Therapeutic Uses of Active Videogames: A Systematic Review

Amanda E. Staiano, PhD,¹ and Rachel Flynn, PhD²

Abstract

Background: Active videogames (AVGs) may be useful for promoting physical activity for therapeutic uses, including for balance, rehabilitation, and management of illness or disease. The literature from 64 peer-reviewed publications that assessed health outcomes of AVGs for therapeutic purposes was synthesized.

Materials and Methods: PubMed, Medline, and PsycInfo were queried for original studies related to the use of AVGs to improve physical outcomes in patients who were ill or undergoing rehabilitation related to balance, burn treatment, cancer, cerebral palsy, Down's syndrome, extremity dysfunction or amputation, hospitalization, lupus, Parkinson's disease, spinal injury, or stroke. The following inclusion criteria were used: (1) human subjects; (2) English language; (3) not duplicates; (4) new empirical data; and (5) tests an AVG, including commercially available or custom-designed. Studies were included regardless of participants' age or the study design.

Results and Limitations: Overall, the vast majority of studies demonstrated promising results for improved health outcomes related to therapy, including significantly greater or comparable effects of AVG play versus usual care. However, many studies were pilot trials with small, homogeneous samples, and many studies lacked a control or comparison group. Some trials tested multiweek or multimonth interventions, although many used a single bout of gameplay, and few included follow-up assessments to test sustainability of improved health.

Conclusions and Implications: AVGs were acceptable and enjoyable to the populations examined and appear as a promising tool for balance, rehabilitation, and illness management. Future research directions and implications for clinicians are discussed.

Introduction

ACTIVE VIDEOGAMES (AVGs) HAVE been extensively tested for their potential capability to promote physical activity, although systematic reviews and meta-analyses focus predominantly on healthy and young populations.¹⁻⁵ Yet, in recent years, AVGs are being studied for a variety of health outcomes independent of acute bouts of physical activity in healthy populations.⁶ For instance, AVGs may promote physical activity in individuals striving to improve balance, undergoing rehabilitation, who have an acute or chronic illness, or who have a physical or developmental impairment.

Several high-quality reviews have been previously published on the therapeutic uses of AVGs. Many focused on a specific outcome or population, such as balance improvement in the elderly⁷ or stroke rehabilitation.⁸ A review of randomized controlled trials (RCTs) using videogames (not just AVGs) as a health intervention found that there were a wide range of uses; psychological and physical therapy in-

terventions were the most successful, whereas interventions to improve disease management were less successful.⁶ However, the authors stated that most studies were of low quality. Using RCT as an inclusion criterion limited the scope of studies included.⁶

The current review included a range of study designs in order to explore a variety of outcomes and exposures related to the therapeutic uses of AVGs. In addition, previous reviews focused on limited age ranges, whereas the current review examines interventions and rehabilitation uses of AVGs across the lifespan. Furthermore, this review extends a prior review of AVGs for rehabilitation that examined publications to the year 2010.⁹ Considering that 51 of 64 studies reviewed in the present article were published after 2010, the time is ripe for an updated review. The aim of this systematic review was to provide an updated examination of the therapeutic health uses of AVGs by synthesizing the literature on physical outcomes in rehabilitation and illness populations.

¹Pennington Biomedical Research Center, Baton Rouge, Louisiana.

²New York University, New York, New York.

Materials and Methods

Eligibility criteria

The following inclusion criteria were used: (1) human subjects; (2) English language; (3) not duplicates; (4) new empirical data; and (5) tested an AVG. Studies were excluded if they did not test physical activity outcomes or tested physical activity outcomes in only a healthy population and not for therapeutic purposes. An AVG was defined as a digital game that involved gross motor activity,¹⁰ which for the purposes of this review includes commercially available off-the-shelf systems as well as custom-designed systems. Studies were included regardless of participants' age or the study design.

Information source and study selection

A systematic review was conducted using three academic search engines: PubMed, Medline, and PsychInfo. Articles were extracted through July 5, 2013. The following medical subject heading terms were used in the search: (1) "exergame," "active video game," or "video game"; and (2) "health," "family health," "holistic health," "men's health," "mental health," "minority health," "occupational health," "public health," "rural health," "suburban health," "veterans' health," "women's health," "world health,"

"physical fitness," "exercise," "exercise therapy," "physical conditioning," "physical endurance," "leisure activities," "physical exertion," "aerobic exercise," "sports," "movement," "motor activity," or "physical activity." Table 1 reports the full electronic search strategy including the specific search terms and limits used for each database.

