hula hoop)</td>
<td>NR; 2 d/wk</td>
<td>Yes Center (hospital); supervised, individual</td>
</tr>
</tbody>
</table>

**Abbreviations:** ↑, increase; ↓, reduction; center, exercise intervention delivered within a research laboratory, gymnasium, or other facility that is not the participant’s place of residence; CT, control trial; Healthy, not high-risk; high-risk, frailty, muscle weakness or a balance and gait impairment was a study inclusion criterion; RACF, residential age care facility; RCT, randomized controlled trial; RCT/C, randomized control trial with crossover; UC, usual care.

<sup>a</sup>Individualized progression can be assumed because of program characteristics.

<sup>b</sup>Individualized feedback can be assumed because of program characteristics.

<sup>c</sup>Calculated from smaller sample in the analysis.

<sup>d</sup>Exercises delivered using technology.
Table 2. Summary of Adherence Rates by Type of Exercise Program and Intervention Variables

<table>
<thead>
<tr>
<th>Intervention Variables</th>
<th>Technology-Based Exercise Interventions</th>
<th>Traditional Exercise Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Studies, n (%)</td>
<td>Participants, n</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall adherence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All included studies</td>
<td>21 (100)</td>
<td>329</td>
</tr>
<tr>
<td>Studies with both technology and traditional exercise groups</td>
<td>10 (48)</td>
<td>157</td>
</tr>
<tr>
<td>Delivery site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Center</td>
<td>14 (67)</td>
<td>229</td>
</tr>
<tr>
<td>RACF</td>
<td>5 (24)</td>
<td>62</td>
</tr>
<tr>
<td>Home</td>
<td>2 (9)</td>
<td>38</td>
</tr>
<tr>
<td>Level of supervision</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supervised</td>
<td>18 (86)</td>
<td>273</td>
</tr>
<tr>
<td>Unsupervised</td>
<td>3 (14)</td>
<td>56</td>
</tr>
<tr>
<td>Delivery mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>7 (38)</td>
<td>122</td>
</tr>
<tr>
<td>Technology used</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial</td>
<td>12 (57)</td>
<td>190</td>
</tr>
<tr>
<td>Step mat</td>
<td>6 (29)</td>
<td>76</td>
</tr>
<tr>
<td>Other</td>
<td>3 (14)</td>
<td>63</td>
</tr>
<tr>
<td>Trial duration, wk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≤4</td>
<td>3 (14)</td>
<td>23</td>
</tr>
<tr>
<td>6-10</td>
<td>8 (38)</td>
<td>168</td>
</tr>
<tr>
<td>≥12</td>
<td>10 (48)</td>
<td>138</td>
</tr>
</tbody>
</table>

Abbreviation: NA, not applicable.

a Adherence calculated as the number of sessions participants attended, out of the total number of sessions prescribed. Calculation is based on participants who completed the intervention (this excludes dropouts or loss to follow-up).
b Analysis for technology-based exercise group is based on 21 studies, as in one study (Keogh et al.35) the exercise dose was self-selected.
c One study did not include participants with poor adherence when reporting adherence rates (Hagedorn and Holm24).
d Analysis for traditional exercise group is based on 9 studies, as in one study (Williams et al.15) adherence to the traditional component was not reported.
e Exercise intervention was delivered within a research laboratory, gymnasium, or other facility that is not the participants’ place of residence.
f Residential age care facility.
g Percentage calculated from 7 studies, as 2 studies did not report delivery mode for traditional exercise group.
h Nintendo Wii and Xbox Kinect.
i Balance rehabilitation program using virtual-reality system, computer feedback system with infrared sensors, and a tablet-computer application.
mean age of participants ranged from 67.4 to 86.3 years (median 78.2).

Intervention Characteristics
Seven studies (32%) compared outcomes between a technology-based exercise group and a traditional exercise (control) group, 15,19,24,26,29,32,36 and 12 (54%) studies compared a technology-based exercise group and a nonexercise control group. 16-18,22,25,27,28,30,33-35 Three studies (14%) compared outcomes between a technology-based exercise group, a traditional exercise group, and a nonexercise control group.21,23,31 Most studies provided supervision to participants while exercising (82% for technology-based exercise interventions, 15,16,19-34 and 90% for traditional exercise interventions15,19,21,23,24,26,29,31,32). Only 3 (14%) technology-based exercise interventions17,18,36 and 1 (11%) traditional exercise intervention36 were unsupervised. One study was classified as semi-supervised,15 as the first week of intervention was supervised and thereafter continuing operational support was provided 3 days per week. Delivery site of the exercise interventions was center-based (research laboratory, university hospital, and outpatient clinic) for 14 studies (64%), 15,17,19,27,30,31 in a common room of an RACF for 6 studies (27%),28,29,32-35 and home-based for 2 studies (9%).18,36

Technology-based exercise intervention
The intervention characteristics, including type of technology, exercise modalities, dose, frequency and training protocols, are outlined in Table 1.

