JAMDA xxx (2020) 1–10

JAMDA

journal homepage: www.jamda.com

Original Study

Effects of Exergaming on Cognitive and Social Functioning of People with Dementia: A Randomized Controlled Trial

Joeke van Santen MSc [a,b,*], Rose-Marie Dröes PhD [a,b], Jos W.R. Twisk PhD [b,c], Olivier A. Blanson Henkemans PhD [d], Annemieke van Straten PhD [e], Franka J.M. Meiland PhD [a,b]

[a] *Department of Psychiatry, Amsterdam UMC, VUmc, Amsterdam, the Netherlands*
[b] *Amsterdam Public Health Research Institute, Amsterdam, the Netherlands*
[c] *Department of Epidemiology and Biostatistics, Amsterdam UMC, VUmc, Amsterdam, the Netherlands*
[d] *Child Health, TNO, Leiden, the Netherlands*
[e] *Department of Clinical- Neuro- and Developmental Psychology, Faculty of Behaviour and Movement Sciences, Vrije Universiteit Amsterdam, the Netherlands*

Keywords:
Randomized controlled trial
dementia
exergaming
physical activity
cognition
social behavior

A B S T R A C T

Objectives: Physical activity in people with dementia (PwD) may enhance physical and mental functioning. Exergaming, which combines physical exercise with cognitive stimulation in a gaming environment, was developed to overcome barriers in performing physical activities. We evaluated the effects of exergaming in day care centers (DCCs) for PwD and informal caregivers (ICs).
Design: A randomized controlled trial among 23 DCCs across the Netherlands randomized to exergaming (interactive cycling during 6 months) or a care-as-usual control group.
Setting and Participants: A total of 112 (73 exergaming, 39 control) community-dwelling dyads (PwD, IC), with the PwD visiting a DCC at least twice per week.
Methods: All outcomes were assessed using structured questionnaires during interviews with PwD and ICs at baseline (T0), 3 months (T1), and 6 months (T2). Primary outcomes: physical activity and mobility of the PwD. Secondary outcomes: physical, cognitive, emotional and social functioning, and quality of life for PwD. For ICs: experienced burden, quality of life, and positive care experiences.
Results: Mixed-model analyses showed no statistically significant effects on primary outcomes. There were statistically significant positive effects on PwD's secondary outcomes at T2 on cognition [Mini-Mental State Examination (MMSE): $r = 2.30$, 95% confidence interval (CI): 0.65, 3.96, $P = .007$; and Trail Making Test part A (TMT-A): $r = -28.98$, 95% CI: −54.89, −3.08, $P = .029$], social functioning (Behavior Observation Scale for Intramural Psychogeriatrics subscale 1 (GIP): $r = -1.86$, 95% CI: −3.56, −0.17, $P = .031$), and positive post-test effects in ICs on distress caused by the PwD's neuropsychiatric symptoms (NPI-Q total distress: $r = -3.30$, 95% CI: −6.57, −0.03, $P = .048$) and on sense of competence (SSCQ: $r = 2.78$, 95% CI: 0.85, 4.71, $P = .005$).
Conclusions and Implications: Exergaming appeared not effective on the primary outcomes. Despite the study being underpowered, we found positive effects on secondary outcomes for PwD and ICs, and no negative effects. We therefore recommend further study, dissemination, and implementation.

Funding sources: The research project received funding from ZonMw-Memorabel programme/ Alzheimer Nederland (project number 733050609), Stichting Dioraphte (project number 16 02 04 03), and the EU. This trial was carried out as part of the Marie Skłodowska Curie funded INDUCT Innovative Training Network (ITN) (Interdisciplinary Network for Dementia Using Current Technology (INDUCT), H2020-MSCA-ITN-2015, under grant agreement number 676265.
The authors declare no conflicts of interest.

* Address correspondence to Joeke van Santen, MSc, Department of Clinical-, Neuro- and Developmental Psychology, Faculty of Behavioural and Movement Sciences, Vrije Universiteit Amsterdam, Room MF-B547, Van der Boechorststraat 7, 1081 BT Amsterdam, the Netherlands.
E-mail address: j.vandermolen@amsterdamumc.nl (J. van Santen).

https://doi.org/10.1016/j.jamda.2020.04.018

Being physically active not only benefits physical functioning, but also cognitive, emotional, and social functioning and quality of life.[1–3] This also applies to people living with dementia (PwD).[4–6] However, PwD may experience barriers being physically active, for example, because of impaired orientation abilities or risk of falling.[7] Psychosocial issues may also play a role, such as a lack of confidence in their ability to perform exercises and negative attitudes of the people around them toward physical activities.[8] Other dementia-related symptoms may also impede being active, for example, a decrease of motivation and interest or an increase of apathy.[9,10] In general, older people tend not to achieve the recommended amount of physical activity (30 minutes/day), and this worsens after admission into residential care.[11–13]

Exergaming is an innovative form of physical exercise used for different target groups and for different aims, such as physical education for school children, rehabilitation for cancer patients, and cognitive rehabilitation for people with neurologic disorders (eg, dementia).[14–16] It can be defined as "physical exercise interactively combined with cognitive stimulation in a gaming environment."[17] The movements of the participant are registered using sensors and influence a game on a screen.[18] An example is interactive cycling. Participants sit on a stationary bicycle and pick a route on a screen. The cycling pace determines the speed of the film.[17]

Exergaming can help PwD overcome barriers they experience with regard to physical exercise, for example, because they do not have to worry about wandering and getting lost or weather conditions. Exergaming can contribute to a decrease of apathy and promote social contact, because it is fun and one engages with others about the images on the screen, which can motivate participation.[18,19] This may add to a positive attitude toward exercise in those who are less interested in the physical activity itself. Their performance in the exergaming activity is something PwD can talk about with their informal caregivers (ICs), which can evoke positive feelings in both.[20] Moreover, some studies among older people with and without dementia have shown that they enjoyed the exergaming activity and as a consequence wanted to exercise more often and longer.[19,20] Interactive cycling, which also stimulates cognitive functioning, is a promising exergaming intervention, as evidenced by neurologic research in which older people participating in exergaming showed enhanced neuroplasticity and therefore a reduced risk of developing clinical Mild Cognitive Impairment compared to traditional exercise.[21] This suggests that simultaneous cognitive and physical exercise has potential to prevent cognitive decline.

There is some research available about the effects of exergaming for PwD. Two systematic literature reviews found effects on physical, cognitive, and emotional functioning, but the samples sizes of the included studies were small and their quality, on average, mediocre.[14,17] Some studies also found improvements on (motor-)cognitive performance, psychomotor speed, activities of daily living, and quality of life.[20,22–24] However, to corroborate these findings, more high-quality clinical trials with larger samples are required.

Dementia also affects family or friends of PwD. They may become ICs, which can lead to stress-related symptoms, high burden, and reduced quality of life.[25,26] Neuropsychiatric symptoms and behavioral problems of the PwD are (bidirectionally) related to caregiver burden.[27,28] Exergaming by the IC can positively impact the quality of life of ICs, although the evidence to date is limited.[20,29] There is no evidence yet whether exergaming by the PwD indirectly affects the ICs when they do not perform exergaming themselves.[17]

The objective of this study was to investigate whether exergaming has positive effects on performance of physical activities, mobility, physical, cognitive, emotional, and social functioning, and quality of life as compared to activities usually offered to community-dwelling PwD visiting psychogeriatric day care centers (DCCs). Additionally, for ICs, positive effects were examined on quality of life, burden experienced, and positive care experiences. This study is part of a larger study in which cost-effectiveness and implementation of exergaming for PwD in DCCs were also studied.

Methods

Study Design

We performed a cluster randomized controlled trial. Random allocation software was used by an independent researcher to randomize DCCs to the experimental (exergaming) or control (traditional, nonexergaming activities) group.[30] The DCC staff recruited dyads (PwD, IC) for the study. Measurements took place at baseline (T0) and after 3 (T1) and 6 months (T2). The study was registered at the Netherlands Trial Register (NTR5537/NL5420) and approved by the Medical Ethics Committee (METc) of the Amsterdam University Medical Centers (UMC), location VU University medical center (VUmc; NL58227.029.16). All DCCs signed a declaration of participation. All PwD and ICs gave written informed consent. The study protocol was published elsewhere and is summarized here.[31]

Participants and Setting

A convenience sample of psychogeriatric DCCs were recruited across the Netherlands. Inclusion criteria for PwD were as follows: all ages, community-dwelling, a diagnosis of any type of dementia, visits the DCC at least 2 days per week, has an IC willing to participate, and are not expected to be admitted into residential care in the coming 6 months. Exclusion criteria were as follows: severe physical disorders or (terminal) diseases (other than dementia) that would make participation in an exergaming activity impossible (according to DCC staff). Figure 1 shows the enrollment and allocation process and reasons for dropout.

Exergaming Group

The exergaming intervention was interactive cycling using a stationary bicycle (ie, home trainer) connected to a screen. While cycling, the PwD sees a route on the screen. They can pick a route, and it mimics the experience of cycling outside, thus offering simultaneous physical and cognitive stimulation. For this study, DCCs had to buy or lease one of the following systems at a discount: DiFiets, Fietslabyrint, PraxFit, or SilverFit Mile.[31] Various brands of equipment were used, but according to experts and care professionals involved in exergaming, these did not vary significantly. The costs ranged from 1500 to 4700 euros.