Data collection and items

Data extracted for each study included (a) the study manipulation, such as if a control group was used and if it was a between- or within-subjects design, (b) the length of AVG exposure, including number of minutes, days, and weeks, (c) the dependent variables, (d) information about the sample (i.e., sample size, age, characteristics), (e) game platform and game used in the study, and (f) key findings based on study goals. Two investigators extracted the data and resolved differences in extraction through ongoing discussion and adjustments, as needed.

Results

Study selection

The search originally identified 3960 articles that were screened (Fig. 1). There were 64 articles remaining after

TABLE 1. SEARCH TERMS AND LIMITS USED FOR EACH DATABASE

Database	Search terms
PubMed	((exergame OR active video game OR video game[MeSH Terms])) AND (Health OR Family Health OR Holistic Health OR Men's Health OR Mental Health OR Minority Health OR Occupational Health OR Public Health OR Rural Health OR Suburban Health OR Veterans Health OR Women's Health OR World Health OR Physical Fitness OR Exercise OR Exercise Therapy OR Physical Conditioning OR Physical Endurance OR Leisure Activities OR Physical Exertion OR Aerobic Exercise OR Sports OR Movement OR Motor Activity OR Physical Activity[MeSH Terms])
Medline	(Topic=(exergame OR "active video game") OR (Topic=("video game") OR MeSH Heading:exp=(Video Games))) AND (((((((((((((((((((Topic=(Health OR "Family Health") OR (Topic=(Holistic Health) OR MeSH Heading:exp=(Holistic Health))) OR (Topic=(Men's Health) OR MeSH Heading:exp=(Health Manpower) OR MeSH Heading:exp=(Men's Health) OR MeSH Heading:exp=(Pharmaceutical Preparations))) OR (Topic=(Mental Health) OR MeSH Heading:exp=(Mental Health))) OR (Topic=(Minority Health) OR MeSH Heading:exp=(Minority Health))) OR (Topic=(Occupational Health) OR MeSH Heading:exp=(Occupational Health))) OR (Topic=(Public Health) OR MeSH Heading:exp=(Public Health) OR MeSH Heading:exp=(Therapeutics))) OR (Topic=(Rural Health) OR MeSH Heading=(Rural Health))) OR (Topic=(Suburban Health) OR MeSH Heading:exp=(Suburban Health))) OR (Topic=(Veterans Health) OR MeSH Heading:exp=(Veterans Health))) OR (Topic=(Women's Health) OR MeSH Heading:exp=(Women's Health))) OR (Topic=(World Health) OR MeSH Heading=(World Health))) OR (Topic=(Physical Fitness) OR MeSH Heading:exp=(Physical Fitness))) OR (Topic=(Exercise) OR MeSH Heading:exp=(Exercise) OR MeSH Heading:exp=(Therapeutics) OR MeSH Heading:exp=(Exercise Therapy))) OR (Topic=(Exercise Therapy) OR MeSH Heading=(Exercise Therapy))) OR (Topic=(Physical Conditioning) OR MeSH Heading=(Exercise))) OR (Topic=(Physical Endurance) OR MeSH Heading:exp=(Physical Endurance))) OR (Topic=(Leisure Activities) OR MeSH Heading:exp=(Leisure Activities))) OR (Topic=(Physical Exertion) OR MeSH Heading:exp=(Physical Exertion))) OR (Topic=(Aerobic Exercise) OR MeSH Heading=(Exercise))) OR (Topic=(Sports) OR MeSH Heading:exp=(Physical Therapists) OR MeSH Heading:exp=(Sports))) OR (Topic=(Movement) OR MeSH Heading:exp=(Movement))) OR Topic=(Motor Activity)) OR (Topic=(Physical Activity) OR MeSH Heading=(Motor Activity)))
PsycInfo	su(exergame OR active video game OR video game) AND su(Health OR Family Health OR Holistic Health OR Men's Health OR Mental Health OR Minority Health OR Occupational Health OR Public Health OR Rural Health OR Suburban Health OR Veterans Health OR Women's Health OR World Health OR Physical Fitness OR Exercise OR Exercise Therapy OR Physical Conditioning OR Physical Endurance OR Leisure Activities OR Physical Exertion OR Aerobic Exercise OR Sports OR Movement OR Motor Activity OR Physical Activity)

MeSH, medical subject heading.