Thirteen studies (59%) employed commercially available systems to prescribe the exercises: 4 (31%) used the Nintendo Wii console with Wii Fit/Sports games,15,22,30,33 8 (62%) used the Wii Fit/Sports games coupled with the Wii balance board,16,20,23,26,27,30,33,34 and 1 (7%) used the Xbox Kinect.17 The remaining 9 studies (41%) used customized technologies: 6 studies (67%) used stepping systems with pressure sensors, 18,19,25,28,29,32 and the others used a balance rehabilitation program using virtual reality system, 22 a computer feedback system with infrared sensors,24 and a tablet-computer application.36

Seventeen studies (77%) used the technology to provide balance training exercises, 15,17,19,24,26,27,30,31,33-36 Eight of these also provided strength,17,21,33,36 endurance,15,20,33 and general fitness exercises27,35; 5 studies used the technology to provide stepping training only18,25,28,29,32; and 9 studies complemented the technology-based exercise prescription with supplementary exercises (not using technology) to train balance,18,29,31,32 strength,16,18,21,24,26,28,29,31,32 gait,31 endurance,24,26 flexibility,31 and proprioception.31

One study prescribed participants’ home-based strength exercises to supplement the technology-based balance exercises.23 Staff was available to complete the exercises with participants if they wished to.

Trial duration ranged from 3 weeks20,23 to 20 weeks31 (median 10 weeks). Three studies (14%) had a duration of 4 weeks or less,20,23,33 9 studies (41%) had a duration of 6 to 10 weeks,16,19,22,23,26,30,34 and 10 studies (45%) had a duration of 12 or more weeks.15,21,24,27,29,31,32,34,36

Training sessions times ranged between 12.5 and 90 minutes (median 45 min) and were most commonly prescribed 2 days per week (67%),15,16,18,19,22,24,27,30,32-34 although 1,31 3,17,20,21,25,26 and 5 to 736 training days per week were also prescribed. The duration of the technology-based exercise component alone ranged between 4.5 and 60 minutes (median 30 minutes). Four studies (18%) had a duration of 15 minutes or less,23,29,32,34 7 studies (32%) had a duration of 20 to 30 minutes,18,20,22,24,26,28 and 7 studies (32%) had technology-based components that lasted over 30 minutes.16,17,19,21,27,30,31 One study (4.5%) did not report the specific duration of the technology-based exercise component,16 2 studies (9%) did not report session length,15,36 and in 1 study (4.5%) the frequency and duration was self-selected.35

All but 1 study25 individually increased the intensity of the technology-based exercise component by progressing participants to higher levels of game difficulty. This was achieved by modifying a number of variables within the games or activities including increasing the stepping speed, the number of distracting visual cues, the cognitive load, the movement amplitude and task precision, the number of repetitions, and the weight used; and by reducing the base of support and the sensory input throughout the exercises. All technologies provided the participants with feedback on their performance, in the form of scores and praise.

Safety procedures and adverse events related to the intervention
Ten studies (46%) reported on safety measures while undertaking the technology-based exercises. These included having a nearby support, such as a chair,20,31,34 walking frame,15,30,33 or ropes suspended from the ceiling for participants to hold on to if necessary.28,29,32 Of the 18 studies (82%) that supervised the technology-based exercise sessions,15,16,19-34 only 1 study reported the presence of a physical trainer as a safety measure to prevent falls.27 Only 1 study reported minor adverse events: backward fall when stepping from the balance board (no injuries sustained) and light-headedness on completion of the exercises.15

Effects of technology-based interventions on improving physical and cognitive outcomes
Technology-based exercise interventions were effective at improving physical measures of balance,15,17,19,20,23-26,31,33,34,36 functional performance,16,19,21,23,25,27,30,33,36 muscle strength,16,17,21,24,35 endurance,24 and stepping ability.29 Improvements were

Journal of GERIATRIC Physical Therapy

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also seen in cognitive measures including executive function and processing speed,\textsuperscript{29} and dual-task costs.\textsuperscript{18,28,29,30,32} Falls efficacy, balance confidence\textsuperscript{19,22,25,26,30,32,33} and quality of life\textsuperscript{34} also improved after training. Studies also reported an increase in physical activity levels,\textsuperscript{34,35} reduction in physical and cognitive parameters of fall risk,\textsuperscript{18} and fewer falls over a 9-month period.\textsuperscript{22}

