Effects of Exergaming in People with Dementia: Results of a Systematic Literature Review

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Abstract.
Background: Physical exercise benefits functioning, health, and well-being. However, people living with dementia in particular hardly engage in exercise. Exergaming (exercise and gaming) is an innovative, fun, and relatively safe way of exercising in a virtual reality or gaming environment. It may help people living with dementia overcome barriers they can experience regarding regular exercise activities.
Objective: This systematic literature review aims to provide an overview of the cost-effectiveness of exergaming and its effects on physical, cognitive, emotional, and social functioning, as well as the quality of life in people living with dementia.
Methods: PubMed, Embase, Cinahl, PsycINFO, the Cochrane Library, and the Web of Science Core Collection were searched. Selection of studies was carried out by at least two independent researchers.
Results: Three studies were found to be eligible and were included in this review. Two of these showed some statistically significant effects of exergaming on physical, cognitive, and emotional functioning in people living with dementia, although based on a very small sample. No articles were found about the cost-effectiveness of exergaming.
Conclusion: Only a few controlled studies have been conducted into the effectiveness of exergaming, and these show very little significant benefits. More well-designed studies are necessary to examine the effects of exergaming.

Keywords: Cognition, dementia, exercise, neuropsychiatry, play, quality of life, review

INTRODUCTION

Research has shown that physical inactivity is linked to negative health outcomes in older adults,

such as increased mortality rates [1], as well as an increase in health-related costs [2], and a decrease in general well-being and quality of life [3]. On the other hand, exercise positively influences physical fitness, cognition, daily functioning, general health, and well-being in older people [3–9]. These effects presumably apply to older people living with or living without dementia [10–18]. Physical activity and exercise are

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therefore recommended as part of healthy aging for community-dwelling older people as well as those in residential care [19–21].

However, people living with dementia may experience barriers to participation in physical activity which make it harder to be independently active outside the house. Examples of barriers are problems with orientation (wandering, getting lost) [22] and various psychosocial issues, such as negative attitudes toward exercise or lack of perceived behavior control [23]. Another impediment is found in dementia-related symptoms, such as increase of apathy, which is most commonly observed in people with frontotemporal dementia [24], or a decrease of initiative and interest [24, 25]. Although awareness of the importance of exercise is increasing, in the residential care provided to older people movement activities are often neglected [26, 27].

Exergaming is an innovative way of exercising in a virtual reality or gaming environment, which may aid people with dementia to be physically active while being stimulated cognitively, despite their impediments. We define exergaming as "physical exercise interactively combined with cognitive stimulation in a gaming environment" (e.g., *Wii Fit*©). Exergaming relies on technology that tracks the participants' body movement or reactions, which are fed back into the digital game, influencing the course of the game that is shown on the screen [28]. There are many different exergaming applications, such as motion sensing devices that interact with the games (e.g., *Wii Fit*©, *Kinect*©, and *PlayStation*© games with tennis or bowling), mobile applications that use GPS, such as *Geocoaching* (to find hidden treasures), and specific equipment, such as a treadmill or a stationary bicycle with digital video images of the environment, which adjust to the walking or bicycling speed. Exergames may be suitable to use in the home environment, outside, in recreation areas (e.g., gym) and in residential care or day care settings. Exergaming differs from dual tasks, where attention has to be divided between two separate components, for example physical exercise simultaneously with a cognitive task (e.g., cycling and counting backwards) without a digital interactive link between the two types of tasks. Exergaming can be performed as an individual or group activity.

Exergaming may help people living with dementia overcome barriers to physical activity. The assumption is that exergaming improves the (intrinsic) motivation of people living with dementia to engage in movement activities. To this end, the exergames

need to be developed to include features like performing familiar activities, attuned to capabilities and preferences, being intuitively usable, cognitively stimulating and safe, allowing a flow experience, arousing curiosity, adding competition elements, or facilitating social participation [28, 29]. Various exergaming applications indeed offer a feasible, fun and relatively safe physical exercise option to people living with dementia [30–33].

Theories which may help formulate hypotheses regarding the possible benefits of exergaming in terms of exercising behavior and positive effects, are the Theory of Planned Behavior [34] and the Cognitive Enrichment hypothesis [35]. According to The Theory of Planned Behavior [34], the best predictor of actual behavior is behavioral intention [36]. Behavioral intention consists of the subjective norm, attitude toward the behavior, and perceived behavioral control [37]. The subjective norm is the way an individual thinks significant others will judge their behavior.

Because exergaming is a feasible, relatively safe, and a fun way to be physically active it is expected to positively influence any negative subjective norm regarding exercise (e.g., a negative attitude of significant others influencing a person's behavior toward physical activities), and consequently the attitude of people living with dementia toward exercise [30–32]. Moreover, because the games can be attuned to the specific needs of people living with dementia [28], they will be able to perform the activity successfully, adding to their belief that they can perform the activity (thus improving the perceived behavioral control).

From the perspective of the Cognitive Enrichment hypothesis [35], exergaming may benefit people living with dementia because of the provided enriched environment in which several factors are simultaneously stimulating. In exergaming these factors are physical exercise, cognitive stimulation, and the unique interactive link between physical exercise and the digital game, which may lead to improvement of brain functioning [38]. These three simultaneously stimulating factors may have an added value over the two factors in a dual task activity (exercise and cognitive stimulation offered separately).

Regular physical exercise, such as walking, strength and balance exercises, dancing, and chair exercises can positively affect fitness, daily functioning, physical and cognitive functions, such as executive functions, language, and working memory, in people living with dementia [10, 12–16]. Movement activation groups, such as psychomotor group

therapy, have been found to have positive effects on emotional functioning (satisfaction, aggression, nighttime restlessness) [39] and social behavior of people living with dementia [12, 40, 41]. Exergaming is expected to have similar effects in people living with dementia because of the improved engagement in physical activities, in a cognitively stimulating environment and in interaction with other people (who also perform exergames or are present as spectators). However, as exergaming is a relatively new intervention for people living with dementia, an overview of the effects of exergaming on overall functioning and quality of life in people with dementia is lacking [42].

In this paper we report on a systematic literature review on the effects of exergaming on overall functioning and quality of life in people with dementia. The primary aim of the review was to describe the effects of exergaming on physical, cognitive, emotional, and social functioning, and quality of life in people living with dementia. The secondary aim was to describe the evidence on the cost-effectiveness of exergaming for people living with dementia.

METHOD

Systematic literature review

A systematic literature review was conducted using the databases PubMed, Embase, Cinahl, PsycINFO, the Cochrane Library, and the Web of Science Core Collection.

A protocol was developed based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement [43]. Details of the protocol for this systematic review were registered on PROSPERO under registration number CRD42016053633 [44].

Search strategies

The databases were searched from inception (by FM, JvS, and RdV) up to the 10th of October 2017. The following terms were used (including synonyms and closely related words) as index terms or free-text words: ('dementia' or 'Alzheimer') and ('video games' or 'exer-games' or 'virtual reality'). The full search strategies for all databases are available from the corresponding author upon request.