FIG. 1. Systematic process to select peer-reviewed articles. AVG, active videogame. Color images available online at www.liebertonline.com/g4h

eligibility criteria were used. Table 2 details characteristics and key findings for each study selected for the final review.

Study characteristics

Study designs included 4 within-subject designs, 24 between-subjects designs, and 36 studies that only used an AVG condition (including 12 case studies with three participants or fewer). Studies were assigned to 1 of 11 categories based on the population and/or study outcome. Categories included balance improvement ($n=22$), a form of distraction during burn treatment ($n=3$), youth with cerebral palsy ($n=11$) or Down's syndrome ($n=1$), persons post-stroke ($n=11$), and persons with cancer ($n=1$), extremity limitations and amputation ($n=5$), lupus ($n=1$), Parkinson's disease ($n=4$), spinal injuries ($n=2$), or hospitalized (not otherwise specified) ($n=3$).

Most studies (> 50 percent) were conducted with patients over the age of 50 years, and 22 percent were conducted with youth under the age of 18 years. In terms of game platforms, most studies ($n=44$) used the Nintendo® (Kyoto, Japan) Wii™ or "Wii Fit™." Only one study used the Xbox® Kinect (Microsoft, Redmond, WA), whereas four used the Sony (Tokyo, Japan) PlayStation® 2 "EyeToy®," and two used the PlayStation 3 "Ultra Glove®." Two studies used Sensamove (Utrecht, The Netherlands), and one used GameCycle (Out-Front, Mesa, AZ). Five studies used other types of AVGs, and five used games custom-designed for the study.

Results of individual studies of AVG play for therapeutic purposes

Balance. Twenty-two studies examined AVG play to improve balance, predominantly among the elderly. The predominant AVG studied was the "Wii Fit,"^{11–22} an adapted or custom-made game using the "Wii Fit,"^{23,24} or a balance board similar to the "Wii Fit."^{25,26} Other games included customized games,^{27–29} "Wii Sports Bowling,"³⁰ "Kinect Your Shape," including tai chi and yoga,³¹ and dance-based games.^{32–34}

Overall, AVGs (specifically the "Wii Fit") were regarded as efficacious, as well as inexpensive, portable, and widely available for the improvement of balance²⁴ and balance confidence.^{20,21} Some studies included AVG play as an addition to normal rehabilitation, making it difficult to parse out any additive effects of AVG beyond usual care (AVGs included "StepMania,"³² "Wii Fit,"⁹ and a customized balance game²⁹). Others observed that AVG play did not confer benefits above adapted physical activity interventions (including the "Wii Fit,"²² and a customized game²⁹). One group preferred traditional therapy over the "Wii Fit," although they demonstrated high adherence to and compliance with the AVG intervention.¹⁶ In contrast, a one-time "Wii Fit" intervention produced high levels of enjoyment, with 89 percent reporting that they would play "Wii Fit" in the future and 73 percent reporting they enjoyed "Wii Fit" play more than usual therapy.¹⁷

Burn wounds. Three studies examined AVG play among patients undergoing treatment for burn wounds. Games

TABLE 2. CHARACTERISTICS AND FINDINGS OF EMPIRICAL STUDIES ON ACTIVE VIDEOGAMES USED FOR PHYSICAL ACTIVITY OUTCOMES FOR THERAPEUTIC PURPOSES