**Control Groups: Type of Interventions**

Studies compared the use of a technology-based exercise group (with and without supplementary exercises) with varying other groups: a traditional exercise group\textsuperscript{15,19,21-24,26,29,31,32} or nonexercise control group.\textsuperscript{16-18,20-23,25,27,28,30,31,33-35}

**Traditional exercise group**

Similar to technology-based interventions, all interventions involving a traditional exercise component included balance and strength training.\textsuperscript{15,19,21,23,24,26,29,31,32,36} Additional exercise components included proprioception,\textsuperscript{31} flexibility exercises,\textsuperscript{21} walking,\textsuperscript{19,21} and stationary cycling.\textsuperscript{19} Most studies (70\%) prescribed exercise doses comparable to that of the technology-based intervention (including supplementary exercises).\textsuperscript{15,19,21,24,26,31,36} In 3 studies (30\%), the prescribed exercise dose was lower in the traditional exercise group compared with the technology-based intervention.\textsuperscript{23,29,32} Most studies provided general information on how the traditional exercises were progressed, but only 1 reported individually progressing the exercises on the basis of the participants’ performance.\textsuperscript{32} Individualized feedback on performance was specifically reported for 1 study where supervision was one-on-one with a therapist.\textsuperscript{24} However, as the majority (90\%) of traditional exercise interventions were supervised,\textsuperscript{15,19,21,23,24,26,29,31,32} it is likely that other studies also provided individual tailoring of exercises and feedback on performance.

**Nonexercise control groups**

The nonexercise control groups varied between a usual care group,\textsuperscript{22,28} which included a supervised health education group,\textsuperscript{33} a sham intervention using shoe insoles,\textsuperscript{16} and a no-intervention/control group.\textsuperscript{16-18,20-23,25,27,28,30,31,34,35} Participants allocated to usual care groups were invited to join standard fall prevention exercise classes,\textsuperscript{22,28} received education on fall prevention\textsuperscript{22,33} as well as other components of evidence-based health care plan for fall prevention (medication review, home-safety assessment, etc.).\textsuperscript{22} Studies consisting of a no-intervention/control group required participants to continue their normal daily activities and maintain their exercise routines.

**Outcome Measures**

**Adherence**

Adherence to the technology-based exercise intervention and the traditional exercise component, where applicable, was extracted (see Table, Supplemental Digital Content 2, http://links.lww.com/JGPT/A7, which summarizes the adherence and dropout rates for the technology-based and traditional exercise groups). Adherence rates were not reported in 4 studies, but provided by the authors upon request as follows: technology-based component\textsuperscript{19,26,33} and traditional exercise component.\textsuperscript{19,26,32} Adherence to the traditional exercise component was not obtained in 1 study.\textsuperscript{15} One study\textsuperscript{35} reported the average number of minutes per week residents used the Nintendo Wii (exercise dose), but as training dose was self-selected, adherence rates could not be calculated.

Table 2 presents a summary of adherence rates by type of intervention (technology-based or traditional exercise) and intervention variables including setting (site, level of supervision, and delivery mode), type of technology used (commercial system, step mat, other), and trial duration (≤4 weeks, 6-10 weeks, ≥12 weeks). Adherence rates to both technology-based and traditional exercise interventions were high, with a median adherence rate of 91.25\% and 83.58\%, respectively. Descriptive analysis suggested that adherence rates were slightly higher for technology-based interventions compared with traditional exercise interventions independent of the study site, level of supervision, and delivery mode. Adherence rates to technology-based programs were high across delivery sites; level of supervision, and delivery mode. Higher adherence was reported in studies that used stepping mats, followed by commercially available systems. Adherence to traditional exercise programs was higher when exercise sessions were center-based, and delivered in a group setting. Low adherence rates were reported for traditional unsupervised home-based interventions.\textsuperscript{36} Adherence rates to both technology and traditional exercise interventions were lower in trials with a duration of 12 or more weeks.

Four studies (18\%) did not include participants with poor adherence when reporting adherence rates.\textsuperscript{24,26,28,29} This can artificially inflate adherence rates reported in the studies. One of these studies,\textsuperscript{28} however, reported adherence rates of participants categorized as low adherent; and authors of 2 other studies provided these data upon request.\textsuperscript{26,29} These data were used when reporting adherence rates in this review.

