

Review

# A systematic review of active video games on rehabilitative outcomes among older patients

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## Abstract

**Background:** Although current research supports the use of active video games (AVGs) in rehabilitation, the evidence has yet to be systematically reviewed or synthesized. The current project systematically reviewed literature, summarized findings, and evaluated the effectiveness of AVGs as a therapeutic tool in improving physical, psychological, and cognitive rehabilitative outcomes among older adults with chronic diseases.

**Methods:** Seven databases (Academic Search Complete, Communication & Mass Media Complete, ERIC, PsycINFO, PubMed, SPORTDiscus, and Medline) were searched for studies that evaluated the effectiveness of AVG-based rehabilitation among older patients. The initial search yielded 946 articles; after evaluating against inclusion criteria and removing duplicates, 19 studies of AVG-based rehabilitation remained.

**Results:** Most studies were quasi-experimental in design, with physical functioning the primary outcome investigated with regard to the use of AVGs in rehabilitation. Overall, 9 studies found significant improvements for all study outcomes, whereas 9 studies were mixed, with significant improvements on several study outcomes but no effects observed on other outcomes after AVG-based treatments. One study failed to find any benefits of AVG-based rehabilitation.

**Conclusion:** Findings indicate AVGs have potential in rehabilitation for older patients, with several randomized clinical trials reporting positive effects on rehabilitative outcomes. However, existing evidence is insufficient to support the advantages of AVGs over standard therapy. Given the limited number of studies and concerns with study design quality, more research is warranted to make more definitive conclusions regarding the ability of AVGs to improve rehabilitative outcomes in older patients.

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**Keywords:** Balance; Depression; Enjoyment; Exergaming; Physical functioning; Quality of life

## 1. Introduction

Active video games (AVGs; also known as exergames) require players to physically interact with on-screen avatars through various physical activities (PAs) such as dancing, jogging, and boxing.<sup>1,2</sup> Given the fact that increased PA has been proven a viable approach to preventing or lessening risk of chronic diseases among a variety of populations,<sup>3,4</sup> AVGs may represent an alternative means in promoting PA participation and improving quality of life (QoL) and life satisfaction. Indeed, the positive effects of AVGs on health-related outcomes have been reported among healthy children and youth.<sup>5–8</sup> More recently, however, AVGs have received considerable

attention from researchers and health care professionals as a rehabilitative tool in clinical settings to promote individuals' physical, psychological, and cognitive functioning.<sup>9–13</sup>

### 1.1. Rationale

Chronic diseases like obesity, Parkinson's disease, hypertension, arthritis, and diabetes, as well as poststroke symptoms, can force seniors to gradually abandon independent activities such as bathing, dressing, and transferring positions.<sup>14</sup> According to the Centers for Disease Control and Prevention, chronic diseases are the leading causes of death among U.S. adults aged 65 years or older, and millions of older adults have chronic illnesses who are struggling to manage their daily symptoms.<sup>15</sup> Additionally, approximately 80% of older adults in the USA are suffering from at least 1 chronic condition, and 50% have at least 2.<sup>16</sup> As a result, chronic diseases place a significant burden on older adults because these diseases can affect an individual's

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ability to perform daily activities, thereby diminishing QoL. Because many of the preceding diseases often require some form of rehabilitation, some researchers and health professionals believe that AVG-based rehabilitation may increase treatment adherence and reduce treatment burden (e.g., the need to travel to a clinic if an AVG system is set up at home) among older adults.<sup>10,11</sup>

A number of reviews with regard to AVGs have been published recently. Yet most systematic reviews on the topic were mainly focused on PA promotion and obesity prevention among healthy children and young adults.<sup>1,17,18</sup> Only a few review articles synthesized the rehabilitative effects of AVGs among rehabilitation patients and/or older adults. Specifically, these reviews evaluated evidence regarding the rehabilitative effects of AVGs on physical outcomes,<sup>19</sup> Parkinson's disease,<sup>20</sup> and heart failure treatment<sup>21</sup> while also investigating the safety and efficacy of AVG interventions among older adults<sup>22</sup>—the population with the greatest need for rehabilitative services. Despite the need for an innovative and effective rehabilitation protocol among older adults, however, no known comprehensive review has specifically addressed the effectiveness of AVGs on rehabilitative outcomes in this population.

### 1.2. Objective

Because 29% of Americans older than 50 years of age play video games,<sup>23</sup> it is important for researchers to synthesize research findings regarding the potential use of AVGs in rehabilitation programs, with the goal of providing practical implications and recommendations for health care professionals. Therefore, the purpose of this review was to systematically examine the effectiveness of AVG-based rehabilitation among older adults ( $\geq 60$  years)<sup>24</sup> with chronic illnesses and/or physical impairments and propose future directions in research and rehabilitation settings utilizing this PA modality.

## 2. Methods

The Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) 2015 statement was consulted and provided the structure for this review.<sup>25</sup>

### 2.1. Eligibility criteria

The following inclusion criteria were used for each study: (1) published in English between January 2000 and August 2016 as peer-reviewed empirical research, (2) employed the use of at least 1 AVG (e.g., Xbox Kinect, Wii, Dance Dance Revolution, *etc.*), (3) composed of older adults (mean age  $\geq 60$  years) with chronic diseases and/or physical impairments (e.g., Parkinson's disease, impaired balance, poststroke status, *etc.*), (4) stated that the main purpose of AVG use was for patient rehabilitation, and (5) used quantitative measures in the assessment of health-related outcomes.

### 2.2. Information sources and search strategies

To ensure inclusion of relevant literature, a comprehensive electronic search was conducted. The following 2-step strategy

was adopted: (1) all studies relating to the topic were located using 7 databases: Academic Search Complete, Communication & Mass Media Complete, ERIC, PsycINFO, PubMed, SPORTDiscus, and Medline. Search terms used in combination were the following: “exergaming” or “active video gam\*” or “wii\*” and “rehabilitation” or “therapy” or “clinical” and physical” or “cognitive” or “psychological”. Relevant studies were further identified by means of cross-referencing the bibliographies of selected articles.