Topic, reference	Study design			Sample			Key findings ^a
	AVG exposure	Manipulation	Dependent variable	Size (n)	Mean Age (years)	Characteristics	
Balance Agmon et al. ¹¹	At least 30 minutes, 3×/week, 3 months	AVG only	Berg Balance Scale, 4-m timed walk, Physical Activity Enjoyment Scale	7	78–92	Impaired balance	<ul style="list-style-type: none"> Balance increased. Walking speed increased.
Batani ¹²	3 sessions/week, 4 weeks	1. AVG 2. Physical therapy 3. Both AVG and physical therapy	Berg Balance Scale, AVG balance test	17	53–91		<ul style="list-style-type: none"> Balance increased in all groups. Groups 2 and 3 improved more than Group 1 on balance. Group 3 improved more on the AVG balance test. Balance improved. Falls decreased. Varied improvements on COP excursions and path length
Becker et al. ²⁷	45-minute session, 8× over 3 weeks	AVG only	Number of falls, range of COP excursions, COP path length	3	20–58	Severe ataxia, stroke, closed head injury	<ul style="list-style-type: none"> Group 1 improved lower limb muscle power, all sit-to-stand mechanics, and time parameters. Group 1 improved more on balance, mobility, and self-confidence. Group 2 only improved maximal vertical ground reaction force. All outcomes improved.
Chen et al. ²⁸	30 minutes, 2×/week, 6 weeks	1. AVG 2. Matched controls	Sit-to-stand movement, mechanics and time parameters, modified falls efficacy scale, Tinetti Performance-Oriented Mobility Assessment, function reach test, TUG test	40	>65	Interactive videogame-based rehabilitation device for lower limb power rehabilitation	<ul style="list-style-type: none"> Groups 1 and 2 improved on the Senior Fitness Test. Group 1 reported more caloric expenditure and balance confidence.
Clark et al. ³⁰	1-h, 6 sessions	AVG only	Berg Balance Scale, dynamic gait index, TUG test, Activities-specific Balance Confidence Scale	1	89	Balance disorder and history of falling	<ul style="list-style-type: none"> No significant change between groups Small improvements in balance
Daniel ¹³	45 minutes, 3×/week, 15 weeks	1. AVG 2. Seated exercise 3. Control	Senior Fitness Test, body weight, Balance Efficacy Scale, Community Healthy Activities Model Program for Seniors, Activities-specific Balance Confidence Scale, Late-Life Function and Disability Index	21	77	One to two frailty characteristics	<ul style="list-style-type: none"> Group 1 improved more on static balance measures. Both groups improved similarly on dynamic balance measures. Group 1 improved more on TUG, functional reach, and flexibility. Both groups improved on TUG time, TURN-180, and flexibility. Group 1 improved hip muscle strength and ground reaction force. Group 2 did not improve. During feedback conditions there was more controlled movement. Task performance improved.
Franco et al. ¹⁴	10–15 minutes for “Wii Fit,” 30–45 minutes for “Matter of Balance,” 2×/week, 3 weeks	1. AVG 2. Control	Berg Balance Scale, Tinetti Gait and Balance Assessment, SF-36 health survey	32	63–90		<ul style="list-style-type: none"> Group 1 improved more on static balance measures. Both groups improved similarly on dynamic balance measures. Group 1 improved more on TUG, functional reach, and flexibility. Both groups improved on TUG time, TURN-180, and flexibility. Group 1 improved hip muscle strength and ground reaction force. Group 2 did not improve. During feedback conditions there was more controlled movement. Task performance improved.
Gil-Gómez et al. ²³	20 1-hour sessions	1. AVG 2. Standard rehabilitation	Static and dynamic balance	17	47.3	Acquired brain injury	<ul style="list-style-type: none"> Group 1 improved more on static balance measures. Both groups improved similarly on dynamic balance measures. Group 1 improved more on TUG, functional reach, and flexibility. Both groups improved on TUG time, TURN-180, and flexibility. Group 1 improved hip muscle strength and ground reaction force. Group 2 did not improve. During feedback conditions there was more controlled movement. Task performance improved.
Griffin et al. ¹⁵	7 weeks	1. AVG 2. Control	TUG test, functional reach, TURN-180, and flexibility scores	65	66.8–90.2	Falls prevention criteria	<ul style="list-style-type: none"> Group 1 improved more on static balance measures. Both groups improved similarly on dynamic balance measures. Group 1 improved more on TUG, functional reach, and flexibility. Both groups improved on TUG time, TURN-180, and flexibility. Group 1 improved hip muscle strength and ground reaction force. Group 2 did not improve. During feedback conditions there was more controlled movement. Task performance improved.
Kim et al. ³¹	1 hour, 3×/week, 8 weeks	1. AVG 2. Control (daily routine)	Hip muscle strength, ground reaction force	32	65–75	Ambulatory	<ul style="list-style-type: none"> Group 1 improved more on static balance measures. Both groups improved similarly on dynamic balance measures. Group 1 improved more on TUG, functional reach, and flexibility. Both groups improved on TUG time, TURN-180, and flexibility. Group 1 improved hip muscle strength and ground reaction force. Group 2 did not improve. During feedback conditions there was more controlled movement. Task performance improved.
Lamoth et al. ²⁵		1. Within-subjects: Visual feedback 2. Visual feedback with competition 3. No feedback	Hilbert amplitude, movement on the board (number of oscillations, fluency, trajectory length, percentage error)	12	61–77; 19–26	Xbox Kinect/“Your Shape Fitness” (tai chi, yoga) Sensamove/“Miniboard”	<ul style="list-style-type: none"> Group 1 improved more on static balance measures. Both groups improved similarly on dynamic balance measures. Group 1 improved more on TUG, functional reach, and flexibility. Both groups improved on TUG time, TURN-180, and flexibility. Group 1 improved hip muscle strength and ground reaction force. Group 2 did not improve. During feedback conditions there was more controlled movement. Task performance improved.