The DCC staff were responsible for carrying out the intervention. In a 1-hour meeting with the investigator, they were instructed to offer exergaming 5 times per week as part of their regular activity program and to encourage research participants to take part at least twice per week for 6 months. They were also offered a free training about the use of the exergaming equipment by the provider of the chosen exergame(s). However, none of the DCCs made use of this offer. Apart from exergaming, PwD joined the regular activity program of the DCC.

Control Group

Psychogeriatric DCCs usually offer a varied activity program, for example, with arts and crafts, music, and physical exercise such as walking outdoors 5 days per week. In the control group, participants joined the regular activity program but were not offered exergaming.

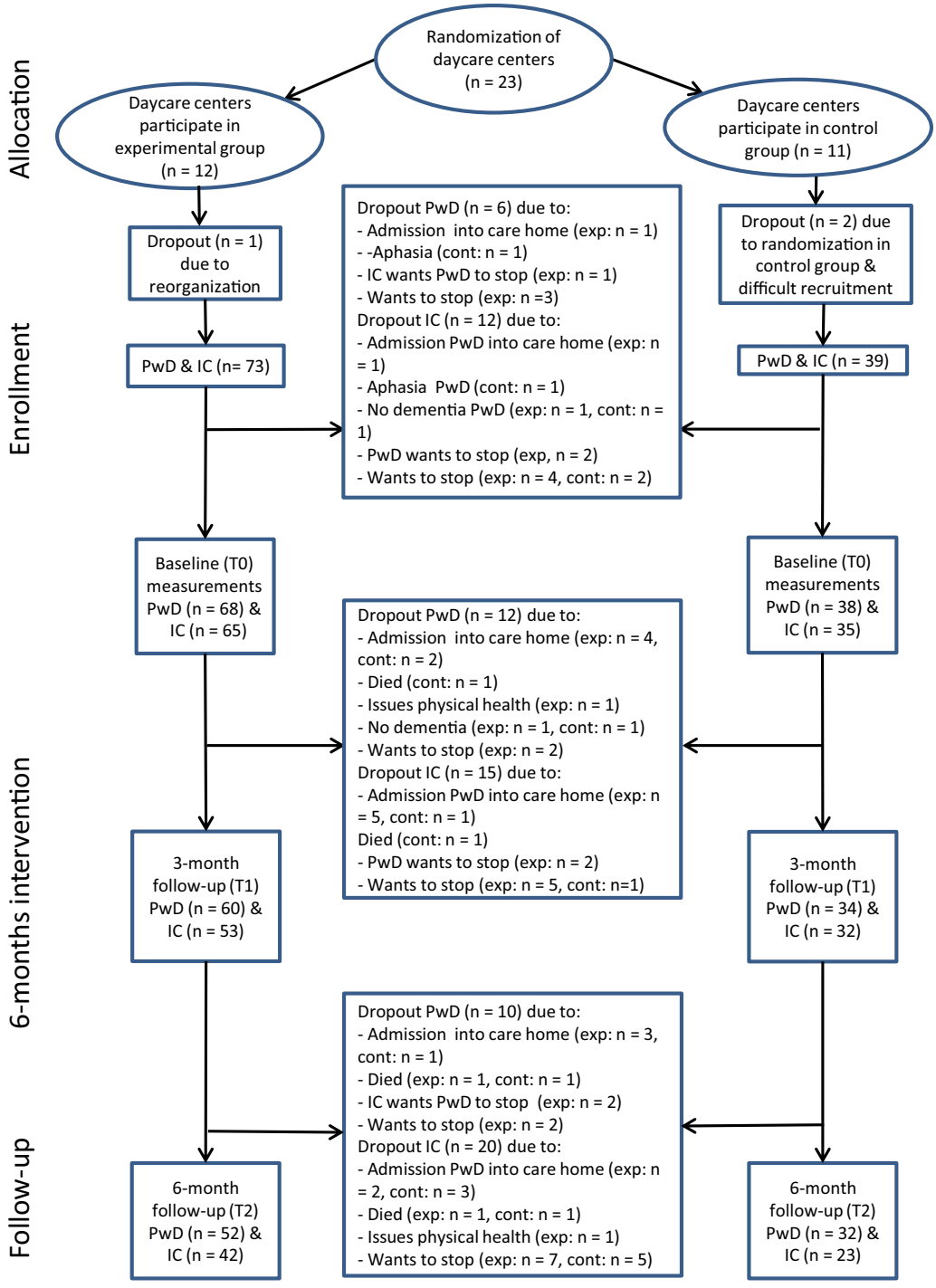

Fig. 1. Flow chart of day care centers and participants. exp, exergaming group; cont, control group; RCT, randomized controlled trial.

Primary Outcome Measures

Primary outcomes were physical activity and mobility of the PwD. All physical activities were recorded (in minutes) at DCCs and at home during 7 days at each measurement (T0, T1, T2) by DCC staff and ICs using a specifically developed form. The time spent by PwD on exergaming was also recorded on this form. We used the total number of minutes per week (T0, T1, T2) for the analysis. To measure mobility, the interviewers administered the Short Physical Performance Battery at DCCs.[32] The Short Physical Performance Battery evaluates lower extremity functioning, which is strongly correlated with a risk of mobility disability in older adults and consists of 3 subtests: balance, gait speed, and chair stands. Total scores range between 0 and 12, with the following categories: good functioning and no risk of developing mobility disability (10-12), elevated risk (4-9), and loss of mobility already being present (0-3).[33]

Secondary Outcome Measures

Secondary outcomes for PwD were cognitive, emotional, and social functioning; quality of life; and other physical outcomes than the primary outcome. For ICs, we assessed the subjective caregivers

burden, quality of life, and positive care experiences. Background characteristics of all PwD and ICs were collected. See Tables 2 and 3 and Supplementary Material 1 (Supplementary Tables 1-3) for a complete list of outcome measures.

Procedures

Data were collected from PwD via face-to-face interviews at the DCC, and ICs were interviewed by telephone at T0, T1, and T2. The interviewers were bachelor's or master's students of (applied) psychology or medicine, who received extensive training.

Power Analysis

The required sample size was based on one of the secondary outcome measures for cognitive functioning [Mini-Mental State Examination (MMSE)], because no high-quality studies investigating the effect of a similar intervention on the primary outcomes (physical activity and mobility) were available at that time. Assuming a power of 80% and a difference of 2 points (standard deviation of 4.6) on the MMSE with an intracluster correlation coefficient of 0.05 and an alpha of 0.05, we needed a sample size of 166 dyads. When adding the cluster effect of DCC (7 dyads per cluster) and dropout (4%), a total sample of 224 dyads was needed.

Statistical Analysis

Analyses were performed using IBM SPSS, version 24.0 (IBM, Armonk, NY). To reveal any significant differences in background characteristics and dropout between the exergaming and control groups, independent samples t and χ^2 tests were performed on baseline data for ordinal and nominal variables, respectively. Missing data of all outcome measures were imputed on item level according to the existing instructions.

Mixed-model (intention-to-treat) analyses were conducted with time (3 and 6 months), intervention (exergaming vs control), and the interaction between intervention and time, to analyze the effects on all outcomes. All analyses were adjusted for the baseline value of the particular outcome. A 3-level structure (ie, repeated observations clustered within individuals and individuals clustered within DCC) was used. This method adjusts for the correlation between the repeated measurements within the individual. Additionally, dose-response relationships were analyzed with the same method, with exergaming as a continuous variable. Effects were considered statistically significant if $P \leq .05$.

Based on previous research, all mixed-model analyses were adjusted for T0-MMSE as a potential confounder (T0-MMSE). Besides that, additional adjustments were made for body mass index (for the PwD), sex, age, and level of education (for both PwD and ICs).[34–36] Furthermore, effect sizes (Cohen d) were calculated, with $d \geq 0.20$ considered a small, $d \geq 0.40$ a medium, and $d \geq 0.80$ a large effect size.[37] Additionally, $d \geq 0.24$ was considered clinically relevant, as at this cutoff patients considered treatment clinically relevant.[38] The sample size was too small to use the method of QUalitative INteraction Trees mentioned in the protocol.[39]

Results

Participant Flow and Baseline Measures of the Study Population

Figure 1 shows the process of enrolment and allocation of DCCs and participants to the experimental and control groups, and the reasons for drop-out. Eleven DCCs participated in the exergaming and 9 DCCs in the control group. In total, 112 PwD and their ICs (73 exergaming, 39 control) enrolled in the study. Because of drop-out, 52 PwD and 42 ICs participated at T2 in the exergaming group and 32 PwD and 23 ICs in the control group. There were no significant differences between PwD and ICs who dropped out and those who continued.

Table 1 shows baseline characteristics. There were no statistically significant differences between the groups. PwD in the exergaming group were more physically active than in the control group, but this difference was not significant. In the exergaming group, the mean (standard deviation) of minutes of exergaming during 1 week by the PwD was 32.4 (39.2) at T0, 22.8 (24.7) at T1, and 29.8 (32.0) at T2.

People With Dementia

Table 2 shows there were no effects on the primary outcome measures for PwD. Effect sizes for mobility (Short Physical Performance Battery) were small (0.14 at T1; 0.11 at T2, corrected for T0-MMSE) and not clinically relevant. Adding other confounders hardly made any difference. The effect sizes for physical activity were also small, but clinically relevant (0.30 at T1; 0.28 at T2, corrected only for T0-MMSE, and 0.35 at T1; 0.37 at T2 with the other potential confounders added).