### 2.3. Data collection process

Three authors (NZ, ZP, ZG) screened the search results independently by evaluating the titles. If the researchers were unable to determine whether an article pertained to the topic, then the abstract was reviewed. All potential articles were downloaded as full text and stored in a shared folder, after which 3 authors (NZ, ZP, JEL) reviewed each article independently to ensure that only relevant entries were included. A list of published articles on the topic of AVGs and rehabilitation was then created in a Microsoft Excel spreadsheet (Microsoft Corporation, Redmond, WA, USA). The following data were extracted: (1) year of publication and country of origin, (2) methodological details (e.g., study design, experimental context, sample characteristics, study duration, outcome measures, AVG types, and instruments), and (3) key findings with respect to clinical effectiveness and the potential for rehabilitative outcomes (e.g., improved functional abilities, reported changes in QoL, reduced fear of falling, *etc.*).

### 2.4. Risk of bias in individual studies

Based on previous literature,<sup>1,18</sup> the risk of bias in each study was rated independently by 3 authors (NZ, ZP, JEL) using a 9-item quality assessment tool (Table 1). Items were assessed for each study as “yes” (explicitly described and present) or “no” (absent, inadequately described, or unclear). In particular, Items 1, 3, 4, and 8 in Table 1 were deemed the most important because these items had greater potential to significantly affect the research findings. Additionally, a design quality score ranging from 0 to 9 was computed by summing up the “yes” answers. A study was considered high quality when it scored above the median after the scoring of all studies. To ensure valid scoring of the quality assessment, 2 authors (NZ, JEL) independently scored each article. When incongruities occurred between the 2 authors, a third author (ZP) assessed any unresolved differences for scoring accuracy.

## 3. Results

### 3.1. Study selection

The initial search yielded 946 articles. After removing duplicates, titles and abstracts of the remaining papers were screened against the inclusion criteria. After a thorough review of the remaining papers, 19 studies were included in this review (Fig. 1). A high inter-rater agreement (i.e., 95%) was obtained between the authors for the articles included.

Table 1  
Design quality analysis for the AVGs intervention studies.

Article	1	2	3	4	5	6	7	8	9	Score	Effectiveness
Bainbridge et al. <sup>36</sup>	N	N	Y	Y	Y	Y	N	N	N	4	NA
Broadbent et al. <sup>41</sup>	N	N	Y	Y	Y	Y	N	N	N	4	+
Clark and Kraemer <sup>42</sup>	N	N	Y	Y	Y	Y	N	N	N	4	+
Esculier et al. <sup>34</sup>	N	Y	Y	Y	Y	Y	N	Y	N	6	+/NA
Fung et al. <sup>26</sup>	Y	Y	N	N	Y	N	N	Y	Y	5	+
Hakim et al. <sup>43</sup>	N	N	Y	Y	Y	Y	N	N	Y	5	+
Herz et al. <sup>37</sup>	N	N	Y	Y	Y	Y	N	N	Y	5	+/NA
Hsu et al. <sup>27</sup>	Y	Y	N	Y	Y	Y	Y	Y	Y	8	+/NA
Imam et al. <sup>28</sup>	Y	Y	Y	Y	Y	Y	Y	Y	Y	9	+
Yong et al. <sup>38</sup>	N	N	Y	Y	Y	Y	N	N	Y	5	+/NA
Mendes et al. <sup>35</sup>	N	Y	N	Y	Y	Y	N	Y	Y	6	+
Mhatre et al. <sup>39</sup>	N	N	Y	Y	Y	Y	N	Y	Y	6	+/NA
Miller et al. <sup>44</sup>	N	N	N	Y	Y	Y	N	N	Y	4	+/NA
Pompeu et al. <sup>29</sup>	Y	Y	N	Y	Y	Y	N	Y	N	6	+
Yavuzer et al. <sup>30</sup>	Y	Y	N	Y	Y	Y	N	Y	Y	7	+/NA
Agmon et al. <sup>40</sup>	N	N	Y	Y	Y	Y	N	N	Y	5	+/NA
Daniel <sup>31</sup>	Y	Y	Y	Y	Y	Y	N	N	Y	6	+
van den Berg et al. <sup>32</sup>	Y	Y	N	Y	Y	Y	N	Y	Y	7	+/NA
Shih et al. <sup>33</sup>	Y	Y	Y	Y	Y	Y	N	Y	Y	8	+

Notes: + indicates significant positive effect; median score = 5; Item 1 = randomization; Item 2 = control; Item 3 = isolate AVGs; Item 4 = pre-post-test; Item 5 = retention ≥ 70%; Item 6 = baseline; Item 7 = missing date; Item 8 = power analysis; Item 9 = validity measure.

Abbreviations: AVGs = active video games; N = no (absent, inadequately described, or unclear); NA = no significant effect; +/NA = significant improvements found on several measures but no significant effects observed on other outcomes; Y = yes (explicitly described and present in details).

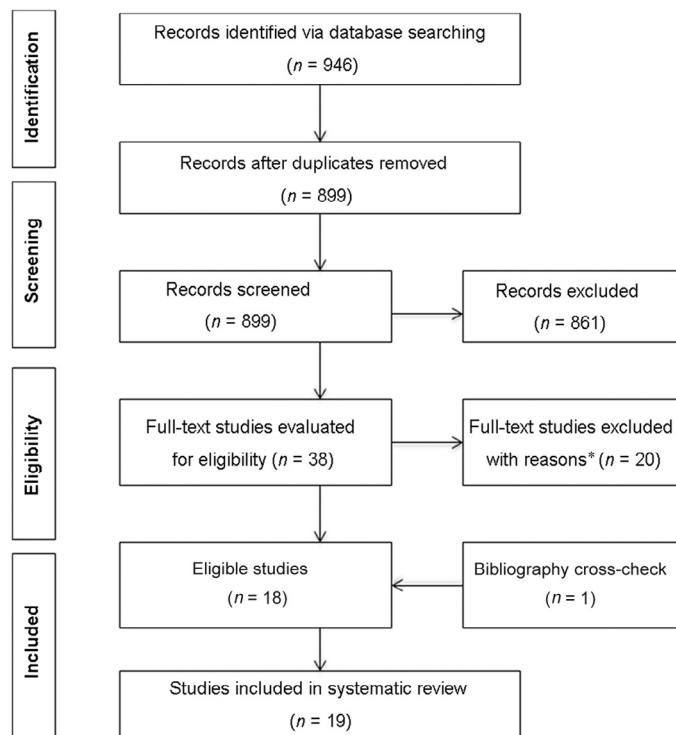


Fig. 1. Preferred reporting items for systematic reviews and meta-analyses flow diagram of studies through the review process. Many studies were excluded for multiple reasons. Databases included the following: Academic Search Complete (n = 224), Communication & Mass Media Complete (n = 9), ERIC (n = 5), PsycINFO (n = 114), PubMed (n = 208), SPORTDiscus (n = 123), and Medline (n = 263). \*Reasons for study exclusion included ineligible age, ineligible populations, ineligible active video game types, and ineligible outcomes.