(continued)

TABLE 2. (CONTINUED)

Topic, reference	Study design			Sample			Key findings ^a
	AVG exposure	Manipulation	Dependent variable	Size (n)	Mean Age (years)	Characteristics	
Lamoth et al. ²⁶	6 weeks	AVG only	Balance, game task performance, postural control	9	>65	Sensamove/"SensBalance Fitness Board"	• Balance and task performance improved.
Laver et al. ¹⁶	25 minutes, 5 ×/week, 12 days (mean)	AVG only	Acceptability using discrete choice experiment (therapy mode, amount, cost; percentage of recovery made)	21	85.4	Geriatric hospitalization patients	• Postural control improved. • Preintervention, participants were most concerned about therapy time and intensity and amount of recovery. • Postintervention, most were concerned about mode of therapy and preferred traditional programs over "Wii Fit."
McGough et al. ²⁴	Within-subjects, one session	AVG only	Mean mass difference between limbs, symmetry index, percentage of time favoring single limb	47	23	Elite soccer players and age-matched, untrained participants	• High adherence and compliance to AVG • Both groups improved weight-bearing symmetry. • Significant reductions in mean mass difference in the untrained group but not the elite group • High levels of asymmetry correlated with greatest response to feedback.
Meldrum et al. ¹⁷	30-minute session	AVG only	Usability, enjoyment	26	43	Balance impairment	• High usability rating; negatively correlated with age • High enjoyment, with 89 percent saying they would use AVG in the future • 73 percent reported more enjoyment and motivation than usual therapy.
Michalski et al. ¹⁸	One session, 10 trials	AVG only	COP sway, shoulder-pelvic movement	16	22–30	Nintendo Wii/"Wii Fit" ("Soccer Heading" and "Ski Slalom")	• No falls during testing • Direction of change dependent on type of game played and body part engaged (i.e., trunk versus lower body)
Pichierri et al. ³²	60 minutes (20 minutes for AVG), 2 ×/week, 12 weeks	1. AVG plus progressive strength and balance training 2. Control (no intervention)	Voluntary step execution	19	84 (Group 1) 86 (Group 2)	"StepMania"	• Group 1 improved in initiation time and backward steps under dual-task conditions.
Pluchino et al. ¹⁹		1. AVG 2. Tai chi	TUG test, one-leg stance, functional reach, balance/mobility, COP, falls risk, fall efficacy	27	72.5	Nintendo Wii/"Wii Fit"	• No condition differences so AVG as effective as tai chi to improve postural control and balance • Forty started the study, but only 27 completed.
Rendon et al. ²⁰	45–60 minutes; 3 ×/week 6 weeks	1. AVG 2. Control	TUG test, balance confidence	40	60–95	Nintendo Wii/"Wii Fit"	• Group 1 improved TUG test and balance confidence more than Group 2.
Szturm et al. ²⁹	45 minutes, 2 ×/week, 8 weeks	1. AVG plus dynamic balance exercises 2. Control (usual care)	Balance, TUG test, balance confidence, sensory interaction, gait	30	81	Customized games ("Under Pressure," "Memory Match," "Balloon Burst")	• Group 1 improved in balance more than Group 2. • No treatment effect on gait function