Regarding the secondary outcomes, 2 outcome measures for cognitive functioning showed positive effects of exergaming. For the MMSE, this was at T2 ($r = 2.30$, 95% CI: 0.65, 3.96, $P = .007$) with a small, but clinically relevant, effect size ($d = 0.36$). Another effect was on the Trail Making Test part A (TMT-A) at T2 ($r = -28.98$, 95% CI: −54.89, −3.08, $P = .029$) again with a small, but clinically relevant, effect size ($d = -0.37$). Both effects (MMSE and TMT-A scores) increased slightly when the other confounders were added.

A third effect was found on the Behavior Observation Scale for Intramural Psychogeriatrics [Gedragsobservatieschaal voor de Intramurale Psychogeriatrie (GIP)], subscale nonsocial behavior of the PwD. There was a positive effect of exergaming at T2 when corrected for T0-MMSE ($r = -1.86$, 95% CI: −3.56, −0.17, $P = .031$) with an almost medium effect size ($d = -0.49$). With the other confounders added, the effect sizes remained small (−0.26 at T1 and −0.34 at T2).

A medium effect size (−0.53) was found on the number of falls at T1 in favor of exergaming. Other clinically relevant effect sizes were on cognitive functioning [Trail Making Test part B (TMT-B)], motivation (IMI subscales: 1 interest/enjoyment, 4 perceived choice of physical exercise), physical activities (Physical Activity Scale of the Elderly), and quality of life both indicated by the PwD themselves and by the ICs about the PwD (EQ-5D-5L).

Informal Caregivers

Table 3 shows the effects for ICs. For distress experienced due to neuropsychiatric symptoms of the PwD (NPI-Q total distress) there was a statistically significant positive effect at T1 when corrected for T0-MMSE ($r = -3.30$, 95% CI: −6.57, −0.03, $P = .048$) with a small, but clinically relevant effect size ($d = -0.38$). This effect becomes nonsignificant when corrected for the other confounders, but the effect size remains clinically relevant. No significant effects were found on the NPI-Q total distress at T2, and the effect sizes remain small but clinically relevant.

There was a positive effect of exergaming on the subjective burden and sense of competence (SSCQ) at T1 when corrected for T0-MMSE and the other confounders ($r = 2.78$, 95% CI: 0.85, 4.71, $P = .005$) with a medium effect size ($d = 0.55$). When only T0-MMSE of the PwD remained as a confounder, this effect size was still small and clinically relevant ($d = 0.35$). This effect disappeared at T2.

We did not find any dose-response effects (see Supplementary Tables 4 and 5).

Table 1
Baseline Characteristics of the Study Population

Variables	Exergaming Group (n = 73)	Control Group (n = 39)	Difference Between Groups	
			Test Statistic (df)	*P* value
People with dementia (PwD)				
Age, y, mean (SD)	79.0 (6.0)	79.0 (7.0)	$t(104) = -0.19$	.99
Gender, n (%)			$\chi^2(1) = 0.70$	.40
Male	37 (51)	23 (59)		
Female	36 (49)	16 (41)		
Body mass index, mean (SD)*	28.0 (4.7)	29.0 (5.5)	$t(98) = 0.96$	.34
Mini-Mental State Examination score, mean (SD)†	18.1 (6.7)	19.4 (6.5)	$t(100) = 0.92$	.36
Dementia type, n (%)			$\chi^2(4) = 2.76$	.60
Alzheimer's	25 (34)	12 (31)		
Vascular	6 (8)	3 (8)		
Mixed	3 (4)	4 (10)		
Other	7 (10)	6 (15)		
Unknown	32 (44)	14 (36)		
Living situation, n (%)			$\chi^2(3) = 0.63$	.89
Independent, alone	15 (21)	9 (23)		
Independent, with others	50 (68)	26 (67)		
Other	1 (1)	0 (0)		
Unknown	7 (10)	4 (10)		
Level of education, n (%)			$\chi^2(3) = 1.79$	.62
Primary education or less	15 (21)	5 (13)		
Secondary education	34 (47)	17 (44)		
Higher education	13 (18)	10 (26)		
Unknown	11 (15)	7 (18)		
Marital status, n (%)			$\chi^2(4) = 5.67$	.23
Married/long-term cohabitation	52 (71)	26 (67)		
Divorced	3 (4)	0 (0)		
Unmarried	0 (0)	2 (5)		
Widowed/partner deceased	12 (16)	8 (21)		
Unknown	6 (8)	3 (8)		
Experience with sports, n (%)	46 (63)	24 (62)	$\chi^2(1) = 0.00$	.98
Experience with cycling, n (%)	57 (78)	33 (85)	$\chi^2(1) = 3.35$	.07
Experience with technology, n (%)	27 (37)	18 (46)	$\chi^2(1) = 1.19$	.28
Experience with computer games, n (%)	12 (16)	6 (15)	$\chi^2(1) = 0.00$	.97
Informal caregivers				
Age, y, mean (SD)	65.0 (13.0)	67.0 (12.0)	$t(97) = 0.91$	.37
Gender, n (%)			$\chi^2(1) = 0.01$	.94
Male	18 (25)	10 (26)		
Female	54 (74)	29 (74)		
Unknown	1 (1)	0 (0)		
Level of education, n (%)			$\chi^2(3) = 3.58$	.31
Primary education or less	5 (7)	0 (0)		
Secondary education	32 (44)	19 (49)		
Higher education	24 (33)	11 (28)		
Unknown	12 (16)	9 (23)		
Marital status, n (%)			$\chi^2(3) = 0.66$	.88
Married/long-term cohabitation	62 (85)	33 (85)		
Unmarried	4 (5)	2 (5)		
Widowed/partner deceased	1 (1)	0 (0)		
Unknown	6 (8)	4 (0)		
Living together with PwD	42 (58)	26 (67)	$\chi^2(1) = 1.62$	.20
Relationship with PwD, n (%)			$\chi^2(3) = 3.65$	.30
Spouse	39 (53)	26 (67)		
Son/daughter	22 (30)	6 (15)		
Other	11 (15)	7 (18)		
Unknown	1 (1)	0 (0)		

*For people of 70 years or older, a body mass index between 22 and 27.9 is considered healthy.
†Scores on the Mini-Mental State Examination range from 0 (severe dementia) to 30 (no dementia).

Discussion

This study shows that exergaming had no effect on the primary outcomes. However, we did observe some small to moderate positive effects on cognitive and social functioning in PwD and small effects on distress and subjective burden and sense of competence of ICs. Furthermore, though not statistically significant, we did observe clinically relevant effect sizes on physical activity of PwD, and their interest or enjoyment and perceived choice of physical exercise. These are important and promising results. This is the first study to show that exergaming for PwD indirectly also has positive effects for the ICs, that is, while the ICs do not perform exergaming themselves. No improvements were found on emotional functioning of PwD, quality of life of PwD and ICs, or positive care experiences of ICs.

Previous research found positive effects of exergaming on physical activity, cognitive and social functioning, and interest or enjoyment in and perceived choice of physical exercise in PwD, which is in line with our findings.[14,17,20,22,23] In contrast with previous studies, we did not find statistically significant effects on physical and emotional functioning of the PwD.[24,50] This may have been caused by differences in outcome measures. For example, we used single items of The Older Persons and Informal Caregivers Survey Minimum DataSet that

Table 2
Test Scores on the Different Outcomes per Time Point, Between-Group Effects, and Effect Sizes for PwD