### 3.2. Study characteristics

The characteristics of included studies are shown in Table 2: among the 19 studies, 8 were randomized clinical trials (RCTs),<sup>26-33</sup> 2 were control trials (CTs; quasi-experimental pre-post-test design without randomization),<sup>34,35</sup> 5 were 1-group pre-post-test designed studies (pre-experimental design with pre-post-test design among same participants),<sup>36-40</sup> and 4 were case studies (pre-experimental design with pre-post-test on 1 to 2 subjects only).<sup>41-44</sup> The USA was the primary location for AVG-based rehabilitation studies,<sup>31,36,37,39,40,42-44</sup> with 4 studies conducted in Canada,<sup>26-28,34</sup> 2 in Brazil<sup>29,35</sup> and Australia,<sup>32,41</sup> and 1 in Singapore,<sup>38</sup> Turkey,<sup>30</sup> and Taiwan, China,<sup>33</sup> respectively. A majority (n = 17; 89%) of the articles were published after 2010, and the oldest publication was in 2008, indicating that research on AVGs and rehabilitation is a young but expanding scientific field.

Relatively large variability was seen for sample size across studies. Specifically, the sample varied from 1 to 58 with median number of participants being 20. Intervention length ranged from 2 to 15 weeks, with the median intervention length being 6 weeks. With regard to AVG type, all studies employed commercially available AVGs. In detail, the predominant gaming consoles for rehabilitation purposes were the Nintendo Wii, Wii Fit, or a balance board (similar to the Wii Fit). Some of the games included were Soccer Heading, Ski Slalom, Ski Jump, Table Tilt, Penguin Slide, Balance Bubble, and Bowling. Most often, the chronic conditions and/or impairments treated with AVG-based rehabilitation included Parkinson’s disease,<sup>29,33-35,37,39</sup> general impaired balance,<sup>36,40,42,43</sup> post-stroke status,<sup>30,38</sup> upper and lower extremity motor deficiencies,<sup>27,28</sup> frailty syndrome,<sup>31</sup> post-knee replacement status,<sup>26</sup> transfemoral amputation,<sup>44</sup> reduced

Table 2  
Summary of active video game studies.

Study description	Sample and design	Types of active video game	Outcomes	Instruments	Dose	Findings
Bainbridge et al. <sup>36</sup> (2011), USA; to determine whether using the Nintendo Wii Fit balance board would lead to improvements in balance among older adults	1 male, 7 females aged 65–87 years with perceived balance deficits; pre–post-test design	Wii Fit balance board (Soccer Heading, Ski Jump, Ski Slalom, Table Tilt, Ski Slalom, Tightrope Walk, Penguin Slide)	Physical outcomes: improved balance and limits of stability; cognitive outcome: balance confidence	BBS, Multidirectional Reach Test, ABC	2 × 30 min per week for 6 weeks	No statistically significant changes were found for any outcome measure
Broadbent et al. <sup>41</sup> (2014), Australia; to evaluate the efficacy of Nintendo Wii Fit in improving functional capacity, exercise tolerance, strength, and balance in an elderly woman	1 female aged 77 years with scleroderma (CREST syndrome) and severe cardiopulmonary symptoms; pre–post-test design	Wii Fit (Step Basic, Rhythm Parade, Ski Slalom, Balance Bubble, Penguin Slide, Tightrope Tension, Tilt City)	Physical outcomes: improved functional ability and balance; cognitive outcome: less fear of falling	6MWT, TUG, 30 s STST, hand grip strength, TBGA, FES-I questionnaire	3 × 30 min per week for 12 weeks	Substantial improvements were seen in all outcomes after intervention
Clark and Kraemer <sup>42</sup> (2009), USA; to examine the effect of a novel interactive video game intervention on balance dysfunction in an elderly woman	1 female aged 89 years with balance disorder and a history of multiple falls; pre–post-test design	Nintendo Wii (Bowling)	Physical outcome: improved balance; cognitive outcome: balance confidence	BBS, DGI, TUG, ABC	6 × 60 min	Improvements were seen in all outcomes after intervention
Esculier et al. <sup>34</sup> (2012), Canada; to evaluate the effects of Nintendo Wii Fit game with balance board on balance and functional abilities in older adults	9 healthy participants (5 males and 4 females, mean age 63.5 years); 11 patients (6 males and 5 females, mean age 61.9 years); Parkinson's disease group ( $n = 11$ ); healthy group ( $n = 9$ ); CT	Wii Fit (Table Tilt, Ski Slalom, Balance Bubble, Ski Jump, Penguin Slide)	Physical outcome: improved functional ability and balance; cognitive outcome: balance confidence	TUG, STST, POMA, 10MWT, CBM, ABC	3 × 40 min per week for 6 weeks	Experimental group significantly improved results in TUG, STST, unipedal stance, 10MWT, CBM, POMA, and force platform after intervention; no significant change in ABC scale
Fung et al. <sup>26</sup> (2012), Canada; to determine whether Nintendo Wii Fit is an acceptable adjunct to physiotherapy in rehabilitation of balance, lower extremity strength, and function in older adults	17 male and 33 female patients with total knee replacement (mean age 68 years); intervention group ( $n = 27$ ); control group ( $n = 23$ ); RCT	Nintendo Wii Fit (Ski Slalom, Tightrope Walk, Penguin Slide, Table Tilt, Hula Hoop, Balance Bubble, Deep Breathing, Half-Moon, Torso Twist)	Physical outcome: improved functional ability; cognitive outcome: improved pain and balance confidence	ROM, 2MWT, LEFS, NPR, ABC	2 × 15 min per week for 6 weeks	No significant differences in pain, knee flexion, knee extension, walking speed, timed standing tasks, LEFS, and ABC between Wii Fit and physiotherapy groups
Hakim et al. <sup>43</sup> (2015), USA; to examine the effect of the Nintendo Wii Fit on balance in an older adult	1 patient (76 years old) with peripheral neuropathy and a history of recurrent near-falls; pre–post-test design	Nintendo Wii Fit (Ski Jump, Ski Slalom, Yoga Chair, Hula, Soccer Headers, Bubble Maze, Penguin Slide)	Physical outcome: improved balance and motor function; cognitive outcome: balance confidence	LOS, ADT, MCT, BBS, TUG, ABC	2 × 60 min per week for 6 weeks	All tests showed improvements after intervention
Herz et al. <sup>37</sup> (2013), USA; to assess the effect of Nintendo Wii on improving motor and nonmotor aspects in patients	13 males and 7 females with Parkinson's disease aged 48–74 years; pre–post-test design	Wii-hab (Tennis, Bowling, Boxing)	Physical outcomes: improved activities of daily living and motor function; psychological outcome: improved quality of life and depression	NEADL, UPDRS, PDQ-39, HAM-D	3 × 60 min per week for 4 weeks	Significant improvements in NEADL, PDQ-39, and UPDRS after Wii therapy