(continued)

TABLE 2. (CONTINUED)

Topic, reference	Study design			Sample			Key findings ^a
	AVG exposure	Manipulation	Dependent variable	Size (n)	Mean Age (years)	Characteristics	
Taylor et al. ²¹	20–60 minutes, 7 weeks, 10-week follow-up	1. Standard plus extra one-on-one AVG training 2. Standard plus extra one-on-one training 3. Standard 4. No training	TUG test, 10-minute walk, confidence in balance, mood states, self-esteem, falls at 10-week follow-up	3	71–85	History of falls and fear of falling	<ul style="list-style-type: none"> Seven of eight functional outcomes improved. Improved well-being and self-esteem No falls during training or follow-up
Toulotte et al. ²²	1 hour, 1×/week, 20 weeks	1. AVG 2. Adapted physical activities training 3. Both 4. No training	Static and dynamic balance, uni-pedal test, “Wii Fit” test	36	75.1	Nintendo Wii/“Wii Fit”	<ul style="list-style-type: none"> Groups 1, 2, and 3 improved balance. Group 1 did not decrease on the dynamic balance test or unipedal test. Group 1 improved center of gravity.
Burn wounds Hoffman et al. ³⁶	3-minute virtual reality and 3-minute videogame (2 sessions of each)	Within-subjects: 1. Virtual reality 2. Game	Sensory and affective pain ratings, anxiety, time spent thinking about pain	2	16–17	“SpiderWorld” (virtual reality) versus Nintendo 64 “Wave Race” and “Mario Kart”	<ul style="list-style-type: none"> All pain and anxiety ratings decreased.
Kipping et al. ³⁷	2–62 minutes during one wound treatment (median, 8 minutes)	1. AVG 2. Standard distraction	Pain intensity by self-, nurse, and caregiver report, heart rate, oxygen saturation	41	11–17	“Chicken Little” or “Need for Speed” (age-dependent)	<ul style="list-style-type: none"> Nurses rated Group 1 as lower pain scores and fewer pain medication doses. No differences in adolescent and caregiver pain score rating Group 1 trended toward lower pain scores and treatment times but not a statistically significant difference. Group 1 experienced less pain. Group 1 trend for lower anxiety, better range of motion and function, and higher enjoyment
Yohanan et al. ³⁵		1. AVG 2. Usual care control	Pain, anxiety, range of motion, function, enjoyment, presence	23	20–78	Nintendo Wii/“Wii Sports” and “Wii Fit”	<ul style="list-style-type: none"> Lost time awareness and felt distracted from daily hospital routine Improved mood state, relaxation, and decreased negative emotions
Cancer Jahn et al. ³⁸	30 minutes, 5 days	AVG only	Acceptance, time awareness, distraction from hospital environment, mood state	7	47–70	Nintendo Wii/“Wii Sports”	<ul style="list-style-type: none"> Improved visual discrimination, visual form constancy, visual closure Reduced sequential memory Improved function and reduced impairment Improved hand function and forearm bone health Maintained increased hand function and bone health at 2 months postintervention Significant increase in gross motor function
Cerebral palsy Deutsch et al. ³⁹	60–90 minutes, 11 sessions	AVG only	Visual-perceptual processing, postural control, functional mobility	1	13	Nintendo Wii/“Wii Sports”	<ul style="list-style-type: none"> Moderate physical activity in dance and boxing Increased muscle activation especially in dominant arm
Golomb et al. ⁴⁵	21 minutes (mean), 2.6×/week (mean), 14 months	AVG only	Exercise time, grip strength, hand function, dual energy x-ray absorptiometry for bone health	1	15	PlayStation 3/“Ultra Glove”	
Gordon et al. ⁴⁰	45 minutes, 2×/week, 6 weeks	AVG only	Attendance, change in gross motor function	7	6–12	Nintendo Wii/“Wii Sports” (boxing, baseball, tennis)	
Howcroft et al. ⁴¹	8 minutes/game, 32 minutes total	AVG only	Energy expenditure, upper limb muscle activation and kinematics, enjoyment	17	9.4	Nintendo Wii/“Wii Sports” (bowling, tennis, boxing) and “Dance Dance Revolution”	