Outcome Measures	Exergaming Group			Control Group			Effect, *r* (95% CI), *P* Value	Effect Size, Cohen *d*	Effect, *r* (95% CI), *P* Value	Effect Size, Cohen *d*	Adj. Effect, *r* (95% CI), *P* Value[†]	Adj. Effect Size, Cohen *d*[‡]	Adj. Effect, *r* (95% CI), *P* Value[†]	Adj. Effect Size, Cohen *d*[‡]
	T0	T1	T2	T0	T1	T2	T1	T1	T2	T2	T1	T1	T2	T2
Primary outcomes														
SPPB, mean (SD), range 0-12	7.0 (2.4)	7.1 (2.1)	7.6 (2.2)	7.8 (2.0)	7.2 (2.2)	8.0 (2.2)	0.30 (−0.52, 1.12), *P* = .47	0.14	0.15 (−0.71, 1.01), *P* = .73	0.11	0.24 (−0.63, 1.11), *P* = .58	0.07	.37 (−.55, 1.28), *P* = .43	0.17
Physical activities per week, min, mean (SD)	281.4 (286.4)	312.3 (380.5)	312.3 (469.4)	182.3 (155.8)	178.3 (181.5)	188.1 (149.0)	97.42 (−43.92, 238.75), *P* = .18	0.30	112.21 (−30.51, 254.93), *P* = .12	0.28	90.85 (−60.79, 242.49), *P* = .24	0.35	119.11 (−35.48, 273.71), *P* = .13	0.37
Secondary outcomes														
MMSE, mean (SD)[‡], range 0-30	18.1 (6.7)	17.1 (6.5)	17.9 (7.3)	19.4 (6.5)	18.0 (4.9)	17.0 (5.9)	0.55 (−1.04, 2.14), *P* = .50	0.09	2.30 (0.65, 3.96), *P* = .007*	0.36	0.97 (−0.78, 2.72), *P* = .28[§]	0.15[§]	2.53 (0.71, 4.34), *P* = .007[§]**	0.39[§]
TMT-A in seconds, mean (SD), max 300	146.1 (80.4)	145.0 (81.0)	140.2 (82.8)	121.2 (70.7)	129.3 (75.2)	136.8 (79.4)	−9.21 (−35.07, 16.65), *P* = .48	−0.12	−28.98 (−54.89, −3.08), *P* = .029***	−0.37	−19.15 (−47.11, 8.82), *P* = .18	−0.24	−29.96 (−57.47, −2.44), *P* = .033****	−0.38
TMT-B in seconds, mean (SD), max 300	221.5 (90.7)	224.5 (88.9)	236.0 (59.0)	224.8 (77.7)	214.7 (65.1)	223.1 (70.9)	17.66 (−23.37, 58.69), *P* = .40	0.23	−0.15 (−44.57, 44.26), *P* = 1.00	0.00	19.81 (−26.40, 66.01), *P* = .40	0.25	3.90 (−47.02, 54.82), *P* = .88	0.05
ASCOT, mean (SD), range 1-4	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)	2 (1)	−0.01 (−0.33, 0.32), *P* = .96	−0.01	−0.72 (−0.41, 0.27), *P* = .68	−0.09	−0.07 (−0.41, 0.26), *P* = .67	−0.09	−0.10 (−0.45, 0.25), *P* = .58	−0.13
IMI01, mean (SD), range from 7-49	13.8 (9.8)	14.0 (8.3)	12.2 (7.0)	16.9 (9.8)	17.5 (10.8)	16.4 (9.0)	−2.45 (−5.98, 1.08), *P* = .17	−0.27	−2.86 (−6.56, 0.83), *P* = .13	−0.31	−0.51 (−4.05, 3.03), *P* = .78	−0.06	−3.06 (−6.74, 0.62), *P* = .10	−0.33
IMI02, mean (SD), range 6-42	19.2 (6.8)	19.4 (6.7)	18.1 (5.8)	21.0 (6.9)	18.9 (7.4)	20.0 (7.7)	1.32 (−1.39, 4.03), *P* = .34	0.19	−1.41 (−4.26, 1.45), *P* = .33	−0.21	1.22 (−1.49, 3.93), *P* = .38	0.18	−0.80 (−3.64, 2.05), *P* = .58	−0.12
IMI03, mean (SD), range 5-35	13.8 (4.8)	13.5 (4.4)	12.8 (4.4)	14.0 (4.8)	14.4 (4.3)	12.4 (3.3)	−0.59 (−2.40, 1.22), *P* = .52	−0.13	−0.01 (−1.94, 1.92), *P* = .99	0.00	−0.27 (−2.16, 1.63), *P* = .78	−0.06	0.19 (−1.84, 2.21), *P* = .86	0.04
IMI04, mean (SD), range 7-49	17.5 (10.7)	18.2 (10.8)	15.4 (8.6)	17.2 (9.2)	18.8 (9.6)	18.8 (9.0)	−0.50 (−4.72, 3.72), *P* = .82	−0.05	−3.51 (−8.02, 1.01), *P* = .13	−0.36	0.10 (−4.37, 4.57), *P* = .97	0.01	−3.16 (−7.94, 1.61), *P* = .19	−0.32
IMI05, mean (SD), range 4-28	5.9 (3.6)	6.3 (4.6)	5.5 (4.8)	7.1 (5.2)	6.2 (4.0)	5.9 (5.2)	0.46 (−1.44, 2.37), *P* = .63	0.1	0.12 (−1.92, 2.16), *P* = .91	0.03	0.94 (−1.01, 2.89), *P* = .34	0.21	1.09 (−1.00, 3.19), *P* = .30	0.25
Psychological well-being, mean (SD), range 5-100	60.0 (10.2)	72.2 (19.4)	75.1 (23.0)	62.5 (10.0)	75.9 (15.6)	75.3 (18.6)	−1.63 (−8.00, 4.74), *P* = .62	−0.09	2.46 (−4.17, 9.09), *P* = .47	0.14	−0.80 (−7.48, 5.88), *P* = .81	−0.04	3.92 (−3.05, 10.89), *P* = .27	0.22
PASE, mean (SD), range 0-400	61.2 (42.6)	46.0 (37.0)	38.6 (38.3)	57.3 (43.2)	55.6 (41.4)	52.0 (43.8)	−9.16 (−23.67, 5.34), *P* = .22	−0.22	−12.71 (−27.22, 1.80), *P* = .09	−0.31	−5.84 (−21.92, 10.24), *P* = .48	−0.14	−4.75 (−20.84, 11.33), *P* = .56	−0.12
GIP, mean (SD), range from 5-24	18.5 (3.2)	18.2 (3.8)	18.0 (3.7)	19.2 (4.4)	19.8 (3.7)	21.0 (4.0)	−0.86 (−2.77, 1.05), *P* = .37	−0.23	−1.86 (−3.56, −0.17), *P* = .031*****	−0.49	−0.97 (−3.04, 1.09), *P* = .35	−0.26	−1.28 (−3.06, 0.50), *P* = .16	−0.34
Number of falls, mean (SD), during 6 months trial	2.5 (2.8)	1.2 (0.5)	1.5 (0.8)	2.0 (1.7)	2.0 (1.0)	1.5 (0.6)	−1.00 (−3.71, 1.70), *P* = .46	−0.53	−0.12 (−2.65, 2.41), *P* = .92	−0.06	−0.89 (−3.92, 2.13), *P* = .55	−0.47	−0.21 (−3.23, 2.82), *P* = .89	−0.11

EQ-5D-5L PwD, mean (SD), range 0-1	0.7 (0.3)	0.7 (0.3)	0.8 (0.2)	0.8 (0.3)	0.8 (0.2)	0.9 (0.2)	−0.07 (−0.17, 0.02), $P = .14$	−0.27	−0.03 (−0.13, 0.07), $P = .61$	−0.10	−0.08 (−0.18, 0.01), $P = .10$	−0.30	−0.02 (−0.13, 0.08), $P = .64$	−0.09
EQ-5D-5L IC_PwD, mean (SD), range 0-1	0.4 (0.3)	0.5 (0.3)	0.5 (0.3)	0.5 (0.3)	0.5 (0.2)	0.5 (0.3)	0.00 (−0.10, 0.11), $P = .96$	0.01	−0.07 (−0.18, 0.04), $P = .23$	−0.24	0.00 (−0.11, 0.11), $P = .98$	0.01	−0.07 (−0.19, 0.05), $P = .25$	−0.25

Adj., adjusted; ASCOT, Adult Social Care Outcomes Toolkit[45]; BMI, body mass index; EQ-5D-5L PwD, quality of life of the participant with dementia as indicated by himself or herself, using the EuroQol 5 dimensions questionnaire with 5-level scale[47] from The Older Persons and Informal Caregivers Survey Minimum DataSet (TOPICS-MDS care recipient[46]); EQ-5D-5L IC_PwD, quality of life of the participant with dementia as indicated by his or her informal caregiver, using the EuroQol 5 dimensions questionnaire with 5-level scale[47] from The Older Persons and Informal Caregivers Survey Minimum DataSet (TOPICS-MDS care recipient[46]); GIP, Behavior Observation Scale for Intramural Psychogeriatrics: subscale 1 Social functioning of the participant living with dementia in the day care center[51]; IMI01, Intrinsic Motivation Inventory[42], subscale 1 interest/enjoyment in physical exercise; IMI02, Intrinsic Motivation Inventory, subscale 2 perceived competence in physical exercise; IMI03, Intrinsic Motivation Inventory, subscale 3 effort in/importance of physical exercise; IMI04, Intrinsic Motivation Inventory, subscale 4 perceived choice of physical exercise; IMI05, Intrinsic Motivation Inventory, subscale 5 value/usefulness of physical exercise; PASE, Physical Activity Scale of the Elderly[43]; Psychological well-being, emotional functioning from The Older Persons and Informal Caregivers Survey Minimum DataSet (TOPICS-MDS care recipient[46]); SPPB, Short Physical Performance Battery[32]; TMT-A, Trail Making Test part A; TMT-B, Trail Making Test part B.[44]
Underlined scores are more positive. Outcomes are with the baseline score (T0) on the MMSE[34] of the PwD as a confounder.

*Mixed-model analysis with time (6 months) and the interaction between intervention and time showed a statistically significant increase in the MMSE score in the exergaming group compared to the control group after 6 months.

**Mixed-model analysis with time (6 months) and the interaction between intervention and time showed a statistically significant increase in the MMSE score in the exergaming group compared to the control group after 6 months, when corrected for BMI, sex, age, and level of education of the PwD as confounders.

***Mixed-model analysis with time (6 months) and the interaction between intervention and time showed a statistically significant reduction in the TMT-A score in the exergaming group compared to the control group after 6 months, when corrected for the baseline score (T0) on the MMSE of the PwD as a confounder.

****Mixed-model analysis with time (6 months) and the interaction between intervention and time showed a statistically significant reduction in the TMT-A score in the exergaming group compared to the control group after 6 months, when corrected for the baseline score (T0) on the MMSE, BMI, sex, age, and level of education of the PwD as confounders.

*****Mixed-model analysis with time (6 months) and the interaction between intervention and time showed a statistically significant reduction in the GIP score in the exergaming group compared to the control group after 6 months, when corrected for the baseline score (T0) on the MMSE of the PwD as a confounder.

†Outcome scores adjusted for confounding variables: baseline score (T0) on the MMSE, BMI, sex, age, and level of education of the PwD.

‡Outcomes are without any confounders.