**Measures of enjoyment and acceptability of technology-based exercise programs**

Eight studies (36\%) used questionnaires\textsuperscript{15,16,18,23,27,36} or semi-structured interviews\textsuperscript{15,33,35} to gain insight into older people’s experiences when exercising with technology-based programs, as well as the acceptability and ongoing commitment to use these programs after the studies were completed (see Table, Supplemental Digital Content 3, http://links.lww.com/JGPT/A8, which presents outcomes related to participants’ enjoyment and program acceptability).
Six studies (75%) reported on the user experience of supervised\(^\text{15,16,23,27,33}\) and semi-supervised\(^\text{35}\) Wii-based exercise interventions. They found them to be enjoyable and acceptable,\(^\text{15}\) fun, and motivating.\(^\text{16}\) Two studies (25%) reported on participants perceived comparability of the technology-based and the traditional exercise programs and reported Wii exercises to be “much better” or “better” than traditional balance exercises,\(^\text{23}\) and to be “very much” and “relatively” comparable to other forms of physical activity.\(^\text{27}\) Furthermore, participants living in residential aged care facilities described playing Wii exergames as “a wonderful experience,” and valued the experience as it helped bond with other residents, as well as allow them to be “more connected” to the younger generation.\(^\text{33,35}\) Both independent-living older adults,\(^\text{15,23,27}\) and those living in RACF\(^\text{33,35}\) desired to continue using the Wii program once the study was completed. Residents from an RACF suggested the facility should continue to offer the program,\(^\text{33}\) and the Wii Fit became a sustainable program after the research was completed in another facility.\(^\text{23}\) A high proportion (92%) of community-dwelling older fallers expressed a desire to continue using the Wii Fit program in the future, with no preference toward exercising with or without supervision or in the company of others.\(^\text{15}\) Furthermore, there was a higher preference toward continuing to exercise with the Wii Fit (61%) compared with a more traditional fall prevention exercise program (8%).\(^\text{15}\) Another study reporting on independent living older people at high risk of falls found that even though participants agreed that using the Wii program was fun and motivating, they expressed mixed responses in regard to continuing to use the Wii program in their home or a nearby center once the research was completed.\(^\text{16}\) Two studies reported on participants’ experience using noncommercial technologies in their homes.\(^\text{18,36}\) All participants thought that it was fun to perform strength and balance exercises using a tablet-computer application; and all but one participant enjoyed playing exergames on a step mat.

**Dropout because of program characteristics**

Dropout rates were similar for the technology-based and traditional exercise interventions (median 15%, range 0%-36%; and median 13%, range 0%-41%, respectively) (see Table, Supplemental Digital Content 2, http://links.lww.com/JGPT/A7, which summarizes the adherence and dropout rates for the technology-based and traditional exercise groups). More participants in the technology-based exercise intervention dropped out for reasons related to the exercise program (median 7% vs 1%). These included low motivation,\(^\text{29}\) loss of interest,\(^\text{30}\) arthritis discomfort,\(^\text{30}\) not enough time,\(^\text{16,23}\) unable to travel to the session,\(^\text{16,22}\) limited space in the home to set up the system,\(^\text{18}\) unable to use the technology,\(^\text{18}\) and ashamed of playing computer games.\(^\text{28}\) Program-related dropouts in the traditional exercise group included lack of motivation\(^\text{36}\) and personal obligations.\(^\text{28}\)

**DISCUSSION**

To maintain optimal health in old age and prevent falls, it is important for older people to adopt an active lifestyle and to incorporate exercise into their daily activities. This systematic review provides evidence that technology offers a safe and well-accepted method to provide older adults with engaging exercise opportunities that they find fun and motivating. The included studies reported high adherence rates (median 91.25%, range 70.25%-100%) to technology-based exercise programs. Ten studies (48%) compared technology-based exercise programs with traditional exercise programs and suggest slightly better adherence rates to the technology-based exercise programs (median 88.61% and 83.58%, respectively). However, it is important to consider that 9 of the 10 (90%) technology-based interventions and 8 of the 9 (89%) traditional exercise interventions provided supervision to participants. It is likely that providing supervision to participants contributed to the high participation rates reported in both intervention types.

Previous research has found that a proportion of older people prefer to exercise in their own homes,\(^\text{37,38}\) as they find it is more convenient and reduces some of the perceived barriers to exercise, including adverse weather conditions,\(^\text{39,40}\) lack of transport,\(^\text{41,42}\) and feelings of intimidation to attend fitness facilities and group exercise settings.\(^\text{7}\) Hence, it is important to evaluate whether technology-based exercise interventions can promote higher participation rates when delivered unsupervised. When looking at studies in unsupervised settings only, adherence rates favored technology-based exercise programs with 100% adherence rates versus 54% for traditional exercise. However, only 3 technology-based interventions\(^\text{37,18,36}\) and 1 traditional exercise intervention\(^\text{36}\) were unsupervised. Although these rates are higher than previously reported rates to home exercise programs (36.7% adherence at 12-month follow-up),\(^\text{35}\) this can be largely explained by the short duration of the included studies.