(continued)

TABLE 2. (CONTINUED)

Topic, reference	Study design			Sample			Key findings ^a
	AVG exposure	Manipulation	Dependent variable	Size (n)	Mean Age (years)	Characteristics	
Huber et al. ⁴⁶	30 minutes, several days/week, 6–10 months	AVG only	Finger range of motion, subjective evaluation, therapist assessments	3	13–15	Cerebral palsy	<ul style="list-style-type: none"> Improved finger range of motion Improved grip, pincer strength, and hand function All attained moderate-intensity activity for both tennis and boxing.
Hurkmans et al. ⁴²	15 minutes each, 2 games	AVG only	VO ₂ while sitting versus playing Wii	8	36	Cerebral palsy	<ul style="list-style-type: none"> All attained moderate-intensity activity for both tennis and boxing.
Jannink et al. ⁴⁷	30 minutes, 2 ×/week, 6 weeks	1. AVG only 2. Control (time-matched regular therapy)	User satisfaction and motivation, upper limb function	10	5–15	Cerebral palsy	<ul style="list-style-type: none"> Functional outcomes were stable or increased, with two children significantly increasing scores. Balance improved significantly. No significant differences in other measures
Jelsma et al. ⁴³	3 weeks	AVG only	Balance, running speed, agility, timed up and down stairs	14		Spastic hemiplegic cerebral palsy	<ul style="list-style-type: none"> No significant difference between testing occasions for balance measures
Ramstrand and Lyngnegard ⁴⁴	30 minutes, 7 ×/week, 5 weeks of Wii play and then 5 weeks of no play	Randomized crossover at baseline	Sensory organization, reactive balance, rhythmic weight shift	18		Hemiplegic or diplegic cerebral palsy	<ul style="list-style-type: none"> Positive parental perception: may promoted positive experiences in rehabilitation Valued social aspects Less need to coach during gaming Desire for more controlled and individualized games Increased convenience in using hands/arms during daily activities No change in upper extremity movement
Sandlund et al. ⁷⁸	Qualitative study of parental perceptions	AVG only	Semistructured interviews	15		Families of children with mild/moderate cerebral palsy	<ul style="list-style-type: none"> Improved postural control close to that of typically developing children
Winkels et al. ⁴⁸	2 ×/week, 6 weeks	AVG only	Upper limb function, user satisfaction, game enjoyment	15		Cerebral palsy	<ul style="list-style-type: none"> No condition differences in any measure
Down's syndrome Berg et al. ⁵⁰	20 minutes, 4 ×/week, 8 weeks	AVG only	Postural stability, motor proficiency, balance, upper limb coordination, manual dexterity, running speed, agility, body composition	1	12	Down's syndrome	<ul style="list-style-type: none"> Improved postural control close to that of typically developing children
Extremity dysfunction and amputations Andrysek et al. ⁵¹	20 minutes, 4 ×/week, 4 weeks	AVG only	Postural control, functional balance, compliance, safety, feasibility	16	8–18	Unilateral lower limb amputation versus age-matched typically developing children	<ul style="list-style-type: none"> Improved postural control close to that of typically developing children
Fung et al. ⁵²	15 minutes	1. AVG plus usual rehab 2. Strengthening/balance training plus usual rehab	Length of rehabilitation, 2-minute walk test, knee range of motion, timed standing, balance confidence, lower extremity function, pain rating, patient satisfaction	50	68	Outpatients following knee replacement	<ul style="list-style-type: none"> No condition differences in any measure
Hsu et al. ⁵⁴	20 minutes of Wii, 2 ×/week, 8 weeks	Randomized, single-blind crossover trial with: 1. AVG 2. Standard exercise	Pain intensity, physical activity enjoyment, functional capacity	34	52–97	Long-term care patients with upper extremity dysfunction	<ul style="list-style-type: none"> All outcomes improved except pain intensity and two functional capacity tests. Group 1 rated as more enjoyable Range of effect sizes, including large improvement in functional capacity

(continued)