§Outcome scores adjusted for confounding variables: BMI, sex, age, and level of education of the PwD.

measures emotional functioning in general, whereas another study used more detailed and specific instruments to measure fear of falling and confidence in balance.[50] This may imply that the effect of exergaming on emotional functioning is closely related to improved physical functioning. In our study, we did not find an effect on physical functioning, which may explain the absence of effect in emotional functioning.

For several outcomes, we found clinically relevant effect sizes, although not statistically significant. This may be explained by the small sample size, but also by the large variation in outcomes of physical activity and mobility, physical, cognitive, emotional and social functioning, and quality of life of the PwD. With a bigger sample size, we could have conducted subgroup analysis. Furthermore, perhaps the prescribed minimum of twice-per-week exergaming was too low to find statistically significant effects.

Although there were no significant differences in cycling experience before the start of the study between the exergaming and control groups (see Table 1), PwD in the control group did tend to have more cycling experience ($P = .07$). This may have influenced the outcomes.

Strengths and Limitations

The fact that many DCCs participated, that there was a high uptake in study participants, and that they were enthusiastic about the exergaming intervention are strengths of this study. Our study showed that the implementation by the organization assigned to the intervention group was successful. As we will report in a separate article, they systematically applied strategies that positively influence implementation factors at the level of the intervention, the users (ie, professionals), organization, and environment (J. van Santen et al, unpublished data, 2020).

However, this study also had several limitations. The recruitment process was complicated by many hindering factors, such as lack of money and time for DCCs to participate in the study, and ICs already feeling overburdened. This resulted in an underpowered sample size. Additionally, many statistical tests were performed, which could mean that some of the statistically significant effects are a coincidence. We did not correct for multiple testing, because we did not focus solely on statistical significance, and also found the clinical relevance of great importance.[51] Nevertheless, to be able to generalize our findings toward a larger population, we think the statistically significant effects and clinically relevant effect sizes found in this study should be confirmed in a larger trial. Additionally, there was a large percentage of drop-out among DCCs, PwD, and ICs.

No outcome data were collected about the staff of DCCs actually offering the intervention 5 times per week and encouraging research participants to take part at least twice per week for 6 months. Neither was the adherence rate of participants measured. Moreover, interactive cycling is only one type of exergaming and it is impossible to verify whether the results are generalizable to other types of exergaming. Another issue with generalizability is selection bias. Perhaps DCCs, PwD, and ICs who were interested in physical activities were more inclined to participate in the study.

Some outcome measures may have been too complicated for (some) PwD. The IMI, for example, has many statements with a 7-point answering scale, which often confused PwD.[44] Additionally, certain outcome measures proved to be challenging when people were illiterate, deaf, or not native Dutch speakers. Furthermore, the number of outcome measures caused lengthy interviews (≥1 hour), which was burdensome. Data were also collected by staff of DCCs and ICs using custom registration forms. This was regularly forgotten (despite reminders) and led to missing data or errors. For some outcomes, like the Physical Activity Scale of the Elderly, the reporting of the PwD and ICs differed, raising questions about reliability.

Table 3
Test Scores on the Different Outcomes per Time Point and Between-Group Effects for IC

Outcome Measures	Exergaming Group			Control Group			Effect, *r* (95% CI), *P* Value	Effect Size, Cohen *d*	Effect, *r* (95% CI), *P* Value	Effect Size, Cohen *d*	Adj. Effect, *r* (95% CI), *P* Value†	Adj. Effect Size, Cohen *d*†	Adj. Effect, *r* (95% CI), *P* Value†	Adj. Effect Size, Cohen *d*†
	T0	T1	T2	T0	T1	T2	T1	T1	T2	T2	T1	T1	T2	T2
EQ-5D-5L IC, mean (SD), range 0-1	0.9 (0.1)	0.8 (0.2)	0.9 (0.2)	0.8 (0.2)	0.8 (0.2)	0.8 (0.2)	−0.00 (−0.07, 0.07), *P* = .90	−0.02	−0.00 (−0.07, 0.07), *P* = .90	0.00	0.00 (−0.07, 0.08), *P* = .95	0.01	−0.01 (−0.09, 0.08), *P* = .86	−0.04
Carer QoL, mean (SD), range 0-100	81.0 (16.0)	81.0 (15.0)	83.0 (12.0)	79.0 (16.0)	78.0 (15.0)	76.0 (18.0)	0.06 (−5.55, 5.67), *P* = .98	0.00	3.16 (−2.92, 9.23), *P* = .31	0.21	−0.17 (−5.85, 5.51), *P* = .95	−0.01	3.58 (−2.55, 9.72), *P* = .25	0.23
NPI-Q total severity of symptoms, mean (SD), range 0-36	10.6 (6.3)	9.5 (6.8)	7.3 (6.3)	8.4 (5.5)	8.9 (6.9)	7.6 (4.8)	−0.44 (−2.83, 1.95), *P* = .72	−0.07	−0.98 (−3.65, 1.69), *P* = .47	−0.15	−0.48 (−3.00, 2.04), *P* = .71	−0.08	−1.30 (−4.09, 1.49), *P* = .36	−0.21
NPI-Q total distress, mean (SD), range 0-60	12.3 (9.0)	9.9 (9.4)	8.2 (8.0)	9.3 (7.8)	11.8 (9.7)	10.3 (7.3)	−3.30 (−6.57, −0.03), *P* = .048*	−0.38	−3.09 (−6.74, 0.57), *P* = .10	−0.35	−3.05 (−6.48, 0.38), *P* = .08	0.35	−3.18 (−6.98, 0.63), *P* = .10	−0.36
NPI-Q total number of symptoms, mean (SD), range 0-12	5.9 (3.6)	7.0 (4.0)	7.4 (4.4)	5.9 (3.8)	6.6 (4.2)	7.2 (4.5)	0.16 (−1.26, 1.58), *P* = .83	0.04	−0.24 (−1.67, 1.18), *P* = .74	−0.06	0.18 (−1.33, 1.70), *P* = .81	0.04	−0.47 (−1.99, 1.05), *P* = .54	−0.12
SSCQ, mean (SD), range 7-35	26.9 (4.9)	27.7 (5.0)	27.2 (5.1)	26.3 (5.5)	26.1 (5.3)	27.5 (4.5)	1.75 (−0.19, 3.69), *P* = .08	0.35	−1.21 (−3.35, 0.93), *P* = .27	−0.24	2.78 (0.85, 4.71), *P* = .005**	0.55	−0.84 (−2.98, 1.30), *P* = .44	−0.17
PES, mean (SD), range 0-8	4.8 (1.8)	4.9 (1.7)	5.1 (1.5)	4.8 (2.1)	4.6 (2.2)	5.0 (2.4)	0.23 (−0.38, 0.84), *P* = .46	0.12	0.09 (−0.58, 0.75), *P* = .80	0.05	0.24 (−0.40, 0.88), *P* = .46	0.13	0.13 (−0.58, 0.84), *P* = .72	0.07

Adj., adjusted; Carer QoL, quality of life of the informal caregiver using the Care-related Quality of Life instrument from The Older Persons and Informal Caregivers Survey Minimum DataSet (TOPICS-MDS caregiver[46]); EQ-5D-5L IC, quality of life of the informal caregiver using the EuroQol 5 dimensions questionnaire with 5-level scale from The Older Persons and Informal Caregivers Survey Minimum DataSet (TOPICS-MDS care recipient); NPI-Q total severity of symptoms, total severity of symptoms using the Neuropsychiatric Inventory–Questionnaire[48]; NPI-Q total distress, total amount of distress caused by the symptoms as experienced by the informal caregiver using the Neuropsychiatric Inventory–Questionnaire; NPI-Q total number of symptoms, total number of symptoms using the Neuropsychiatric Inventory–Questionnaire; PES, positive care experiences of the informal caregiver using Scale of Positive Experiences [in Dutch: Positieve Ervaringen Schaal[50]]; SSCQ, subjective burden for the informal caregiver using the Short Sense of Competence Questionnaire.[49]
Underlined scores are more positive. Outcomes are with the baseline score (T0) on the MMSE[34] of the PwD as a confounder.
*Mixed-model analysis with time (3 months) and the interaction between intervention and time showed a statistically significant reduction in the NPI-Q total distress score in the exergaming group compared to the control group after 3 months, when corrected for the baseline score (T0) on the MMSE of the PwD as a confounder.
** Mixed-model analysis with time (3 months) and the interaction between intervention and time showed a statistically significant increase in the SSCQ score in the exergaming group compared to the control group after 3 months, when corrected for the baseline score (T0) on the MMSE of the PwD and sex, age, and level of education of the IC as confounders.
†Outcome scores adjusted for confounding variables: baseline score (T0) on the MMSE of the PwD and sex, age, and level of education of the IC.

Conclusions and Implications

Despite a lack of power in our study, we would recommend (staff of) care organizations to offer exergaming to PwD. Ways to obtain funding for the equipment would need to be explored as this was sometimes a problem for DCCs. Our recommendation to offer exergaming is based on the positive effects on cognitive and social functioning of the PwD and on distress and sense of competence of their carers and the lack of adverse events. Communication of these results may encourage PwD to exercise more and to experience the benefits. Based on this study, this can be expected to indirectly benefit their carers' sense of competence, subjective burden, and distress. Future studies with larger samples are recommended to confirm our findings and to extend the knowledge about the effectiveness of different types of exergaming in different settings.