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Table 2 (continued)

Study description	Sample and design	Types of active video game	Outcomes	Instruments	Dose	Findings
Hsu et al. <sup>27</sup> (2011), Canada; to determine the effect of Wii Bowling game on measures of symptom intensity, enjoyment, and physical function in patients	10 males and 24 females aged 52–97 years with upper extremity dysfunction; intervention ( $n = 19$ ), control group ( $n = 15$ ); RCT	Wii Sports (Bowling)	Physical outcomes: improved functional ability and movement; psychological outcome: enjoyment; cognitive outcome: decreased pain intensity	NHPPT, ROM, PACES, NPR	4–20 min per week for 4 weeks	Participants improved on all outcomes after intervention, but only enjoyment of activity showed a significant difference between the standard exercise and Wii groups
Imam et al. <sup>28</sup> (2017), Canada; to assess the feasibility of Wii.n.Walk in improving walking capacity in older adults	28 participants aged 50–78 years with lower limb amputation; intervention group ( $n = 14$ ); control group ( $n = 14$ ); RTC	Nintendo Wii Fit (Wii.n.Walk)	Physical outcome: improved walking capacity	2MWT	3–40 min per week for 4 weeks	Improvement in walking capacity for intervention group, whereas the control group's performance declined
Yong et al. <sup>38</sup> (2010), Singapore; to assess the feasibility of using the Nintendo Wii as an adjunct to conventional rehabilitation of patients	13 males and 7 females (mean age 64.5 years) with poststroke and upper limb weakness; pre–post-test design	Wii Sports (Bowling, Boxing, Tennis, Golf, Baseball)	Physical outcome: improved upper limb motor function; cognitive outcome: reduced upper limb pain	FMA, MAS, VAS	6–30 min per week for 2 weeks	Small but statistically significant improvements in FMA and Motricity Index Score; no significant improvements seen in MAS and VAS
Mendes et al. <sup>35</sup> (2012), Brazil; to evaluate the learning, retention, and transfer of performance improvements after Nintendo Wii Fit training in older patients	16 Parkinson's disease patients (mean age 68.6 years) and 11 healthy elderly (mean age 68.7 years); CT	Nintendo Wii Fit (Table Tilt, Obstacle Course, Rhythm Parade, Tilt City, Single-Leg Extension, Basic Run Plus, Basic Step, Torso Twist, Soccer Heading, Penguin Slide)	Cognitive outcomes: improved learning, retention, and transfer of learning	Learning and retention were determined based on the scores of 10 Wii Fit games over 8 sessions; transfer of learning was assessed using the functional reach test	2 times per week for 14 weeks	Learning, retaining, and transfer performance improvements after the Nintendo Wii Fit training
Mhatre et al. <sup>39</sup> (2013), USA; to assess the effect of Nintendo Wii Fit playing and balance board system on balance and gait in older adults	4 males and 6 females with Parkinson's disease (mean age 67.1 years); pre–post-test design	Wii balance board games (Marble Tracking, Skiing, Bubble Rafting)	Physical outcome: improved balance; psychological outcome: reduced depression; cognitive outcome: balance confidence	BBS, DGI, SRT, GDS, ABC	3–30 min per week for 8 weeks	Improvements were seen in balance and gait, but no significant changes in mood and balance confidence
Miller et al. <sup>44</sup> (2012), USA; to examine the effects of the Nintendo Wii Fit balance board and body weight supported training on aerobic capacity, balance, gait, and fear of falling in 2 older adults	2 males with transfemoral amputation (62 and 58 years old); pre–post-test design	Wii Fit (Tilt Table, Skiing, Tightrope Walk, etc.)	Physical outcomes: improved aerobic capacity, dynamic balance, limits of stability, gait; cognitive outcome: balance confidence	OUES, LOS, GAITRite, ABC	2–20 min per week for 6 weeks	Both participants demonstrated improvement in dynamic balance, balance confidence, economy of movement, and spatial-temporal parameters of gait, but participant A did not improve aerobic capacity
Pompeu et al. <sup>29</sup> (2012), Brazil; to investigate the effect of Nintendo Wii–based motor and cognitive training vs. balance exercise therapy on activities of daily living in patients	17 males, 15 females with Parkinson's disease aged 60–85 years; intervention group ( $n = 16$ ), control group ( $n = 16$ ); RCT	Nintendo Wii Fit (Static Balance: Single-Leg Extension, Torso Twist; Dynamic Balance: Table Tilt, Tilt City, Soccer Heading, Penguin Slide; Stationary Gait: Rhythm Parade, Obstacle Course, Basic Step, Basic Run)	Physical outcomes: improved activities of daily living, static and dynamic balance; cognitive outcome: better cognitive performance	UPDRS, BBC, UST, MCA	2–30 min per week for 7 weeks	Improvements seen in all outcomes after intervention for both types of training

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Table 2 (continued)