Eight studies\(^\text{15,16,18,23,27,33,35,36}\) reported on older people’s experiences of using exergames, and all found that participants considered them to be fun and engaging. This suggests that the higher participation rates to technology-based exercise programs may be largely explained by the high reported levels of enjoyment.

Technology-based exercise programs offer several advantages over traditional exercise programs that can contribute to a more enjoyable and stimulating exercise experience. Among these are the opportunity to tailor the program to include different exercise modalities (balance, strength, functional exercises, etc), offer a wide variety of exercises, the ability to provide exercises that are both physically and cognitively challenging, further increasing motivation to
continue exercising (unpublished). Exergames can also provide users with reinforcement and real-time feedback while exercising, and the opportunity to monitor performance over time. The interactive nature of technology-based exercise programs further allows older people to exercise unsupervised in their homes. This is important when aiming to increase exercise participation, as research has found that older people are more open to exercise programs undertaken in their own home.44

Although there are many theoretical advantages to using technology-based exercise programs, more work is required toward tailoring these programs to older people. Reasons for discontinuing technology-based exercise provided by participants included difficulty in using the technology, being ashamed of playing “computer games,” lack of time, and inability to travel to the exercise sessions.16,18,22,23,28 Most studies in this review used commercially available programs that can be difficult to use for those with little or no experience with technology. These commercial systems often lack clear instructions, are fast-paced, and present too much graphical information. Also, off-the-shelf games have not been designed to provide optimal exercise interventions to improve fall risk factors in older people (exercise type, dose, intensity), and therefore limit the efficacy of this type of intervention.

Recently, 2 large home-based randomized control trials further emphasized the need to develop programs that are suitable for older people with limited technical experience and skills.45,46 Both studies employed programs that were designed for older people. One used Kinect technology to provide balance and strength exercises,45 and the other used a step mat to deliver cognitive-motor games.46 Even though the programs were designed to facilitate usability and enhance exercise adherence (high visual-contrast, simple graphics, uncluttered display, automatic reminders to exercise, exercise tutorials, immediate feedback, and progress tracking), technical difficulties significantly impacted training adherence and thus the effectiveness of the intervention. Both technologies were in their proof-of-principle (prototype) stage and thus still need further refinement to increase their reliability and usability, to successfully increase exercise adherence and maximize the benefits of such interventions.

One study examining ways to increase exercise adherence to technology-based exercise programs in older people found older people desire explicit on-screen instructions, tailored exercise prescription and progression, a variety of physical and cognitive exercises, and the ability to exercise at home in their own time. Therefore, to facilitate the implementation of these technologies, programs should take into account the specific needs of older people and follow effective exercise recommendations for this group.47

Lastly, an underused advantage of technology-based exercise programs is that they can provide automatic recording of exercise adherence, including number of sessions completed, length of each session, or number of exercise and repetitions completed, thereby providing objective measures of exercise adherence.

Limitations
Several issues need further consideration as they can limit the generalizability of our findings to the broader population. First, the findings should be interpreted with some caution because of the poor reporting of adherence and designs of the included studies. Future studies should report the average adherence rate in values and percentages including and excluding dropouts for both the number of exercise sessions completed and for individuals, to allow for meta-analyses. It is apparent that high participant adherence was crucial in these efficacy trials, which limited the validity of adherence as a study variable for the current review. Adherence could have been further inflated because of a likely volunteer bias and the relatively minor commitment required because of the short duration of the trials. Second, it is possible that trials not published in the main databases, or referred by other articles were not included. Third, we excluded articles published in languages other than English, and 5 articles were excluded because adherence data could not be attained. Fourth, we only included randomized control trials, clinical control trials, and parallel group trials reporting adherence to technology-based interventions, thus studies with single group were excluded. Finally, the often poor to moderate quality, small sample size, short follow-up periods, and inclusion of mostly healthy older people limit the generalizability of the results.

CONCLUSION
This systematic review indicates that technology-based exercise interventions have good adherence and may provide a sustainable means of promoting physical activity and preventing falls in older people. More research is required to investigate the feasibility, acceptability, and effectiveness of technology-based exercise programs undertaken by older people at home over extended trial periods. It is recommended that authors place a stronger emphasis on reporting accurate measures of exercise adherence in future studies.

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