Acknowledgments

We would like to thank Sjef van Bommel (Sjef van Bommel Management & Support), Judith Bosmans (Vrije Universiteit Amsterdam), Esther Hakvoort (Evean), Marije Holstege (GRZ Plus), Carla Scholten (Embedded Fitness), Marian Schoone (TNO), Marjolein Smit (SilverFit), Ronald Valk (HilverZorg), and Joris Wiersinga (SilverFit) for their contributions as project group members. Additionally, we would like to thank the members of our Advisory Committee: Conchita Hofstede (Nictiz), Thed van Kempen (Stichting Groenhuysen), Martin Krommert (Argos Zorggroep), and Jeroen Olthof (Municipality of Zaandam) for their contributions to the project and Annelies van Rijn (Saffier) for providing practical support throughout the process of obtaining METc approval.

References

1. Penedo FJ, Dahn JR. Exercise and well-being: A review of mental and physical health benefits associated with physical activity. Curr Opin Psychiatry 2005;18:189–193.
2. Blondell SJ, Hammersley-Mather R, Veerman JL. Does physical activity prevent cognitive decline and dementia? A systematic review and meta-analysis of longitudinal studies. BMC Public Health 2014;14:510.
3. Taylor AH, Cable NT, Faulkner G, et al. Physical activity and older adults: A review of health benefits and the effectiveness of interventions. J Sports Sci 2004;22:703–725.
4. Pitkälä K, Savikko N, Poysti M, et al. Efficacy of physical exercise intervention on mobility and physical functioning in older people with dementia: A systematic review. Exp Gerontol 2013;48:85–93.
5. Potter R, Ellard D, Rees K, Thorogood M. A systematic review of the effects of physical activity on physical functioning, quality of life and depression in older people with dementia. Int J Geriatr Psychiatry 2011;26:1000–1011.
6. Heyn P, Abreu BC, Ottenbacher KJ. The effects of exercise training on elderly persons with cognitive impairment and dementia: A meta-analysis. Arch Phys Med Rehabil 2004;85:1694–1704.
7. van Alphen HJM, Hortobágyi T, van Heuvelen MJG. Barriers, motivators, and facilitators of physical activity in dementia patients: A systematic review. Arch Gerontol Geriatr 2016;66:109–118.
8. Nyman SR. Psychosocial issues in engaging older people with physical activity interventions for the prevention of falls. Can J Aging 2011;30:45–55.
9. Crombie IK, Irvine L, Williams B, et al. Why older people do not participate in leisure time physical activity: A survey of activity levels, beliefs and deterrents. Age Ageing 2004;33:287–292.
10. Clarke DE, van Reekum R, Simard M, et al. Apathy in dementia: Clinical and sociodemographic correlates. J Neuropsychiatry Clin Neurosci 2008;20:337–347.
11. Binnekade T, Eggermont L, Scherder E. Unmoved about movement: Physical (in) activity in care institutions. VU University, Dept. of Clinical Neuropsychology, Amsterdam; 2012.
12. Anderiesen H, Scherder EJA, Goossens RHM, Sonneveld MH. A systematic review—physical activity in dementia: The influence of the nursing home environment. Appl Ergon 2014;45:1678–1686.
13. Sun F, Norman IJ, While AE. Physical activity in older people: A systematic review. BMC Public Health 2013;13:449.
14. Mura G, Carta MG, Sancassiani F, et al. Active exergames to improve cognitive functioning in neurological disabilities: A systematic review and meta-analysis. Eur J Phys Rehabil Med 2018;54:450–462.
15. Sun H. Exergaming impact on physical activity and interest in elementary school children. Res Q Exerc Sport 2012;83:212–220.
16. Staiano AE, Flynn R. Therapeutic uses of active videogames: A systematic review. Games Health J 2014;3:351–365.
17. van Santen J, Dröes RM, Holstege M, et al. Effects of exergaming in people with dementia: Results of a systematic literature review. J Alzheimers Dis 2018;64:741–760.
18. Heuvelink A, Groot J, Hofstede-Kleyweg C. Let's play: stimulate older people to move with applied games. Ede: Coalitie Applied Gaming for Healthy Aging; TNO; VitaValley; 2014-01-01 2014.
19. Meekes W, Stanmore EK. Motivational determinants of exergame participation for older people in assisted living facilities: Mixed-methods study. J Med Internet Res 2017;19:e238.
20. Unbehaun D, Vaziri DD, Aal K, et al. Exploring the potential of exergames to affect the social and daily life of people with dementia and their caregivers. Paper presented at: The 2018 CHI Conference on Human Factors in Computing Systems; 2018. Montreal, QC, Canada.
21. Anderson-Hanley C, Arciero PJ, Brickman AM, et al. Exergaming and older adult cognition: A cluster randomized clinical trial. Am J Prev Med 2012;42:109–119.
22. Werner C, Rosner R, Wiloth S, et al. Time course of changes in motor-cognitive exergame performances during task-specific training in patients with dementia: Identification and predictors of early training response. J Neuroeng Rehabil 2018;15:100.
23. Karssemeijer EGA, Aaronson JA, Bossers WJR, et al. The quest for synergy between physical exercise and cognitive stimulation via exergaming in people with dementia: A randomized controlled trial. Alzheimers Res Ther 2019;11:3.
24. Burdea G, Polistico K, Krishnamoorthy A, et al. Feasibility study of the BrightBrainer™ integrative cognitive rehabilitation system for elderly with dementia. Disabil Rehabil Assist Technol 2015;10:421–432.
25. Shim SH, Kang HS, Kim JH, Kim DK. Factors associated with caregiver burden in dementia: 1-year follow-up study. Psychiatry Investig 2016;13:43–49.
26. Cross AJ, Garip G, Sheffield D. The psychosocial impact of caregiving in dementia and quality of life: A systematic review and meta-synthesis of qualitative research. Psychol Health 2018;33:1321–1342.
27. Isik AT, Soysal P, Solmi M, Veronese N. Bidirectional relationship between caregiver burden and neuropsychiatric symptoms in patients with Alzheimer's disease: A narrative review. Int J Geriatr Psychiatry 2019;34:1326–1334.
28. Schur D, Whitlatch CJ. Circumstances leading to placement: A difficult caregiving decision. Lippincotts Case Manage 2003;8:187–195.
29. Stowell E, Zhang Y, Castaneda-Sceppa C, et al. Caring for Alzheimer's disease caregivers: A qualitative study investigating opportunities for exergame innovation. Proc ACM Hum-Comput Interact 2019;3:1–27.
30. Saghaei M. Random allocation software for parallel group randomized trials. BMC Med Res Methodol 2004;4:26.
31. van Santen J, Dröes RM, Bosmans JE, et al. The (cost-) effectiveness of exergaming in people living with dementia and their informal caregivers: Protocol for a randomized controlled trial. BMC Geriatr 2019;19:50.
32. Guralnik JM, Simonsick EM, Ferrucci L, et al. A Short Physical Performance Battery assessing lower extremity function: Association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol 1994;49:M85–M94.
33. Vasunilashorn S, Coppin AK, Patel KV, et al. Use of the Short Physical Performance Battery Score to predict loss of ability to walk 400 meters: Analysis from the InCHIANTI study. J Gerontol A Biol Sci Med Sci 2009;64:223–229.
34. Cockrell J, Folstein MF. Mini Mental State Examination (MMSE). Psychopharmacol Bull 1988;24:689–692.
35. Ferretti MT, Iulita MF, Cavedo E, et al. Sex differences in Alzheimer disease—The gateway to precision medicine. Nat Rev Neurol 2018;14:457–469.
36. Breteler MMB, Schrijvers EMC. Epidemiologie. In: Jonker C, Slaets JPJ, Verhey FRJ, editors. Handbook on Dementia: Latest insights in Diagnosis and Treatment. Houten, the Netherlands: Bohn Stafleu van Loghum; 2009. p. 13–22.
37. Sawilowsky SS. New effect size rules of thumb. J Modern Appl Stat Methods 2009;8:26.
38. Cuijpers P, Turner E, Koole S, et al. What is the threshold for a clinically relevant effect? The case of major depressive disorders. Depress Anxiety 2014;31:374–378.
39. Dusseldorp E, Van Mechelen I. Qualitative interaction trees: A tool to identify qualitative treatment–subgroup interactions. Stat Med 2014;33:219–237.
40. van Leeuwen KM, Bosmans JE, Jansen AP, et al. Dutch translation and cross-cultural validation of the Adult Social Care Outcomes Toolkit (ASCOT). Health Qual Life Outcomes 2015;13:56.
41. Herdman M, Gudex C, Lloyd A, et al. Development and preliminary testing of the new five-level version of EQ-5D (EQ-5D-5L). Qual Life Res 2011;20:1727–1736.
42. van den Brink D, Lutomski JE, Qin L, et al. TOPICS-MDS: Veelzijdige bron voor wetenschappelijke en maatschappelijke kennisgeneratie ten behoeve van de ouderenzorg. Tijdschr Gerontol Geriatr 2015;46:78–91.
43. Verstraten PFJ, Van Eekelen CWJM. Manual for the GIP: Behavioural Observation Scale for Intramural Psychogeriatrics. Deventer, the Netherlands: Van Loghum Slaterus; 1987.
44. Deci EL, Eghrari H, Patrick BC, Leone DR. Facilitating internalization: The self-determination theory perspective. J Pers 1994;62:119–142.
45. Washburn RA, Smith KW, Jette AM, Janney CA. The physical activity scale for the elderly (PASE): Development and evaluation. J Clin Epidemiol 1993;46:153–162.