Eligibility criteria

Articles were accepted in all languages and including persons with all types of dementia, living in the community or residential care. No restrictions were set with regard to the publication date. Regarding the design, (randomized) controlled studies investigating the effects of exergaming in people living with dementia were included. In case of meta-analyses, the original studies described in the paper were considered for inclusion. Studies needed to address exergaming in a way that corresponded with our definition. Comparison or control conditions could be care as usual, as well as any other existing psychosocial intervention, such as psychomotor therapy, a walking program, pleasant activities, or cognitive stimulation therapy.

Selection process

The search results from the six databases were uploaded into EndNote X8. Duplicates were removed according to the guidelines of the VU University Library Amsterdam, the Netherlands [45]. Remaining duplicates were removed manually by the first author.

From the remaining search results, the titles and abstracts were screened independently by two review team members (FM, JvS, RMD, MH, AvR, OBH) to identify studies that potentially met the inclusion criteria. If no abstract was available, additional information was searched manually on the internet to aid the selection process. In case of disagreement about in- or exclusion of a study, or reason for exclusion, a team of three authors needed to reach consensus. The full text of selected studies for inclusion were retrieved as were potentially interesting reviews (to search their lists of references manually). Reviews were selected if two review team members based on title and abstract marked them as potentially referring to studies about exergaming for people living with dementia. The reference lists of both were manually searched independently by two members of the review team for additional studies to include. When reviewers disagreed, this was settled through a discussion with a third reviewer from the review team.

Data extraction and quality assessment

A data extraction form for the included studies was developed in Windows Office Excel 2010, based on the Cochrane Handbook for Systematic Reviews of

Interventions [46] and the data collection form of the Effective Practice and Organisation of Care [47]. The data extraction form used for this review is available from the author upon request, and included:

– data about the publication (authors, titles of the article and the journal);
– aims/hypothesis;
– method of the study (study design, setting, diagnosis and severity (incl. type(s) of dementia) of the sample, comorbidities, description of the intervention and of the control condition, number of participants in the intervention and the control/comparison group(s), including how many were randomized and how many analyzed (with reasons for drop out), duration of the trial (incl. duration of the intervention(s) and timing of follow up(s)), outcome measures, type(s) of analysis);
– results (baseline and follow up(s), between groups (exergaming versus control condition) effects: p-values & effect sizes (95% CI, Cohen's d)) [48];
– a summary of the conclusion.

We noted whether the authors needed to be contacted for any additional information and if so, which specific information was required. Two reviewers extracted the data independently. Any disagreement between the reviewers was resolved through discussion with a third reviewer from the review team. If relevant information could not be found in the included studies, the authors were requested to provide the missing information if possible.

Two reviewers independently assessed the risk of bias (quality) of the included studies. This was based on the Cochrane Collaboration's tool for assessing risk of bias [46], which includes selection bias, performance bias, detection bias, attrition bias, reporting bias, and any other potential sources of bias. Any disagreements between the two review team members about the risk of bias assessment was resolved through discussion with a third review team member.

Data synthesis

Key information about the included studies were described and the risk of bias (quality) in assessment outcomes was summarized. A critical analysis was conducted to assess potential differences in effects of exergaming for people with different backgrounds and in different contexts.

RESULTS

Study selection

In Fig. 1, the selection process has been summarized according to the PRISMA flow chart [43]. The initial search strategy yielded 1,226 results from the selected databases, consisting of 209 records from PubMed, 353 from Embase.com, 67 from EBSCO/Cinahl, 148 from EBSCO/PsycINFO, 53 from Wiley/Cochrane Library, and 396 from the Web of Science Core Collection. After removal of duplicates, 748 records were screened based on title, abstract, and, if applicable, additional information. Disagreements about in- or exclusion of 41 studies were solved in a team of three authors. In this first stage, 734 records were excluded for the reasons presented in Fig. 1. An example of other reasons for exclusion is that the research participants were animals. The full text was retrieved of the remaining articles ($n = 14$) and of potentially interesting reviews ($n = 57$). The lists of references of this total of 71 articles were screened, but this did not lead
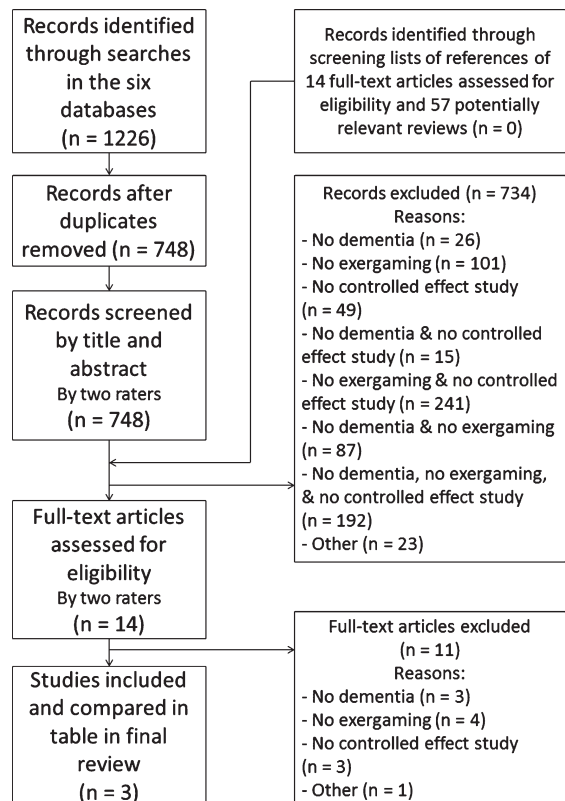

Fig. 1. Selection process of the systematic review (from: Moher et al., 2009) [43].

to any records being added. Fourteen articles were read in full text, of which 11 were excluded. During data extraction, the authors of one study [49] were contacted to request the data and analysis of the subgroups with dementia which were not separately described in the article. The authors of the other studies were contacted about minor questions regarding drop out and locations of the assisted living facility and medical center, which were clarified [50, 51].

A total of three studies [49–51] were included in this review.

Study design and aims

Table 1 presents the study design and aims of the three included studies. The first was a pre-test/post-test control group study with five arms; three of which were intervention groups (physical training, cognitive training, or combined) and two control groups (passive and active) [49]. The other studies were both prospective randomized controlled pilot studies in which exergaming was compared to a walking program [50, 51]. The primary aims of the studies were to investigate the benefits of exergaming on global cognition [49], and to determine the effects of exergaming on the measures balance and gait in older adults with mild Alzheimer's disease (AD) [50, 51].

Participants and settings

The characteristics of the participants and the settings are presented in Table 1. The study by Bamidis and colleagues (2015) included 322 participants but we only considered the 19 participants with dementia [49]. The other two studies had sample sizes of 22 [50] and 30 [51]. Diagnosis varied from dementia to mild cognitive impairment (MCI, both amnestic and non-amnestic) [49] and mild AD [50, 51]. One study, which also included cognitively healthy participants as controls, was the only study to include people with MCI [49]. Because we were interested in dementia and not MCI, we only used the data on the participants with dementia in our analysis. Other

Table 1
Study and intervention characteristics

Study	Design & aims/hypothesis	Participants & setting	Dementia diagnosis & severity (incl. type(s) of dementia), comorbidities	Exergaming intervention	Control/comparison
Bamidis et al. [49]	**Design:** a multi-center pre-test/post-test control group study	**All IGs & CGs (dementia subgroup)** $N = 19$ Community-dwelling older adults in Athens and Thessaloniki, Greece	**All IGs & CGs (dementia subgroup)** Dementia ($n = 19$), diagnosis not further specified. Comorbidities not described.	**IG: physical training** Mean of 24 sessions over 7-8 weeks of 1-h *FitForAll* exergames, (10 min warming up, 4x 10–15 min, 5 min cooling down). Exergames were: 1) aerobics: "Hiking" (running on the spot) & "Cycling"(on a stationary mini-bike) moving an avatar through a landscape; 2) strength: weightlifting & resistance training gradually revealing pictures; 3) dynamic balance: "Ski Jump", "Arkanoid", "Apple Tree", "Fishing", and "Golf"	**IG: cognitive training** Mean of 24 sessions over 7-8 weeks of one hour *Brain Fitness Program* (4 exercises of 15 min each), consisting of 6 tasks targeting auditory processing and working memory, i.e., "Story Teller" in which participants had to answer multiple choice questions about story facts.