Study description	Sample and design	Types of active video game	Outcomes	Instruments	Dose	Findings
Yavuzer et al. <sup>30</sup> (2008), Turkey; to evaluate the effects of PlayStation EyeToy games on upper extremity motor recovery and upper extremity-related motor functioning in patients	20 poststroke patients with a mean age of 61.2 years; intervention group ( $n = 10$ ); control group ( $n = 10$ ); RCT	PlayStation EyeToy games	Physical outcome: improved motor functioning	Brunnstrom stages and FIM	5–30 min per week for 4 weeks	FIM showed significant improvement in the EyeToy group compared with the control group; no significant differences were found between the groups for the Brunnstrom stages for hand and upper extremity
Agmon et al. <sup>40</sup> (2011), USA; to determine the safety and feasibility of using Nintendo Wii Fit to improve balance in older adults	3 males and 4 females aged 78–92 years with impaired balance; pre–post-test design	Wii Fit balance games (Basic Step, Soccer Heading, Ski Slalom, Table Tilt)	Physical outcomes: improved balance and gait speed; psychological outcome: enjoyment	BBS, 4MWT, PACES	3 × 30 min per week for 12 weeks	Improvements were found in balance and gait speed but no changes in physical activity enjoyment
Daniel <sup>31</sup> (2012), USA; to examine the effectiveness of a novel intervention aimed at decreasing indices related to frailty through systematic, progressive functional rehabilitation	9 males and 12 females with frailty syndrome (mean age 72.6 years); Wii fit group ( $n = 8$ ); seated exercise group ( $n = 8$ ); control group ( $n = 5$ ); RCT	Wii Fit (Bowling, Tennis, Boxing)	Physical outcome: improved physical function; cognitive outcome: balance confidence	SFT, CHAMPS, LLFDI, ABC	3–45 min per week for 15 weeks	Improvements were found in all the tests for Wii group
van den Berg et al. <sup>32</sup> (2016), Australia; to investigate whether adding video-based interactive exercises to inpatient geriatric and neurologic rehabilitation improves mobility outcomes	58 patients with reduced mobility, aged 68–95 years; intervention group ( $n = 29$ ), control group ( $n = 29$ ); RCT	Nintendo Wii and Xbox Kinect	Physical outcomes: improved balance and motor function; psychological outcome: improved quality of life and enjoyment; cognitive outcome: fall-related self-efficacy	SPPB, maximum balance range test, Rivermead Mobility Index; EuroQol Questionnaire, PACES, FES	5 × 60 min per week for 12 weeks	Improvements seen in balance and enjoyment but no changes in overall mobility or other outcomes
Shih et al. <sup>33</sup> (2016), Taiwan, China; to examine the effects of a balance-based exergaming intervention using the Kinect sensor on postural stability and balance in older adults	20 participants with Parkinson's disease; balance-based exergaming group ( $n = 10$ , mean age 67.5 years), balance training group ( $n = 10$ , mean age 68.8 years); RCT	Xbox Kinect	Physical outcomes: postural stability, functional balance	LOS, OLS, BBS, TUG	2 × 50 min per week for 8 weeks	Participants in the balance-based exergaming group showed significant improvements in LOS and OLS tests; improvements were also observed in BBS and TUG performance for both groups

Abbreviations: 2MWT = 2 min walk test; 4MWT = 4 min walk test; 6MWT = 6 min walk test; 10MWT = 10 min walk test; ABC = Activities-specific Balance Confidence Scale; ADT = Adaptation Test; BBS = Berg Balance Scale; CBM = Community Balance and Mobility scale; CHAMPS = Community Healthy Activities Model Program for Seniors; CREST = calcinosis, Raynaud phenomenon, esophageal dysmotility, sclerodactyly, and telangiectasia; CT = control trial; DGI = Dynamic Gait Index; FES = Falls Efficacy Scale; FES-I = Falls Efficacy Scale–International; FIM = Functional Independence Measure; FMA = Fugl-Meyer Assessment; GAITrite = test of spatial-temporal parameters of gait; GDS = Geriatric Depression Scale; HAM-D = Hamilton Depression Rating Scale; LEFS = Lower Extremity Functional Scale; LLFDI = Late Life Function and Disability Index; LOS = Limits of Stability; MAS = Modified Ashworth Scale; MCA = Montreal Cognitive Assessment; MCT = Motor Control Test; NEADL = Nottingham Extended Activities of Daily Living Test; NHPPT = Nursing Home Physical Performance Test; NPR = Numeric Pain Rating Scale; OLS = 1-leg stance; OUES = oxygen uptake efficiency slope; PACES = Physical Activity Enjoyment Scale; PDQ-39 = 39-item Parkinson's Disease Questionnaire; POMA = Tinetti Performance-Oriented Mobility Assessment; RCT = randomized clinical trial; ROM = range of motion; SFT = Senior Fitness Test; SPPB = Short Physical Performance Battery; SRT = Sharpened Romberg Test; STST = Sit-to-Stand Test; TBGA = Tinetti Balance and Gait Assessment; TUG = Timed Up and Go; UPDRS = Unified Parkinson's Disease Rating Scale; UST = unipedal stance test; VAS = visual analogue scale.

mobility,<sup>32</sup> and scleroderma and severe cardiopulmonary symptoms.<sup>41</sup>

### 3.3. Data items

The included studies measured several variables with diverse instruments. We categorized these variables as physical, psychological, and cognitive rehabilitative outcomes. The physical outcomes included but were not limited to static and dynamic balance, gait speed, motor functioning, functional capacity, mobility, upper and lower extremity movement, strength, and aerobic capacity. Studies that investigated the effectiveness of AVG-based rehabilitation on patients' psychological and cognitive outcomes were relatively scarce compared with studies assessing physical outcomes. In this review, psychological and cognitive outcome variables included exercise enjoyment, QoL, depression, balance confidence, fear of falling, pain intensity, and cognitive performance.

### 3.4. Risk of bias within studies

Risk of bias assessments for included studies is presented in Table 1. In detail, 8 studies used a randomized design allowing for comparison between the intervention and control/comparison groups as well as measured outcome variables before and after the intervention. Twelve studies utilized isolated AVGs for rehabilitative purposes (i.e., no therapy other than AVGs). All the studies succeeded in retaining at least 70% of the participants and in statistically comparing groups at baseline on key outcome variables. Furthermore, 2 studies described how the missing data were accounted for in the statistical analyses, with power calculations for appropriate sample sizes presented in 10 studies. Finally, numerous validated measures were used in 14 studies.