46. Ashendorf L, Jefferson AL, O'Connor MK, et al. Trail Making Test errors in normal aging, mild cognitive impairment, and dementia. Arch Clin Neuropsychol 2008;23:129–137.
47. Cummings JL, Mega M, Gray K, et al. The Neuropsychiatric Inventory: Comprehensive assessment of psychopathology in dementia. Neurology 1994; 44:2308.
48. de Boer AH, Oudijk D, van Groenou MIB, Timmermans JM. Positive experiences through informal care: Construction of a scale. Tijdschr Gerontol Geriatr 2012; 43:243–254.
49. Vernooij-Dassen MJFJ, Felling AJA, Brummelkamp E, et al. Assessment of caregiver's competence in dealing with the burden of caregiving for a dementia patient: A Short Sense of Competence (SSCQ) suitable for clinical practice. J Am Geriatr Soc 1999;47:256–257.
50. Padala KP, Padala PR, Lensing SY, et al. Home-based exercise program improves balance and fear of falling in community-dwelling older adults with mild Alzheimer's disease: A pilot study. J Alzheimers Dis 2017;59:565–574.
51. Wasserstein RL, Schirm AL, Lazar NA. Moving to a world beyond "$p < 0.05$". Am Stat 2019;73:1–19.

Supplementary Table 1
Secondary Outcome Measures for Participants Living With Dementia

Outcome	Outcome Measure	Recorded By	Timing		
			Baseline	3 mo	6 mo
Physical functioning	Physical Activity Scale of the Elderly (PASE)[45]	Researcher during interview	X	X	X
Cognitive functioning	Mini-Mental State Examination (MMSE)[34]	Researcher by means of test	X	X	X
Cognitive functioning	Trail Making Test (TMT)[46]	Researcher by means of test	X	X	X
Social functioning	One question from the Adult Social Care Outcomes Toolkit (ASCOT)[40]	Researcher during interview	X	X	X
Demographics and personal characteristics Physical functioning Cognitive functioning Social functioning Emotional functioning Quality of life	The Older Persons and Informal Caregivers Survey Minimum DataSet (TOPICS-MDS care recipient),[42] including EuroQol 5 dimensions questionnaire with 5-level scale (EQ-5D-5L)[41]	Researcher during interview	X	X	X
Interest in and enjoyment of physical exercise	Intrinsic Motivation Inventory (IMI)[44]	Researcher during interview	X	X	X
Body mass index (BMI)	Weight scale and measuring tape to measure height	Researcher during interview	X		

TMT-A, Trail Making Test part A; TMT-B, Trail Making Test part B.

Supplementary Table 2
Secondary Outcome Measures for Participants Living With Dementia and Informal Caregivers Answered by Informal Caregivers

Outcome	Outcome Measure	Recorded By	Timing			
			Baseline	3 mo	6 mo	0-6 mo (Ongoing)
Physical functioning of the participant living with dementia	Physical Activity Scale of the Elderly (PASE)[45]	Researcher during interview	X	X	X	
Fall incident rate of the participant with dementia during the past 3 mo	Custom registration form	Informal caregiver	X	X	X	
Behavior and mood of the participant living with dementia Emotional burden for the informal caregiver	Neuropsychiatric Inventory–Questionnaire (NPI-Q)[47]	Researcher during interview	X	X	X	
For both informal caregiver and participant with dementia: Demographics and personal characteristics Physical functioning Cognitive functioning Social functioning Emotional functioning Quality of life Experiences of the informal caregiver	The Older Persons and Informal Caregivers Survey Minimum DataSet (TOPICS-MDS informal caregiver)[42] including EuroQol 5 dimensions questionnaire with 5-level scale (EQ-5D-5L)[41]	Researcher during interview	X	X	X	
Subjective burden for the informal caregiver	Short Sense of Competence Questionnaire (SSCQ)[49]	Researcher during interview	X	X	X	
Positive care experiences of the informal caregiver	Scale of Positive Experiences (Positieve Ervaringen Schaal (PES))[48]	Researcher during interview	X	X	X	
Unexpected (Adverse) Events, falls and reasons of (potential) drop out	(Care) diaries (1 for the participant living with dementia, 1 for the informal caregiver)	Informal caregiver				X
Experience of the participant living with dementia with sports or cycling, technology and digital games in the past	Separate questions	Researcher during interview	X			

Supplementary Table 3
Secondary Outcome Measures for Participants Living With Dementia Answered by Staff of the Day Care Centers

Outcome	Outcome Measure	Recorded By	Timing		
			Baseline	3 mo	6 mo
Fall incident rate of the participant with dementia during the past 3 mo	Custom registration form	Staff at day care center	X	X	X
Social functioning of the participant living with dementia in the day care center	GIP: Behavior Observation Scale for Intramural Psychogeriatrics: subscale 1 (unsocial behavior) [Gedragsobservatieschaal voor de Intramurale Psychogeriatrie (GIP): subschaal 1][43]	Staff at day care center	X	X	X

Supplementary Table 4
Test Scores on the Different Outcomes per Time Point, Dose-Response Effects, and Effect Sizes for PwD

Outcome Measures	Exergaming Group			Dose-Response Effect*, *r* (95% CI), *P* Value	Effect Size, Cohen *d*	Dose-Response Effect*, *r* (95% CI), *P* Value	Effect Size, Cohen *d*	Adj. Dose-Response Effect*, *r* (95% CI), *P* Value†	Adj. Effect Size, Cohen *d*†	Adj. Dose-Response Effect*, *r* (95% CI), *P* Value†	Adj. Effect Size, Cohen *d*†
	T0	T1	T2	T1	T1	T2	T2	T1	T1	T2	T2
Primary outcomes											
SPPB, mean (SD), range 0-12	7.0 (2.4)	7.1 (2.1)	7.6 (2.2)	0.01 (−0.12, 0.22), *P* = .55	0.02	0.05 (−0.01, 0.02), *P* = .51	0.02	0.00 (−0.01, 0.02), *P* = .71	0.01	0.01 (−0.01, 0.02), *P* = .42	0.03
Physical activities per week, min, mean (SD)	281.4 (286.4)	312.3 (380.5)	312.3 (469.4)	1.98 (−0.12, 4.07), *P* = .07	0.06	1.55 (−0.09, 3.18), *P* = .06	0.05	1.94 (−0.26, 4.14), *P* = .08	0.06	1.62 (−0.12, 3.36), *P* = .07	0.05
Secondary outcomes											
MMSE, mean (SD)‡, range 0-30	18.1 (6.7)	17.1 (6.5)	17.9 (7.3)	−0.01 (−0.04, 0.03), *P* = .73	−0.01	0.00 (−0.03, 0.02), *P* = .73	−0.01	0.00 (−0.04, 0.03), *P* = .95§	0.00§	−0.01 (−0.03, 0.02), *P* = .70§	−0.01§
TMT-A, s, mean (SD), max 300	146.1 (80.4)	145.0 (81.0)	140.2 (82.8)	−0.07 (−0.58, 0.43), *P* = .78	−0.01	−0.23 (-0.72, 0.27), *P* = .37	−0.03	−0.12 (−0.65, 0.40), *P* = .65	−0.02	−0.27 (−0.79, 0.25), *P* = .31	−0.03
TMT-B, s, mean (SD), max 300	221.5 (90.7)	224.5 (88.9)	236.0 (59.0)	0.66 (−0.05, 1.38), *P* = .07	0.09	0.31 (−0.56, 1.17), *P* = .48	0.04	0.67 (−0.09, 1.43), *P* = .08	0.09	0.42 (−0.50, 1.33), *P* = .37	0.05
ASCOT, mean (SD), range 1-4	2 (1)	2 (1)	2 (1)	0.00 (−0.01, 0.01), *P* = .58	0.03	0.00 (−0.01, 0.00), *P* = .42	−0.03	0.00 (−0.01, 0.01), *P* = .53	0.03	0.00 (−0.01, 0.00), *P* = .42	−0.03
IMI01, mean (SD), range from 7-49	13.8 (9.8)	14.0 (8.3)	12.2 (7.0)	−0.02 (−0.10, 0.06), *P* = .62	−0.02	−0.02 (−0.08, 0.05), *P* = .57	−0.02	0.00 (−0.07, 0.08), *P* = .93	0.00	−0.02 (−0.08, 0.04), *P* = .48	−0.02
IMI02, mean (SD), range 6-42	19.2 (6.8)	19.4 (6.7)	18.1 (5.8)	0.01 (−0.05, 0.08), *P* = .66	0.02	−0.01 (-0.06, 0.04), *P* = .58	−0.02	0.01 (−0.05, 0.07), *P* = .72	0.02	−0.01 (−0.06, 0.04), *P* = .66	−0.02
IMI03, mean (SD), range 5-35	13.8 (4.8)	13.5 (4.4)	12.8 (4.4)	−0.02 (−0.06, 0.03), *P* = .44	−0.04	−0.01 (-0.05, 0.02), *P* = .47	−0.03	−0.02 (−0.06, 0.02), *P* = .30	−0.05	−0.01 (−0.05, 0.02), *P* = .41	−0.03
IMI04, mean (SD), range 7-49	17.5 (10.7)	18.2 (10.8)	15.4 (8.6)	0.03 (−0.07, 0.13), *P* = .50	0.03	−0.04 (−0.12, 0.04), *P* = .33	−0.04	0.04 (−0.06, 0.14), *P* = .39	0.04	−0.03 (−0.11, 0.05), *P* = .49	−0.03
IMI05, mean (SD), range 4-28	5.9 (3.6)	6.3 (4.6)	5.5 (4.8)	0.00 (−0.04, 0.05), *P* = .96	0.00	−0.01 (−0.05, 0.02), *P* = .42	−0.03	−0.00 (−0.04, 0.04), *P* = .98	0.00	−0.01 (−0.04, 0.02), *P* = .57	−0.02
Psychological well-being, mean (SD), range 5-100	60.0 (10.2)	72.2 (19.4)	75.1 (23.0)	0.02 (−0.12, 0.17), *P* = .74	0.01	−0.08 (−0.19, 0.03), *P* = .17	−0.04	0.04 (−0.10, 0.18), *P* = .60	0.02	−0.01 (−0.13, 0.10), *P* = .81	−0.01
PASE, mean (SD), range 0-400	61.2 (42.6)	46.0 (37.0)	38.6 (38.3)	−0.07 (−0.40, 0.26), *P* = .68	−0.02	0.01 (−0.25, 0.26), *P* = .97	0.00	−0.10 (−0.43, 0.23), *P* = .55	−0.02	0.11 (−0.15, 0.37), *P* = .41	0.03
GIP, mean (SD), range from 5-24	18.5 (3.2)	18.2 (3.8)	18.0 (3.7)	0.00 (−0.03, 0.03), *P* = .90	0.01	−0.01 (−0.04, 0.01), *P* = .30	−0.04	0.00 (−0.03, 0.04), *P* = .87	0.01	-0.00 (−0.03, 0.03), *P* = .89	−0.01
Number of falls, mean (SD), during 6-mo trial	2.5 (2.8)	1.2 (0.5)	1.5 (0.8)	−0.04 (−0.10, 0.03), *P* = .26	−0.20	−0.01 (−0.05, 0.04), *P* = .69	−0.05	−0.03 (−0.11, 0.05), *P* = .41	−0.17	−0.00 (−0.05, 0.05), *P* = .89	−0.02
EQ-5D-5L PwD, mean (SD), range 0-1	0.7 (0.3)	0.7 (0.3)	0.8 (0.2)	0.00 (−0.00, 0.00), *P* = .73	0.01	−0.00 (−0.00, 0.00), *P* = .13	−0.05	0.00 (−0.00, 0.00), *P* = .63	0.02	−0.00 (−0.00, 0.00), *P* = .21	−0.04
EQ-5D-5L IC_PwD, mean (SD), range 0-1	0.4 (0.3)	0.5 (0.3)	0.5 (0.3)	0.00 (−0.00, 0.00), *P* = .21	0.05	0.00 (−0.00, 0.00), *P* = .21	0.05	0.00 (−0.00, 0.00), *P* = .17	0.06	0.00 (−0.00, 0.00), *P* = .20	0.05