(*Continued*)

Table 1
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Study	Design & aims/hypothesis	Participants & setting	Dementia diagnosis & severity (incl. type(s) of dementia), comorbidities	Exergaming intervention	Control/comparison
	Aim: to investigate the benefits of combined training on global cognition while assessing the effect of training dosage and exploring the role of several potential effect modifiers.	**IG: physical training** $N=4$ 4 females, 0 males Mean age (y): 71.5 Mean education (y): 5.1 **IG: cognitive training** $N=5$ 5 females, 0 males Mean age (y): 74.8 Mean education (y): 4.9 **Active CG** $N=6$ 4 females, 2 males Mean age (y): 76.2 Mean education (y): 4.5 **Passive CG** $N=4$ 2 females, 2 males Mean age (y): 73.5 Mean education (y): 7.8		**Total:** 24 h over 7-8 weeks **Supervisor/ moderator:** group setting (apart from 1 participant who trained at home) with physiotherapists, sport-experts/physical educators, psychologists, or trained facilitators (formal care givers).	**Total:** 24 h over 7-8 weeks **Supervisor/ moderator:** group setting with psychologists, physical educator, researchers, or nurses. **Active CG** Mean 24 sessions over 7-8 weeks of 35–45 min watching documentaries. **Total:** 14–18 h over 7-8 weeks **Supervisor/ moderator:** group setting with psychologists, physical educator, researchers, or nurses. **Passive CG** No intervention. **Total:** n/a **Supervisor/ moderator:** n/a
Padala et al. [50]	**Design:** a prospective randomized controlled pilot study **Aim:** to determine the effects on balance and gait of a *Wii-Fit* program compared to a walking program in subjects with mild AD.	**IG & CG** $N=22$ Setting IG & CG: Living in an assisted living facility Nebraska, USA. **IG** $N=11$ in IG 8 females, 3 males Mean age (y): 79.3 Mean BMI: 24.5 Mean education (y): 13.8 Use of assistive walking device: 4 Mean time of exercise (h): 11.1 **CG** $N=11$ 8 females, 3 males Mean age (y): 81.6 Mean BMI: 26.4 Mean education (y): 14.0 Use of assistive walking device: 3 Mean time of exercise (h): 13.1	**IG & CG** medical chart documenting history of mild AD & an MMSE score between 18 & 29, mean number of 3.2 comorbidities	**IG** *Wii-Fit*, 30 min daily, 5 times per week, for 8 weeks: 10 min on strength training (i.e., single leg extensions, lunges, torso twists), 10 min on yoga (i.e., half-moon, warrior pose, chair, sun salutation), 10 min on balance games (i.e., ski slalom, ski jump, table tilt, penguin slide). Walking to and from the *Wii-Fit* room as warming up and cooling down. **Total:** 20 h over 8 weeks **Supervisor/ moderator:** one in one guidance from research personnel	**CG** Walking program indoors, 30 min daily, 5 times per week, for 8 weeks. Walking to and from the starting point as warming up and cooling down. Walking at own pace. **Total:** 20 h over 8 weeks **Supervisor/ moderator:** research personnel with a group of 3 or 4 subjects

Table 1
(*Continued*)

Study	Design & aims/hypothesis	Participants & setting	Dementia diagnosis & severity (incl. type(s) of dementia), comorbidities	Exergaming intervention	Control/comparison
Padala et al. [51]	**Design:** a prospective randomized controlled parallel-group pilot trial	**IG & CG** *N* = 30 Setting IG & CG: Community-dwelling older adults recruited through pre-screening of the electronic medical records of a medical center in Arizona, USA.	**IG & CG** medical chart documenting history of fear of falling in the past year, history of mild AD & MMSE score ≥ 18.	**IG** *Wii-Fit*, 30 min daily, 5 times per week, for 8 weeks. Exercises from 5 categories of the *Wii-Fit* program: yoga, strength training, aerobics, balance games, and training plus, which includes more complex exercise tasks. Warm up and cool down: 5 min 'basic walk' on *Wii-Fit*	**CG** Walking program either indoors or outdoors, 30 min daily, 5 times per week, for 8 weeks. Walking at own pace. **Total:** mean: 16 h + 25 min (SD = 3 h + 31 min) over 8 weeks
	Aim: to study the effects of a Wii-Fit interactive video-game-led physical exercise program compared to a walking program on measures of balance in older adults with mild AD.	**IG** *N* = 15 in IG 5 females, 10 males Mean age (y): 72.1 Mean BMI: 26.1 Education: 13 high school diploma, 1 some college, 1 Bachelor's degree Mean number of exercise sessions ± SD: 38 ± 2 **CG** *N* = 15 6 females, 9 males Mean age (y): 73.9 Mean BMI: 27.9 Education: 13 high school diploma, 1 some college, 1 Bachelor's degree Mean number of exercise sessions ± SD: 37 ± 6	**IG** Median number of comorbidities: 6, most commonly: hypertension (*n* = 13), hyperlipidemia (*n* = 13), and depression (*n* = 8). **CG** Median number of comorbidities: 7, most commonly: hypertension (*n* = 15), hyperlipidemia (*n* = 14), and depression (*n* = 9).	**Total:** mean: 20 h + 53 min (SD = 7 h + 24 min) over 8 weeks **Supervisor/moderator:** home-based exercises under caregiver supervision.	**Supervisor/ moderator:** home-based under caregiver supervision.

IG, intervention group; CG, comparison/control group; AD, Alzheimer's disease; MCI, mild cognitive impairment; BMI, body mass index; MMSE, Mini-Mental State Examination.

characteristics described in the papers are presented in Table 1.

Intervention programs

The exergaming interventions and the usual care or comparison treatments are also summarized in Table 1. In the study conducted by Bamidis and colleagues (2015), the exergaming intervention consisted of physical training with the FitForAll exergames and the *Wii*[©] Balance Board or the *Wii*[©] Remote. The combined intervention (physical and cognitive training) in the same study consisted of exergaming with an added cognitive training (the

Brain Fitness Program). In the context of this review, the combined intervention group was not of interest and therefore not included. The active control group watched documentaries about art, history, and nature and completed questionnaires about these documentaries. The passive control group did not receive any intervention [49]. The interventions in both other studies consisted of only exergaming [50, 51].