### 3.5. Quality assessment and effectiveness of AVG-based rehabilitation

In this review, all the included studies were AVG-based interventions. The design quality of the studies ranged from 4 to 9 (Table 1). Ten studies were rated above the median score of 5 and were subsequently considered high quality. Notably, of the 9 lower-quality studies, 5 were scored as being equal to the median score and 4 scored below the median—all of which were case reports. Because the quality of research designs was low among the literature on this topic, a meta-analysis was prohibited.

Concerning the effectiveness of AVG-based interventions on older patients' rehabilitative outcomes, 9 studies found significant improvements for all the outcome measures investigated, such as functional ability, walking capacity, balance confidence, and cognitive performance.<sup>26,28,29,31,33,35,41–43</sup> Nine studies had mixed findings, observing remarkable enhancements on several variables (e.g., balance, fear of falling, mobility, QoL, enjoyment, *etc.*) with no significant effects found for other outcomes (e.g., mobility, aerobic capacity, pain intensity, depression, *etc.*) after AVG-based treatments.<sup>27,30,32,34,37–40,44</sup> In particular, 1 AVG study failed to produce any beneficial rehabilitative outcomes (e.g., balance, limits of stability, and balance confidence).<sup>36</sup>

### 3.6. Physical effects of AVGs

Studies on AVGs for older patients investigated a wide range of physical functioning outcomes, with a majority of the studies on the topic focusing on whether AVG-based rehabilitation has a positive effect on balance. Indeed, 11 studies examined the use of AVGs on static and dynamic balance ability, with 10 studies indicating that AVG-based rehabilitation could improve balance performance. Specifically, 6 pre-experimental studies demonstrated improved balance scores after AVG therapy as follows: in Study 1, Timed Up and Go (TUG) test decreased by 0.9 s and Tinetti Balance and Gait Assessment increased by 5.5 units;<sup>41</sup> in Study 2, Berg Balance Scale (BBS) increased by 5 units, Dynamic Gait Index (DGI) increased by 2 units, and TUG decreased by 4.4 s;<sup>42</sup> in Study 3, Limits of Stability (LOS) increased by 22%, Adaptation Test (ADT) improved for downward platform rotations, TUG decreased by 4.0 s, and BBS increased by 6 units;<sup>43</sup> in Study 4, DGI increased by 2.8 units, BBS increased by 3.3 units, and Sharpened Romberg Test (SRT) increased by 6.85 units;<sup>39</sup> in Study 5, LOS participants A and B improved by 20% and 2%, respectively;<sup>44</sup> and in Study 6, BBS increased by 5 units.<sup>40</sup> In particular, 4 experimental studies also found positive results. The first study had a CT design and observed significant improvements for AVG groups on the Community Balance and Mobility scale (CMB) (increased by 15 units,  $p < 0.001$ ) and TUG (decreased 1.9 s,  $p < 0.04$ ).<sup>34</sup> (The  $p$  values represent comparisons between AVG-based rehabilitation and comparison/control groups.) The other 3 studies were RCTs, indicating substantial balance changes on (1) the BBS (increased by 1.3 units,  $p < 0.005$ ) and unipedal stance test (UST) (improved by 7.7 units with eyes open,  $p < 0.001$ ; improved by 1.1 units with eyes closed,  $p < 0.005$ );<sup>29</sup> (2) maximal balance range (improved 38 mm,  $p < 0.05$ );<sup>32</sup> and (3) LOS (reaction time decreased by 0.22 s,  $p < 0.001$ ; endpoint excursion and directional control improved by 4.8%,  $p < 0.04$ , and 3.2%,  $p < 0.02$ , respectively), 1-leg stance (OLS) (less affected with eyes closed increased by 2.75 s,  $p < 0.002$ ), BBS (increased by 2.3 units), and TUG (decreased by 0.8 s)<sup>33</sup> as compared with control/comparison groups after AVG-based rehabilitation. Finally, 1 study failed to find balance change after an AVG-based rehabilitation program.<sup>36</sup>

As previously mentioned, studies in this review evaluated diverse physical outcomes, making it difficult to classify each outcome variable into a specific category. In this review, 14 studies examined other components of physical functioning besides balance. Among these nonbalance studies, 4 of 7 nonexperimental studies indicated substantial improvements in the 6 min walk test (increased by 100 m), 30 s Sit-to-Stand Test (STST) (increased 2 repetitions), hand grip strength (right increased by 2 kg, left increased by 1 kg),<sup>41</sup> motor control test (improved for amplitude with forward translations),<sup>43</sup> Nottingham Extended Activities of Daily Living Test (NEADL) (overall score decreased), unified Parkinson Disease Rating Scale (UPDRS) (overall motor score decreased),<sup>37</sup> and 4 m walk test (4MWT) (speed increased 0.29 m/s)<sup>40</sup> after the AVG-based rehabilitation. Conversely, 2 other studies showed no significant changes in oxygen uptake efficiency slope<sup>44</sup> and overall mobility after intervention.<sup>32</sup> In particular, although enhancements

were observed in Fugl-Meyer Assessment (FMA) (increased by 5.0 units) and Motricity Index (increased by 0.6 units), the study failed to improve performance on the Modified Ashworth Scale (MAS).<sup>38</sup> In addition, 7 studies comparing AVG-based rehabilitation with other treatment protocols observed comparable or equal improvements in several outcomes. In detail, 1 CT found significant improvements for AVG groups in STST (increased by 7.5 units,  $p < 0.01$ ), 10 m walk test (10MWT) (decreased by 0.7 s,  $p < 0.001$ ), and Tinetti Performance-Oriented Mobility Assessment (POMA) (increased by 4 units,  $p < 0.05$ ).<sup>34</sup> Moreover, 4 of 6 RCTs observed significant changes in 2 min walk test (2MWT) (increased by 7.4 units,  $p < 0.05$ ),<sup>28</sup> UPDRS (increased 1.2 units,  $p < 0.001$ ),<sup>29</sup> Functional Independence Measure (FIM) (decreased 3.7 units,  $p = 0.018$ ),<sup>30</sup> Senior Fitness Test (SFT) (overall scores increased), Community Healthy Activities Model Program for Seniors (CHAMPS) (increased by 3598 kcal/week), and Late Life Function and Disability Instrument (LLFDI) (overall scores decreased)<sup>31</sup> as compared with the control/comparison groups. Notably, the 2 other RCTs indicated no significant differences in active range of knee motion ( $p = 0.22$ ), 2MWT ( $p = 0.855$ ), Lower Extremity Functional Scale (LEFS) ( $p = 0.289$ ),<sup>26</sup> and Nursing Home Physical Performance Test (NHPPT) ( $p = 0.299$ )<sup>27</sup> between AVG-based rehabilitation and conventional therapy—providing evidence that AVGs might best be utilized as an adjunctive therapy to standard treatment.