Adj., adjusted; ASCOT, Adult Social Care Outcomes Toolkit; BMI, body mass index; EQ-5D-5L PwD, quality of life of the participant with dementia as indicated by himself or herself, using the EuroQol 5 dimensions questionnaire with 5-level scale from The Older Persons and Informal Caregivers Survey Minimum DataSet (TOPICS-MDS care recipient); EQ-5D-5L IC_PwD, quality of life of the participant with dementia as indicated by his or her informal caregiver, using the EuroQol 5 dimensions questionnaire with 5-level scale from The Older Persons and Informal Caregivers Survey Minimum DataSet (TOPICS-MDS care recipient); GIP, Behavior Observation Scale for Intramural Psychogeriatrics: subscale 1 Social functioning of the participant living with dementia in the day care center; IMI01, Intrinsic Motivation Inventory, subscale 1 interest/enjoyment in physical exercise; IMI02, Intrinsic Motivation Inventory, subscale 2 perceived competence in physical exercise; IMI03, Intrinsic Motivation Inventory, subscale 3 effort in/importance of physical exercise; IMI04, Intrinsic Motivation Inventory, subscale 4 perceived choice of physical exercise; IMI05, Intrinsic Motivation Inventory, subscale 5 value/usefulness of physical exercise; MMSE, Mini-Mental State Examination; PASE, Physical Activity Scale of the Elderly; Psychological well-being, emotional functioning from The Older Persons and Informal Caregivers Survey Minimum DataSet (TOPICS-MDS care recipient); PwD, participant with dementia; SPPB, Short Physical Performance Battery; TMT-A, Trail Making Test part A; TMT-B, Trail Making Test part B.

Outcomes are with the baseline score (T0) on the MMSE of the PwD as a confounder. Underlined scores are more positive.

*Dose-response effects per 10 minutes more exergaming.

†Outcome scores adjusted for confounding variables: baseline score (T0) on the MMSE, BMI, sex, age, and level of education of the PwD.

‡Outcomes are without any confounders.

§Outcome scores adjusted for confounding variables: BMI, sex, age, and level of education of the PwD.

Supplementary Table 5
Test Scores on the Different Outcomes per Time Point, Dose-Response Effects, and Effect Sizes for IC

Outcome Measures	Exergaming Group			Dose-Response Effect*, *r* (95% CI), *P* Value	Effect Size, Cohen *d*	Dose-Response Effect*, *r* (95% CI), *P* Value	Effect Size, Cohen *d*	Adj. Dose-Response Effect*, *r* (95% CI), *P* Value†	Adj. Effect Size, Cohen *d*†	Adj. Dose-Response Effect*, *r* (95% CI), *P* Value†	Adj. Effect Size, Cohen *d*†
	T0	T1	T2	T1	T1	T2	T2	T1	T1	T2	T2
EQ-5D-5L IC, mean (SD), range 0-1	0.9 (0.1)	0.8 (0.2)	0.9 (0.2)	−0.00 (−0.00, 0.00), *P* = .40	−0.04	0.00 (−0.00, 0.00), *P* = .88	0.01	−0.00 (−0.00, 0.00), *P* = .53	−0.03	0.00 (−0.00, 0.00), *P* = .76	0.01
Carer QoL, mean (SD), range 0-100	81.0 (16.0)	81.0 (15.0)	83.0 (12.0)	0.07 (−0.06, 0.20), *P* = .27	0.05	0.09 (−0.02, 0.21), *P* = .12	0.06	0.05 (−0.08, 0.17), *P* = .48	0.03	0.08 (−0.03, 0.20), *P* = .17	0.05
NPI-Q total severity of symptoms, mean (SD), range 0-36	10.6 (6.3)	9.5 (6.8)	7.3 (6.3)	−0.00 (−0.06, 0.05), *P* = .86	−0.01	−0.04 (−0.09, 0.02), *P* = .18	−0.06	−0.01 (−0.07, 0.04), *P* = .70	−0.02	−0.04 (−0.09, 0.02), *P* = .17	−0.06
NPI-Q total distress, mean (SD), range 0-60	12.3 (9.0)	9.9 (9.3)	8.2 (8.0)	−0.02 (−0.09, 0.06), *P* = .62	−0.02	−0.07 (−0.14, 0.01), *P* = .08	−0.08	−0.02 (−0.10, 0.06), *P* = .64	−0.02	−0.07 (−0.15, 0.00), *P* = .06	−0.08
NPI-Q total number of symptoms, mean (SD), range 0-12	5.9 (3.6)	7.0 (4.0)	7.4 (4.4)	0.02 (−0.01, 0.05), *P* = .27	0.05	−0.01 (−0.03, 0.02), *P* = .54	−0.02	0.03 (−0.01, 0.06), *P* = .11	0.06	−0.01 (−0.03, 0.02), *P* = .47	−0.02
SSCQ, mean (SD), range 7-35	26.9 (4.9)	27.7 (5.0)	27.2 (5.1)	0.02 (−0.02, 0.07), *P* = .28	0.05	−0.02 (−0.06, 0.02), *P* = .43	−0.03	0.03 (−0.01, 0.07), *P* = .17	0.06	−0.02 (−0.05, 0.02), *P* = .44	−0.03
PES, mean (SD), range 0-8	4.8 (1.8)	4.9 (1.7)	5.1 (1.5)	0.01 (−0.01, 0.02), *P* = .41	0.03	0.00 (−0.01, 0.01), *P* = .90	0.00	0.01 (−0.01, 0.02), *P* = .35	0.04	0.00 (−0.01, 0.01), *P* = .83	0.01

Adj., adjusted; Carer QoL, quality of life of the informal caregiver using the Care-related Quality of Life instrument from The Older Persons and Informal Caregivers Survey Minimum DataSet (TOPICS-MDS caregiver); EQ-5D-5L IC, quality of life of the informal caregiver using the EuroQol 5 dimensions questionnaire with 5-level scale from The Older Persons and Informal Caregivers Survey Minimum DataSet (TOPICS-MDS care recipient); IC, informal caregiver; NPI-Q total severity of symptoms, total severity of symptoms using the Neuropsychiatric Inventory−Questionnaire; NPI-Q total distress, total amount of distress caused by the symptoms as experienced by the informal caregiver using the Neuropsychiatric Inventory−Questionnaire; NPI-Q total number of symptoms, total number of symptoms using the Neuropsychiatric Inventory−Questionnaire; PES, positive care experiences of the informal caregiver using Scale of Positive Experiences [in Dutch: Positieve Ervaringen Schaal]; SSCQ, subjective burden for the informal caregiver using the Short Sense of Competence Questionnaire.
Outcomes are with the baseline score (T0) on the MMSE of the participant with dementia (PwD) as a confounder. Underlined scores are more positive.

*Dose-response effects per 10 minutes more exergaming.

†Outcome scores adjusted for confounding variables: the baseline score (T0) on the MMSE of the PwD and sex, age, and level of education of the IC.