Outcome measures and intervention effects

Tables 2–6 present the outcome measures and effects by outcome category and study, as well as the between-group effects with the effect sizes.

Table 2
Outcome measures and between group effects* on physical functioning by study and different comparison/control groups (if applicable)

	Baseline		Follow up at 8 weeks		ANCOVA**		Effect size
	Exergaming	Passive control group	Exergaming	Passive control group			
Bamidis et al. [49]	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Exergaming-passive control group (95% CI)	p	(Cohen's d)
Subtests of the Senior Fitness Test (SFT)***:							
SFT-Chair stand	13.8 (3.1)	10.5 (3.1)	19.3 (4.6)	9.3 (1.5)	14.4 (10.2 to 18.7)	0.152	2.70
SFT-Arm curl	19.8 (7.3)	16.0 (4.2)	24.8 (4.3)	14.3 (3.1)	19.7 (16.8 to 22.7)	**0.032**	2.72
SFT-2-min step	61.8 (19.9)	68.5 (23.9)	81.0 (9.2)	69.0 (24.3)	74.9 (66.7 to 83.1)	0.082	0.71
SFT-Back scratch	0.3 (7.2)	–9.8 (9.3)	0.0 (6.8)	–13.0 (5.6)	–5.8 (–7.2 to –4.4)	0.135	2.06
SFT-Chair sit-and-reach	0.8 (7.7)	2.3 (7.5)	4.0 (6.9)	0.0 (8.7)	1.9 (–1.1 to 4.9)	0.074	0.52
SFT-8-foot up-and-go	5.5 (1.7)	7.5 (2.3)	4.7 (0.9)	7.4 (0.5)	5.9 (5.6 to 6.3)	**0.019**	–3.26
	Baseline		Follow up at 8 weeks		ANCOVA**		Effect size
	Exergaming	Active control group	Exergaming	Active control group			
Bamidis et al. [49]	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Exergaming-active control group (95% CI)	p	(Cohen's d)
Subtests of the Senior Fitness Test (SFT)***:							
SFT-Chair stand	13.8 (3.1)	12.3 (1.8)	19.3 (4.6)	12.8 (1.5)	15.9 (13.6 to 18.4)	**0.027**	2.12
SFT-Arm curl	19.8 (7.3)	18.5 (3.2)	24.8 (4.3)	18.8 (3.3)	21.7 (19.4 to 24.1)	**0.033**	1.60
SFT-2-min step	61.8 (19.9)	63.7 (19.8)	81.0 (9.2)	67.0 (18.3)	74.1 (66.3 to 81.9)	0.056	0.90
SFT-Back scratch	0.3 (7.2)	–12.8 (9.1)	0.0 (6.8)	–12.3 (7.7)	–7.2 (–9.1 to –5.3)	0.401	1.67
SFT-Chair sit-and-reach	0.8 (7.7)	2.7 (3.2)	4.0 (6.9)	2.2 (2.9)	3.3 (0.3 to 6.3)	0.191	0.38
SFT-8-foot up-and-go	5.5 (1.7)	5.7 (2.3)	4.7 (0.9)	6.3 (1.5)	5.5 (4.5 to 6.5)	0.122	–1.22

(*Continued*)

Table 2
(*Continued*)

	Baseline		Follow up at 8 weeks				ANCOVA**		Effect size
	Exergaming	Cognitive intervention	Exergaming	Cognitive intervention					
Bamidis et al. [49]	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))			Exergaming-cognitive group (95% CI)	*p*	(Cohen's *d*)
Subtests of the Senior Fitness Test (SFT)***:									
SFT-Chair stand	13.8 (3.1)	10.0 (2.8)	19.3 (4.6)	12.0 (6.1)			15.6 (11.1 to 20.1)	0.349	1.35
SFT-Arm curl	19.8 (7.3)	12.8 (2.6)	24.8 (4.3)	12.8 (3.8)			18.6 (16.1 to 21.1)	**0.019**	2.97
SFT-2-min step	61.8 (19.9)	39.4 (18.2)	81.0 (9.2)	38.0 (10.8)			59.5 (52.5 to 66.5)	**0.002**	4.29
SFT-Back scratch	0.3 (7.2)	–17.6 (11.2)	0.0 (6.8)	–15.6 (11.3)			–8.7 (–12.2 to –5.2)	0.982	1.62
SFT-Chair sit-and-reach	0.8 (7.7)	–3.2 (10.3)	4.0 (6.9)	1.6 (15.9)			2.6 (–3.7 to 9.0)	0.938	0.19
SFT-8-foot up-and-go	5.5 (1.7)	9.7 (2.7)	4.7 (0.9)	7.4 (2.4)			6.1 (4.5 to 7.7)	0.412	–1.40
	Baseline		Follow up at 8 weeks				Independent samples *t*-test		
	Exergaming	Comparison	Exergaming	Comparison	Exergaming	Comparison			
Padala et al. [50]	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Change (mean (SD))	Change (mean (SD))	Difference (95% CI)	*p*	Effect size (Cohen's *d*)
Berg Balance Scale (max. poss. score: 56)	43.4 (8.9)	41.3 (7.6)	49.6 (5.7)	46.6 (8.7)	6.2 (7.5)	5.3 (8.2)	1.0 (–5.9 to 7.9)	0.768	0.41
Tinetti Test (max. poss. score: 28)	23.5 (3.7)	22.9 (2.6)	25.3 (2.8)	24.9 (3.4)	1.8 (3.3)	2.0 (3.0	–0.2 (–3.0 to 2.6)	0.883	0.13
Timed Up and Go (in s)	14.7 (7.2)	14.9 (4.7)	13.9 (7.9)	12.8 (3.2)	–0.8 (7.6)	–2.1 (4.0)	1.3 (–4.1 to 6.7)	0.621	0.18
Padala et al. [51]	Score (mean (SD))	Score (mean (SD))	Exergaming group: change (mean (95% CI))		Comparison group: change (mean (95% CI))		Difference (95% CI)	*p*	Effect size (Cohen's *d*)
Berg Balance Scale (max. poss. score: 56)	46.5 (2.4)	45.8 (2.5)	5.8 (4.8 to 6.8)		1.0 (0.0 to 2.0)		4.8 (3.3 to 6.2)	**<0.001**	2.24

*Statistically significant between group effects (*p* ≤ 0.05) are printed in bold. **Mean differences between exergaming and control/comparison group resulting from the ANCOVA analysis. ***Subtests of the Senior Fitness Test (SFT) [61]: SFT-Chair stand: testing lower body strength by the number of completed chair stands in 30 seconds. SFT-Arm curl: testing upper body strength by the number of arm curls in 30 seconds using the dominant arm. SFT-2-min step: measuring aerobic endurance by the number of steps in 2 minutes. SFT-Back scratch: testing upper body flexibility by measuring the distance between the tips of the middle fingers. If the fingertips touch then the score is zero. If they do not touch, the distance between the fingertips is measured resulting in a negative score. If they overlap, it is measured by how much resulting in a positive score. All scores are in centimeters. SFT-Chair sit-and-reach: testing lower body flexibility by measuring the distance between the tip of the fingertips and the toes. If the toes are reached, the score is zero. If the toes cannot be reached, this results in a negative score. If a participant can reach further than the toes, this results in a positive score. All scores are in centimeters. SFT-8-foot up-and-go: measuring speed, agility and balance while moving, scores are in seconds.