### 3.7. Psychological effects of AVGs

In this review, studies investigating psychological rehabilitative outcomes were few but included assessment of enjoyment, QoL, and depression. Specifically, 3 articles investigated enjoyment in relation to AVG-based rehabilitation, with 2 RTCs indicating a positive effect on Physical Activity Enjoyment Scale ( $p = 0.014$ <sup>27</sup>;  $p < 0.05$ <sup>32</sup> for AVG groups after AVG intervention in relation to the comparison groups), whereas another nonexperimental study<sup>40</sup> reported the opposite. Interestingly, 2 nonexperimental studies seem to suggest that AVGs could be an effective rehabilitative tool in improving QoL, but not to a degree sufficient to trigger changes in mood.<sup>37,39</sup> Conversely, 1 RCT stated that no significant change was found for the Wii group in QoL despite a slight upward trend indicating improvement after AVG-based treatment ( $p > 0.05$ ).<sup>32</sup>

### 3.8. Cognitive effects of AVGs

Because most studies on the use of AVGs to improve older patients' rehabilitative outcomes mainly concentrated on physical functioning, this activity modality's effectiveness in promoting cognitive rehabilitative outcomes was rarely investigated. Although 14 studies examined patients' cognitive function, 10 studies were concerned with balance confidence. Generally, findings were equivocal for balance confidence, with 4 case studies<sup>41–44</sup> and 1 RCT<sup>31</sup> indicating improvements, whereas 2 nonexperimental studies,<sup>36,39</sup> 1 CT,<sup>34</sup> and 2 RCTs<sup>26,32</sup> observed no changes after AVG-based rehabilitation as compared with control/comparison groups. In this review, other cognitive rehabilitative outcomes included pain intensity and cognitive performance. Specifically, 1 nonexperimental study<sup>38</sup> and 1 RCT<sup>27</sup>

demonstrated that AVGs were not effective for upper extremity pain management after an AVG intervention, whereas another RCT<sup>26</sup> revealed no significant difference in lower extremity pain between an AVG group and a physiotherapy group. Finally, 1 CT demonstrated significantly improved cognitive performance for Wii groups for attention ( $p = 0.003$ ) and decision-making ( $p = 0.02$ ),<sup>35</sup> and 1 RCT indicated significant improvements in executive function, naming, memory, orientation, *etc.* (overall Montreal Cognitive Assessment (MCA),  $p < 0.001$ )<sup>29</sup> vs. the comparison group.

## 4. Discussion

The purpose of the current review was to provide a synthesis of the current evidence regarding AVG-based rehabilitation in the treatment of chronic diseases and/or impairments in older adults. The final analysis included 19 studies. Given the limited number of included studies, as well as the high proportion of pre-experimental designs employed ( $n = 9$ , 47%), more high-quality studies are warranted prior to drawing conclusions regarding the effectiveness of AVGs as a rehabilitative tool in older patients.

### 4.1. Summary of evidence

It appears that AVGs are effective in improving the overall balance abilities of older patients. However, some limitations within the included studies make discerning the overall consensus among the literature difficult. First, although 6 low-quality nonexperimental design studies demonstrated balance improvements after AVG-based rehabilitation, 4 of these did not indicate whether the improvements were statistically significant.<sup>41–44</sup> Without providing the inferential statistics, it is hard to discern the effectiveness of AVG-based interventions on balance abilities. Second, as a result of the large number of pre-experimental designs employed, evidence of the effectiveness of AVG-based treatment cannot be surmised given the absence of a control group and the inability to monitor a patient's PA outside the intervention.<sup>39–44</sup> Third, only 3 RCTs indicated a positive effect of AVGs on overall balance, with 1 study employing AVG-based rehabilitation in combination with traditional therapy, making it difficult to isolate any additive effects of the AVG-based rehabilitation beyond usual care.<sup>29</sup> Nevertheless, based on the present literature, AVGs either have a null or a positive impact on older patients' balance abilities. Thus, the overall findings tend to be positive, generally indicating that as AVG play increases, balance abilities may also increase. As such, AVG-based rehabilitation shows great promise as an effective modality in promoting older patients' balance abilities.

Overall, most studies indicated that AVG-based rehabilitation had positive effects on physical functioning. However, given that half the studies (7 of 14) were pre- or quasi-experimental designs, a conclusion concerning the effects of AVG rehabilitation on patients' nonbalance physical functioning cannot be drawn from these non-RCTs. Even though the majority of RCTs reported favorable results, the limited number of publications and the use of different instruments measuring dissimilar physical outcomes made it challenging to compare each study and



draw a definite conclusion regarding the effects of AVG-based rehabilitation on specific physical functions. Additionally, because a couple of RCTs<sup>28,31</sup> were designed as feasibility trails, with the primary goal to assess the feasibility of AVG-based rehabilitation as opposed to drawing conclusions regarding the efficacy of this treatment modality, the results cannot readily be interpreted to suggest that AVG-based intervention is more effective than usual care. Finally, a generalized conclusion must be regarded with caution because the reviewed studies had a wide range of sample sizes and relatively short intervention durations, which may limit the generalizability and practical implications of the findings. Despite these mixed findings, based on our examination of the literature, there appears to be an emphasis on positive results. That is, beneficial physical outcomes from AVG-based rehabilitation are possible. Most important, negative effects of AVGs on physical functioning were not reported.