Table 3
Outcome measures and between group effects* on cognitive functioning by study and different comparison/control groups (if applicable)

	Baseline		Follow up at 8 weeks				Effect size
	Exergaming	Passive control group	Exergaming	Passive control group	ANCOVA**		
Bamidis et al. [49]	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Exergaming-passive control group (95% CI)	*p*	(Cohen's *d*)
Mini-Mental State Examination	22.3 (1.5)	22.0 (3.2)	23.5 (1.3)	24.0 (4.2)	23.8 (21.9 to % 25.5)	0.602	−0.16
California Verbal Learning Test (CVLT)***:							
CVLT-Short delay free recall	3.3 (3.3)	3.8 (4.4)	7.3 (3.6)	3.8 (4.5)	5.5 (3.5 to 7.5)	0.056	0.86
CVLT-Short delay cued recall	5.0 (2.9)	6.0 (2.6)	8.3 (4.4)	7.5 (2.7)	7.9 (6.8 to 8.9)	0.069	0.21
CVLT-Long delay free recall	1.8 (2.1)	3.5 (2.9)	6.5 (4.4)	4.3 (3.1)	5.4 (3.1 to 7.7)	0.071	0.59
CVLT-Long delay cued recall	5.0 (3.5)	−7.3 (5.7)	7.8 (3.9)	7.0 (3.7)	7.4 (4.8 to 9.9)	0.376	0.20
CVLT-Recognition	11.3 (2.1)	12.0 (4.3)	13.3 (3.1)	13.3 (3.2)	13.3 (10.6 to 15.9)	0.862	0.00
Digit Span Test (DST) (no. of digits):							
DST-Forward	4.0 (1.4)	5.8 (1.5)	4.0 (1.6)	5.3 (2.1)	4.6 (3.3 to 5.9)	0.825	−0.66
DST-Backward	2.3 (0.5)	2.8 (1.0)	3.5 (1.0)	3.3 (1.3)	3.4 (2.4 to 4.4)	0.936	0.22
Trail Making Test part A & B (TMT A & B):							
TMT A time (in s)	196.3 (110.1)	104.0 (76.8)	124.8 (50.9)	64.3 (33.1)	98.6 (72.4 to 124.8)	0.879	1.35
TMT A (no. of) errors	1.0 (0.8)	2.0 (2.8)	0.8 (0.5)	0.7 (0.6)	0.7 (−0.4 to 1.9)	0.840	0.07
TMT B time (in s)	299.3 (62.7)	218.3 (104.6)	331.0 (129.9)	173.3 (97.9)	252.2 (126.4 to 377.9)	0.426	1.37
TMT B (no. of) errors	1.7 (0.6)	0.7 (0.6)	1.7 (2.1)	0.7 (0.6)	1.2 (−1.1 to 3.5)	0.743	0.65

	Baseline		Follow up at 8 weeks				Effect size
	Exergaming	Active control group	Exergaming	Active control group	ANCOVA**		
Bamidis et al. [49]	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Exergaming-active control group (95% CI)	*p*	(Cohen's *d*)
Mini-Mental State Examination	22.3 (1.5)	19.2 (6.4)	23.5 (1.3)	19.2 (3.9)	21.2 (19.6 to 22.7)	0.800	1.37
California Verbal Learning Test (CVLT)***:							
CVLT-Short delay free recall	3.3 (3.3)	2.6 (2.2)	7.3 (3.6)	4.6 (1.8)	5.9 (4.4 to 7.3)	0.132	0.97
CVLT-Short delay cued recall	5.0 (2.9)	4.8 (1.5)	8.3 (4.4)	6.0 (3.1)	7.1 (4.8 to 9.4)	0.322	0.61
CVLT-Long delay free recall	1.8 (2.1)	2.4 (1.8)	6.5 (4.4)	3.0 (2.1)	4.8 (3.0 to 6.6)	**0.026**	1.05
CVLT-Long delay cued recall	5.0 (3.5)	3.6 (1.7)	7.8 (3.9)	4.8 (2.6)	6.2 (4.4 to 8.0)	0.335	0.92
CVLT-Recognition	11.3 (2.1)	13.2 (1.5)	13.3 (3.1)	14.0 (1.0)	13.7 (11.8 to 15.5)	0.979	−0.35
Digit Span Test (DST) (no. of digits):							
DST-Forward	4.0 (1.4)	3.8 (1.5)	4.0 (1.6)	4.2 (1.5)	4.1 (3.2 to 4.9)	0.627	−0.13
DST-Backward	2.3 (0.5)	3.0 (1.0)	3.5 (1.0)	3.2 (0.8)	3.4 (2.8 to 3.9)	0.174	0.33
Trail Making Test part A & B (TMT A & B):							
TMT A time (in s)	196.3 (110.1)	129.2 (43.6)	124.8 (50.9)	121.2 (33.4)	121.2 (130.9 to 138.5)	0.126	0.08
TMT A (no. of) errors	1.0 (0.8)	0.2 (0.5)	0.8 (0.5)	0.2 (0.5)	0.4 (−0.3 to 1.2)	0.745	0.53
TMT B time (in s)	299.3 (62.7)	308.7 (170.7)	331.0 (129.9)	333.5 (153.1)	333.5 (208.9 to 458.1)	0.953	−0.03
TMT B (no. of) errors	1.7 (0.6)	4.0 (3.5)	1.7 (2.1)	3.7 (3.1)	2.7 (0.3 to 5.0)	0.981	−0.76

(*Continued*)

Table 3
(*Continued*)

	Baseline		Follow up at 8 weeks		ANCOVA**		Effect size
	Exergaming	Cognitive intervention	Exergaming	Cognitive intervention			
Bamidis et al. [49]	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Exergaming-cognitive group (95% CI)	*p*	(Cohen's *d*)
Mini-Mental State Examination	22.3 (1.5)	20.8 (2.3)	23.5 (1.3)	23.4 (3.4)	23.4 (21.4 to 25.4)	0.596	1.37
California Verbal Learning Test (CVLT)***:							
CVLT-Short delay free recall	3.3 (3.3)	5.8 (4.1)	7.3 (3.6)	9.2 (4.3)	8.4 (6.4 to 10.4)	0.879	–0.49
CVLT-Short delay cued recall	5.0 (2.9)	6.8 (3.7)	8.3 (4.4)	9.6 (3.6)	9.0 (7.9 to 10.1)	0.531	–0.34
CVLT-Long delay free recall	1.8 (2.1)	6.4 (4.9)	6.5 (4.4)	8.2 (4.3)	7.6 (4.8 to 10.3)	0.514	–0.39
CVLT-Long delay cued recall	5.0 (3.5)	7.0 (4.0)	7.8 (3.9)	8.2 (4.3)	8.1 (5.9 to 10.3)	0.526	–0.11
CVLT-Recognition	11.3 (2.1)	13.2 (3.1)	13.3 (3.1)	12.8 (3.6)	13.1 (10.8 to 15.5)	0.387	0.13
Digit Span Test (DST) (no. of digits):							
DST-Forward	4.0 (1.4)	4.0 (1.9)	4.0 (1.6)	4.8 (1.1)	4.4 (3.5 to 5.4)	0.336	–0.59
DST-Backward	2.3 (0.5)	2.8 (0.8)	3.5 (1.0)	3.4 (0.9)	3.5 (2.7 to 4.2)	0.583	0.11
Trail Making Test part A & B (TMT A & B):							
TMT A time (in s)	196.3 (110.1)	151.0 (29.1)	124.8 (50.9)	120.4 (59.4)	16.2 (81.8 to 161.1)	0.660	0.08
TMT A (no. of) errors	1.0 (0.8)	0.4 (0.6)	0.8 (0.5)	0.4 (0.9)	0.6 (–0.4 to 1.5)	0.946	0.29
TMT B time (in s)	299.3 (62.7)	304.0 (66.1)	331.0 (129.9)	258.8 (70.5)	287.8 (140.8 to 434.9)	0.405	0.80
TMT B (no. of) errors	1.7 (0.6)	2.3 (1.5)	1.7 (2.1)	0.5 (0.6)	1.0 (–0.3 to 3.3)	0.434	0.87

	Baseline		Follow up at 8 weeks				Independent samples *t*-test		
	Exergaming	Comparison	Exergaming	Comparison	Exergaming	Comparison			
Padala et al. [50]	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Change (mean (SD))	Change (mean (SD))	Difference (95% CI)	*p*	Effect size (Cohen's *d*)
Mini Mental State Examination	22.6 (4.3)	24.9 (3.6)	22.4 (2.8)	25.5 (4.1)	–0.2 (3.6)	0.6 (3.9)	–0.8 (–4.1 to 2.5)	0.623	–0.88
Padala et al. [51]	Score (mean (SD))	Score (mean (SD))	Exergaming group: change (mean (95% CI))		Comparison group: change (mean (95% CI))		Difference (95% CI)	*p*	Effect size (Cohen's *d*)
Mini-Mental State Examination	23.3 (2.2)	22.7 (2.3)	0.7 (–0.3 to 1.7)		–0.1 (–1.1 to 0.9)		0.8 (–0.7 to 2.2)	0.264	0.00
Modified Mini Mental (max. poss. score: 100)	87.5 (3.6)	85.7 (7.8)	–0.4 (–2.6 to 1.7)		–0.6 (–2.7 to 1.6)		0.1 (–3.0 to 3.2)	0.946	0.33

*Statistically significant between group effects ($p \leq 0.05$) are printed in bold. **Mean differences between exergaming and control/comparison group resulting from the ANCOVA analysis. ***California Verbal Learning Test (CVLT) [62]: testing episodic verbal learning and memory. All scores are in number of words, maximum possible score is 16 per subtest.

Table 4
Outcome measures and between group effects* on daily life functioning by study and different comparison/control groups (if applicable)

	Baseline		Follow up at 8 weeks		ANCOVA**		Effect size
	Exergaming	Passive control group	Exergaming	Passive control group	ANCOVA**		Effect size
Bamidis et al. [49]	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Exergaming-passive control group (95% CI)	*p*	(Cohen's *d*)
Instrumental Activities of Daily Living Scale***	8.0 (0.0)	6.5 (1.7)	8.0 (0.0)	6.5 (1.7)	7.3 (7.3 to 7.3)	**<0.001**	1.23
	Exergaming	Active control group	Exergaming	Active control group	ANCOVA**		Effect size
Bamidis et al. [49]	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Exergaming-active control group (95% CI)	*p*	(Cohen's *d*)
Instrumental Activities of Daily Living Scale***	8.0 (0.0)	6.8 (1.6)	8.0 (0.0)	8.3 (4.0)	7.3 (7.3 to 7.3)	**<0.001**	0.97
	Exergaming	Cognitive intervention	Exergaming	Cognitive intervention	ANCOVA**		Effect size
Bamidis et al. [49]	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Exergaming-cognitive group (95% CI)	*p*	(Cohen's *d*)
Instrumental Activities of Daily Living Scale***	8.0 (0.0)	8.0 (0.0)	8.0 (0.0)	7.8 (0.5)	7.9 (7.6 to 8.2)	0.407	0.59

	Baseline		Follow up at 8 weeks				Independent samples *t*-test		
	Exergaming Score (mean (SD))	Comparison Score (mean (SD))	Exergaming Score (mean (SD))	Comparison Score (mean (SD))	Exergaming Change (mean (SD))	Comparison Change (mean (SD))	Difference (95% CI)	*p*	Effect size (Cohen's *d*)
Padala et al. [50]									
Activities of Daily Living****	22.3 (1.6)	22.0 (2.7)	22.6 (1.3)	21.4 (2.5)	0.3 (1.5)	–0.6 (2.6)	0.9 (–0.9 to 2.8)	0.332	0.60
Instrumental Activities of Daily Living***	11.3 (4.3)	10.9 (3.5)	10.4 (2.8)	11.6 (4.2)	–0.9 (3.6)	0.7 (3.9)	–1.6 (–4.9 to 1.7)	0.329	–0.34
Padala et al. [51]	Score (mean (SD))	Score (mean (SD))	Exergaming group: change (mean (95% CI))		Comparison group: change (mean (95% CI))		Difference (95% CI)	*p*	Effect size (Cohen's *d*)
Activities of Daily Living****	23.4 (1.1)	23.2 (1.4)	0.2 (–0.2 to 0.5)		0.1 (–0.3 to 0.4)		0.1 (–0.4 to 0.6)	0.708	0.24
Instrumental Activities of Daily Living***	18.4 (2.4)	18.3 (4.0)	1.7 (0.7 to 2.6)		1.0 (0.1 to 1.9)		0.7 (–0.7 to 2.0)	0.316	0.24

*Statistically significant between group effects ($p \leq 0.05$) are printed in bold. **Mean differences between exergaming and control/comparison group resulting from the ANCOVA analysis. ***Instrumental Activities of Daily Living [63, 64]: maximum possible score is 23. A higher score indicates a higher level of autonomy. ****Activities of Daily Living [65]: maximum possible score is 24. A higher score indicates a higher level of function.

Table 5
Outcome measures and between group effects* on emotional functioning by study and different comparison/control groups (if applicable)

	Baseline		Follow up at 8 weeks				
	Exergaming	Passive control group	Exergaming	Passive control group	ANCOVA**		Effect size
Bamidis et al. [49]	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Exergaming-passive control group (95% CI)	*p*	(Cohen's *d*)
Geriatric Depression Scale Short	2.8 (1.5)	1.0 (0.8)	1.5 (1.3)	1.5 (1.3)	1.5 (0.3 to 2.7)	0.644	0.00
	Exergaming	Active control group	Exergaming	Active control group	ANCOVA**		Effect size
Bamidis et al. [49]	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Exergaming-active control group (95% CI)	*p*	(Cohen's *d*)
Geriatric Depression Scale Short	2.8 (1.5)	2.2 (4.4)	1.5 (1.3)	2.0 (3.2)	1.9 (0.2 to 3.7)	0.459	–0.34
	Exergaming	Cognitive intervention	Exergaming	Cognitive intervention	ANCOVA**		Effect size
Bamidis et al. [49]	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Exergaming-cognitive group (95% CI)	*p*	(Cohen's *d*)
Geriatric Depression Scale Short	2.8 (1.5)	3.6 (4.9)	1.5 (1.3)	5.4 (3.8)	3.5 (1.6 to 5.4)	0.69	–1.31
	Baseline		Follow up at 8 weeks		Independent samples *t*-test		
	Exergaming	Comparison					
Padala et al. [51]	Score (mean (SD))	Score (mean (SD))	Exergaming group: change (mean (95% CI))	Comparison group: change (mean (95% CI))	Difference (95% CI)	*p*	Effect size (Cohen's *d*)
Activities-specific Balance Confidence scale***	83.2 (6.1)	81.4 (7.3)	5.6 (3.6 to 7.7)	–0.9 (–2.9 to 1.2)	6.5 (3.6 to 9.4)	**<0.001**	1.23
Falls Efficacy Scale****	16.7 (3.1)	16.5 (2.9)	–3.7 (–5.7 to –1.7)	1.1 (–0.9 to 3.1)	–4.8 (–7.6 to –2.0)	**0.002**	–1.53