One advantage of AVG-based rehabilitation over conventional physical therapy is that this modality not only provides physical benefits but also acts as a form of entertainment. The most appealing aspect of AVGs lies in the activity's motivating features.<sup>1,45</sup> That is, AVGs offer players a much higher level of engagement, which can significantly reduce the level of perceived exertion in players.<sup>46</sup> As a result, the level of motivation to stick with the activity is also much higher than with traditional rehabilitation. In this sense, players may improve enjoyment during AVG gameplay leading to potentially reduced depression as well as increased QoL over time and, more important, sustained participation in AVG-based rehabilitation activities. In general, evidence of the effectiveness of AVGs on psychological rehabilitative outcomes is favorable, with some studies indicating positive effects but others reporting no effect. The findings were inconsistent, with previous studies indicating positive psychological effects of AVGs on enjoyment and depression among healthy youth and adults.<sup>47,48</sup> Notably, extrinsic factors within the included studies may have affected the results owing to the high proportion of participants with pre-existing depression.<sup>39</sup> Additionally, it is possible that the intensity and length of AVG-based rehabilitation were not high enough to elicit changes in mood (e.g., 3 × 60 min per week for 4 weeks<sup>37</sup> vs. 3 × 30 min per week for 8 weeks<sup>39</sup>). Finally, it is also likely that some participants had previous experience playing AVGs, leading to low stimulation across the patients during the treatment. As a result, the patients may have had differing perspectives regarding the effectiveness of AVG-based rehabilitation on psychological outcomes. Meanwhile, because modern technology is not part of daily life for many seniors, with many of them being unfamiliar with technology, the motivation to learn how to use AVGs is rather weak because the learning process may be frustrating for many older adults—particularly among older patients already burdened enough by treatments related to their diseases and/or impairments. Nevertheless, AVG-based rehabilitation still has huge potential to generate psychological benefits among seniors with chronic diseases.

At this point, it is unclear whether AVGs are a viable rehabilitative tool to improve cognitive outcomes in older patients. First, as previously stated, despite findings demonstrating

improved balance confidence postintervention, studies did not indicate whether these improvements were statistically significant.<sup>31,41–44</sup> Without providing inferential statistics, we cannot conclude that AVG-based rehabilitation is effective for balance confidence. Second, most current studies have examined the acute effects of AVG-based rehabilitation without follow-ups to assess the sustainability of intervention adaptations, which might cause researchers to under- or over-rate the potential of AVGs and result in inaccurate conclusions regarding the effectiveness of AVGs on patients' cognitive outcomes. Additionally, because individuals with higher education levels and/or socioeconomic status may possess greater cognitive ability than individuals of lower education levels and/or socioeconomic status,<sup>49</sup> some factors such as education, occupation, and even personality could have affected individuals' cognitive performance within those studies. Finally, the nature of AVGs could be a confounding factor influencing intervention results because some types of AVGs (e.g., games that require more executive functions) may have a stronger cognitive demand than others. In this regard, patients may receive varying stimulation intensities from different AVG-based treatments, leading to different results in cognitive rehabilitative outcomes. Therefore, we cannot yet conclude whether AVG-based rehabilitation has a positive effect on older patients' cognitive outcomes. Indeed, PA likely influences multiple pathways including physiological, neurologic, psychological, and even social factors,<sup>50</sup> which may result in improved cognitive function. Physiologically, regular PA has been proven effective in promoting brain function,<sup>51</sup> and neuroelectric measures have shown improved cognitive control and attention after acute and chronic PA.<sup>52</sup> That said, as one type of PA, AVGs hold great promise to improve older adults' cognitive outcomes.

#### 4.2. Limitations and recommendations

Although the current study's strength lies in the provision of the first known synthesis of the effects of AVG-based rehabilitation in older patients in a systematic manner, the study is not without limitations. To begin, the current review is limited by the inclusion of only peer-reviewed full-text and English language publications despite the fact other unpublished and non-English work may be available on the topic. Second, qualitative perspectives such as user experience were not included in this review because they fell outside the review's primary objective. However, these viewpoints would have important relevance for long-term engagement in AVG-based rehabilitation. Third, the heterogeneity of samples, outcomes, interventions, effects, measurement instruments, and research designs lessened the power to detect significant differences and summarize overall significant findings. Finally, the variety of AVGs employed in these intervention studies limited the ability to discern which specific games, and which aspects of those games, are most useful for rehabilitation of specific diseases and/or impairments.

To better evaluate the effects of AVG-based rehabilitation on older patients, future studies should continue to determine guidelines regarding the ideal dose (i.e., AVG-based interventions' intensity, duration, and frequency) of AVG gameplay

among older adults with specific diseases and/or impairments. This could be achieved via the use of more high-quality study designs (i.e., RCTs or quasi-experimental pre–post-test designed studies) and more follow-up testing with patients to discern the sustainability of the adaptations stimulated by certain durations and frequencies of AVG-based rehabilitation. Second, researchers may want to isolate AVG-based rehabilitation and standard therapy procedures during rehabilitation with older patients. Isolating these treatments will allow for better examination of the stand-alone benefits that AVG-based rehabilitation may have in comparison with standard therapy. Third, researchers may want to integrate newer technology, such as the Microsoft Xbox Kinect, and employ multiple types of AVGs to distinguish and surmise the effectiveness of specific AVGs on specific diseases and/or impairments.

## 5. Conclusion

Researchers have made considerable progress in examining the effectiveness of AVG-based rehabilitation among older adults with chronic diseases. Although findings are generally positive (i.e., demonstrating improvements in clinical outcomes as a result of AVG-based rehabilitation compared with standard therapy or no difference between AVG-based rehabilitation and standard therapy), findings are still inconsistent. Indeed, AVGs showed potential as rehabilitative tools among older patients, with several RCTs indicating that AVG-based rehabilitation had positive effects on some aspects of physical, psychological, and cognitive functioning. Notably, little to no evidence suggesting that AVGs had a negative impact on any outcomes was documented. That is, beneficial rehabilitative outcomes from AVG-based rehabilitation are possible. However, the limited number of available RCTs and concerns with design quality of other non-RCTs restrict the ability to provide definitive conclusions supporting the possible advantages of AVG-based rehabilitation over standard therapy. Owing to limitations present in the current literature, the effectiveness of AVGs in clinical rehabilitation settings might have been under- or overestimated, with more research warranted to make more definitive conclusions regarding the value of AVG-based rehabilitation in the improvement of rehabilitative outcomes in older patients. Nonetheless, researchers and health care professionals should continue to explore the rehabilitation benefits of AVGs and harness the potential of AVGs to motivate patients in a trustworthy manner.

## Authors' contributions

NZ carried out the study, performed the data sorting and analysis, and drafted the manuscript. ZP performed the data sorting and analysis and helped draft the manuscript. JEL performed the data sorting and analysis and helped draft the manuscript. ZG conceived of the study, retrieved papers, and helped draft the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

## Competing interests

None of the authors declare competing financial interests.

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