*Statistically significant between group effects ($p \leq 0.05$) are printed in bold. **Mean differences between exergaming and control/comparison group resulting from the ANCOVA analysis. ***Activities-specific Balance Confidence scale [66]: percentage of self-confidence, as indicator for functioning and risk of falling. ****Falls Efficacy Scale [67]: maximum possible score is 100. Lower scores indicate a greater confidence in maintaining daily living activities.

Table 6
Outcome measures and between group effects* on quality of life by study and different comparison/control groups (if applicable)

	Baseline		Follow up at 8 weeks		ANCOVA**		Effect size
	Exergaming	Passive control group	Exergaming	Passive control group			
Bamidis et al. [49]	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Exergaming-passive control group (95% CI)	*p*	(Cohen's *d*)
Short version of the World Health Organization Quality of Life questionnaire***	54.0 (5.2)	60.7 (4.2)	57.2 (8.8)	58.3 (4.6)	57.7 (48.9 to 66.5)	0.962	–0.15
	Exergaming	Active control group	Exergaming	Active control group	ANCOVA**		Effect size
Bamidis et al. [49]	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Exergaming-active control group (95% CI)	*p-*	(Cohen's *d*)
Short version of the World Health Organization Quality of Life questionnaire***	54.0 (5.2)	54.5 (8.2)	57.2 (8.8)	56.7 (7.4)	56.9 (50.7 to 63.2)	0.892	0.06
	Exergaming	Cognitive intervention	Exergaming	Cognitive intervention	ANCOVA**		Effect size
Bamidis et al. [49]	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Score (mean (SD))	Exergaming-cognitive group (95% CI)	*p*	(Cohen's *d*)
Short version of the World Health Organization Quality of Life questionnaire***	54.0 (5.2)	45.3 (12.5)	57.2 (8.8)	50.7 (15.5)	53.5 (45.9 to 61.1)	0.800	0.50

	Baseline		Follow up at 8 weeks				Independent samples *t*-test		
	Exergaming Score (mean (SD))	Comparison Score (mean (SD))	Exergaming Score (mean (SD))	Comparison Score (mean (SD))	Exergaming Change (mean (SD))	Comparison Change (mean (SD))	Difference (95% CI)	*p*	Effect size (Cohen's *d*)
Padala et al. [50]									
Quality of Life-AD****	36.5 (3.3)	37.3 (4.9)	35.9 (2.8)	35.6 (5.6)	–0.6 (3.1)	–1.7 (5.3)	1.1 (–2.7 to 4.9)	0.559	0.07
Padala et al. [51]	Score (mean (SD))	Score (mean (SD))	Exergaming group: change (mean (95% CI))		Comparison group: change (mean (95% CI))		Difference (95% CI)	*p*	Effect size (Cohen's *d*)
Quality of Life-AD****	36.8 (3.5)	37.2 (3.0)	1.7 (0.6 to 2.8)		1.1 (0.0 to 2.3)		0.6 (–1.0 to 2.2)	0.445	Effect size (Cohen's *d*) 0.06

*No statistically significant between group effects ($p \leq 0.05$) were found. **Mean differences between exergaming and control/comparison group resulting from the ANCOVA analysis. ***Short version of the World Health Organization Quality of Life questionnaire [68]: maximum possible score is 130 with a higher score indicating a higher quality of life. ****Quality of Life-AD [65]: maximum possible score is 52 with a higher score indicating a higher quality of life.

Bamidis and colleagues (2015) did not publish the results for the dementia subgroup. Therefore, JvS and FM analyzed the data of the dementia subgroup after receiving these from the authors [49]. Outcomes of the intervention group (physical training/exergaming) were compared with an alternative intervention (cognitive training) and both control groups (active and passive control group) using ANCOVA. The groups (physical training/exergaming, cognitive training, active or passive control group) were used as the fixed variables, the baseline scores on the outcomes measures as covariates and the dependent variables consisted of the follow-up scores on the outcome measures. These analyses were done using SPSS 22.

With regard to physical functioning (see Table 2), several significant between-group effects were found on the subtests of the Senior Fitness Test. The physical intervention (= exergaming) group scored better on the chair stand test than the active control group ($p = 0.027$). The exergaming group also scored better on the arm curl test than the active control group ($p = 0.033$), the passive control group ($p = 0.031$) and the cognitive intervention (comparison) group ($p = 0.019$). Additionally, the exergaming group did better than the cognitive intervention (comparison) group on the 2-minute step test ($p = 0.002$) and on the eight minute up and go test than the passive control group ($p = 0.019$) [49]. The second study did not report any significant between-group intervention effects with regard to physical functioning [50]. The third study showed statistically significant improvements in the exergaming group compared to the comparison (walking) group on the Berg Balance Scale ($p < 0.001$) [51].

For cognitive functioning (see Table 3), only the first study found that the exergaming group scored better than the active control group on long delay free recall of the California Verbal learning test ($p = 0.026$) [49]. With regard to daily life functioning (see Table 4), the exergaming group scored better on the Instrumental Activities of Daily Living Scale than both the passive and active control groups (both: $p < 0.0001$) in the first study [49]. Finally, for emotional functioning (see Table 5), the third study found that the exergaming group scored better on the Activities-specific Balance Confidence scale ($p < 0.001$) and the Falls Efficacy Scale ($p = 0.002$) than the walking intervention comparison group [51].

No other statistically significant effects of exergaming were found on physical, cognitive, emotional, and social functioning, or on quality of life in

people living with dementia. The number of included studies and total number of research participants was low. Moreover, there was a large variability of comparison/control conditions. Therefore, meta-analysis was not considered meaningful.

Risk of bias assessment

Table 7 presents the risk of bias (quality) assessment of the three included studies. Overall, the study by Bamidis et al. [49] had a high risk of bias, with a score of five out of six. The other two studies both had low risk of bias with scores of two out of six, and were therefore assessed as the studies with the best methodological quality [50, 51].

DISCUSSION

This systematic literature review aimed to present the evidence regarding the effects of exergaming on physical, cognitive, emotional, and social functioning, and quality of life in people living with dementia. The secondary aim was to provide an overview of the evidence on the cost effectiveness of exergaming for people living with dementia.

Only three studies were found that met the inclusion criteria [49–51]. The number of participants in two studies [50, 51] and in the dementia subgroup in the other article was small, and so the results should be interpreted cautiously [49]. Especially where the control and/or comparison groups also showed an improvement, this could be partly explained by other factors such as learning effects or the personal attention during the research interviews rather than the exergaming intervention.

Two of the included studies showed some effects of exergaming [49, 51]. The third study included in this review showed that exergaming can be as effective as a walking program to improve balance, gait and physical performance in people living with dementia [50]. However, walking only programs have not always shown to improve executive functions of older people with cognitive impairments [52]. The study also indicated that exergaming can be used safely and effectively by people with dementia in an assisted living facility. However, in this particular study the walking group showed greater exercise compliance on average, although this was not statistically significant. Padala and colleagues (2012) have theorized that this difference in compliance could explain the lack of significant between-group effects [50]. Moreover, the social aspect of the walking intervention

Table 7
Risk of bias (quality) assessment

Study	Risk of selection bias	Information about risk of selection bias	Risk of performance bias	Information about risk of performance bias	Risk of detection bias	Information about risk of detection bias	Risk of attrition bias	Information about risk attrition bias	Risk reporting bias	Information about risk of reporting bias	Risk of other bias	Overall risk of bias score
Bamidis et al. [49]	High	No random allocation	High	No blinding of participants or staff	High	Not reported who conducted outcome assessments	High	No imputation of missing values	High	Not all separate outcome measures mentioned. No results on scores at pre- and post-test presented (only outcome analyses/*t*-test)	Low	5 out of 6
Padala et al. [50]	Low	Participants were randomized using a random number generator	High	No blinding of participants or staff	High	No blinding of outcome assessment	Low	Only 1 of 11 participants (in both intervention and control group) completed just 4 of 8 weeks of the study	Low	All outcome results are available in the (tables) of the paper	Low	2 out of 6
Padala et al. [51]	Low	Subjects were randomized using a randomized block design to the intervention and walking control groups using sealed envelopes prepared by the statistician	High	No blinding of participants or staff	High	No blinding of outcome assessment	Low	4 of 15 participants (in both intervention and control group) did not complete the study, however *post-hoc* intent-to-treat analysis showed no difference in significance of results	Low	All outcome results are available in the (tables) of the paper	Low	2 out of 6

may have introduced a difference between the groups as the walking was done in a group of three or four participants and research staff, whereas the *Wii-Fit* intervention was done individually with one-on-one guidance from research personnel. Comparing these interventions with the same group size would have been more reliable.

In contrast, in the other study by Padala et al. (2017), the exergaming group showed slightly better adherence to the exergaming intervention compared to the walking group [51]. This was concluded because these participants spent more time on exercising. The difference in time spent on exercising by itself might also cause improvements in balance, and the question is whether this necessarily had to be exergaming. However, it is quite possible that the fun and interactive aspects of exergaming lead to more engagement in physical exercise [50].

Furthermore, two studies only had the Berg Balance Scale as primary outcome [50, 51], one of which was specifically powered *a priori* to address this outcome [51].

Although no other statistically significant effects of exergaming were found in people living with dementia, some results almost reached statistical significance. Looking at the effect sizes and applying the most common rules of thumb [53], some (very) large effect sizes were found. Examples are several Subtests of the Senior Fitness Test in Table 2 [49] and outcome measures in the area of cognitive functioning [49–51] in Table 3. However, because of the small sample sizes and the low quality of one of the studies involved these effect sizes should be interpreted with caution [54] and do not necessarily imply a clinically relevant effect for people living with dementia.

In addition to the results of this systematic literature review, other studies into exergaming that did not meet the inclusion criteria also found effects of exergaming in older people. For example, a cluster randomized trial among older adults found that exergaming could contribute to prevention of cognitive decline [55]. Another study into the use of *Wii Sports*© by older women concluded from qualitative data that it led to a perception of improved sense of physical, social and psychological wellbeing [56]. A small-scale (non-randomized, non-controlled) study investigating exergaming for care home residents found that it decreased apathy and behavioral problems, and improved mood. Moreover, the exergaming intervention was well accepted, and participants were very interested in the exergaming sessions [57].

Other studies investigated exergaming in different groups, for example by comparing people living with dementia to a cognitively healthy control group, or by including people with MCI rather than people living with dementia. A pre-test/post-test control group study evaluated the usability and short-term training effects of X-Torp (an exergame) on emotional, cognitive and physical outcomes [58]. It had two groups (one group with people with neurodegenerative disease and one with cognitively healthy controls) and found significant within-group effects for the Short Physical Performance Battery in the neurodegenerative disease group [58]. Another study found that exergaming improved global cognitive functioning and decreased symptoms of depression in both MCI and cognitively healthy participants [59].

We did not find research investigating the cost-effectiveness of exergaming for people living with dementia. A previous review which included the cost-effectiveness of new technologies in dementia care also concluded that this aspect remains unclear [60].

Limitations

One of the limitations of this systematic review is that only three studies met our inclusion criteria and that they had their own limitations. We used the original (unpublished) data from one of these studies to conduct additional analysis for the purpose of this review [49]. From the other two included studies the published results were used [50, 51]. The search strategy of this review may also have some limitations, and perhaps relevant publications have been missed. For example, no grey literature was searched and some databases (i.e., Google Scholar) were not included. The included databases might have a delay in indexing the most recent publications and potentially relevant journals have not been searched manually. Furthermore, exergaming is a relatively new intervention, especially for people living with dementia. New journals in this area may have emerged which have not yet been indexed by any database.

Finally, after contacting the authors of one of the eventually excluded yet interesting studies [58], we realized that we might have to specify our definition of exergaming even further. Apparently there are variations within exergames, which can influence the effectiveness as well as the mechanism through which these effects are reached. Ben-Sadoun et al. [55] are in the process of publishing recommendations for the different definitions of Serious Games,

Video Games definition (i.e., *Wii Fit*©) and Neuropsychological software (simulators or computer-based training exercises). They hypothesize that these differences may partly explain training effects through social, motivational and emotional components. This also applies to the presence and role of the supervisor or moderator (i.e., clinician) during the intervention.

Conclusion

Our review showed that hardly any robust scientific research into exergaming and dementia has been conducted. With only three studies of varying research quality included, the answers to our review questions remain inconclusive. However, the included studies did find some effects of exergaming on physical, cognitive and emotional functioning in people with dementia. In addition, some improvements were found that were not statistically significant, which may have been caused by the fact that these studies were underpowered [49–51]. No articles were found about the cost-effectiveness of exergaming for people living with dementia.

As exergaming has been shown to be a feasible intervention for people with dementia and benefits have been reported of physical exercises on physical fitness, daily functioning, general health and well-being of people living with dementia, the potential effects of exergaming for this population are considerable [10, 12–16]. Exergaming can offer a fun and relatively safe way of exercising by providing an enriched environment in which physical and cognitive exercise are combined [28, 35]. These features of the exergames, together with exergaming's potential to influence the behavioral intention [36] are arguments in favor of more research, preferably consisting of randomized controlled trials with larger sample sizes that study both the effectiveness and cost-effectiveness compared to usual care in people living with dementia. Furthermore, research into the usability and implementation of exergaming for people living with dementia would be of added value. In light of the variety of available exergames, studies into combinations of different exergames among people with different types of dementia might also be useful.

Acknowledgments

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