TABLE 2. (CONTINUED)

Topic, reference	Study design			Sample			Key findings ^a
	AVG exposure	Manipulation	Dependent variable	Size (n)	Mean Age (years)	Characteristics	
Miller et al. ⁵³	20 minutes, 2×/week, 6 weeks of Wii Fit, gait training	AVG only	VO ₂ efficiency, economy of movement, dynamic balance, balance confidence, gait	2	60	3–9 years post-ampulation	<ul style="list-style-type: none"> Reduced need for assistive device Improved aerobic capacity
Rowland and Rimmer ⁵⁵	3 10-min/game, 3 games	AVG only	Energy expenditure (indirect calorimetry), heart rate	3	19–21	Nonambulatory wheelchair users; upper extremity limitation from severe or moderate (cerebral palsy) or none (spina bifida)	<ul style="list-style-type: none"> Significant increase in energy expenditure for both games Severe/moderate limitation: Higher increase in energy expenditure in Wii play versus “Dance Dance Revolution” No limitation: Higher increase in “Dance Dance Revolution” versus Wii
Hospitalized or long-term care Brandt and Pamiagua ⁵⁶	≥1×/week, 4 weeks	AVG only	Self-report questionnaire (interview), mental function	11		Long-term care residents	<ul style="list-style-type: none"> AVG one of their favorite activities; considered easy or very easy to learn, very enjoyable, meaningful, and exciting to play
Chan et al. ⁵⁷	10 minutes, 8 sessions plus conventional rehab	1. AVG 2. Matched historical controls	Maximal heart rate reserve, perceived exertion scale, acceptability, functional independence	30	80.1	Rehab inpatients	<ul style="list-style-type: none"> Group 1 increased functional independence more than Group 2. No difference in perceived exertion or heart rate between Wii play and conventional rehab No improvement in functional capacity or quality of life
Rosipal et al. ⁵⁸	≥60 minutes/week, 3.5 weeks (mean)	1. AVG 2. Standard exercise	6-minute walk test, TUG test, quality of life	18	19–25	Hematopoietic stem cell transplant recipients	
Lupus Yuen et al. ⁵⁹	30 minutes, 3×/week, 10 weeks	AVG only	Fatigue severity, body weight, waist circumference, fatigue-related distress, anxiety level, pain, activity level, fitness	15		Systemic lupus, African American women	<ul style="list-style-type: none"> Decreased fatigue severity, body weight, waist circumference, anxiety level, total pain
Parkinson's disease dos Santos Mendes et al. ⁶²	8 sessions, follow-up for 60 days post-training	AVG only	Functional reach	27		Early-stage Parkinson's versus healthy elderly	<ul style="list-style-type: none"> Patients with Parkinson's showed deficits on 3 of 10 games Patients with Parkinson's improved functional reach.
Esculier et al. ⁶³	6-week training, assessed at 6 weeks; 6 and 12 weeks posttraining	AVG only	Physical ability, mobility, balance, balance confidence, 10-minute walk test	18		Moderate Parkinson's versus healthy elderly	<ul style="list-style-type: none"> Both groups improved in physical ability, mobility, and balance. Patients with Parkinson's also improved in the 10-minute walk test.
Mhatre et al. ⁶¹	30 minutes, 3×/week, 8 weeks	AVG only	Balance, gait, postural sway, balance confidence, depression	10	67	Parkinson's disease	<ul style="list-style-type: none"> Improved balance, gait, postural sway No change in balance confidence or depression
Pompeu et al. ⁶⁴	30 minutes, 2×/week, 7 weeks	1. AVG 2. Control group without feedback or cognitive stimulation	Activities of daily living	32		Parkinson's disease	<ul style="list-style-type: none"> Both groups improved activities of daily living. No difference between groups
Spinal injury Sayenko et al. ⁶⁶	60 minutes, 3×/week, 16 weeks	AVG only	Neuromuscular intensity, torque, ankle joint position, motivation	1	57	Spinal cord injury 4 years prior	<ul style="list-style-type: none"> Improved strength, endurance, and range of motion Enjoyed and would continue treatment

(continued)

TABLE 2. (CONTINUED)

Topic, reference	Study design			Sample			Key findings ^a
	AVG exposure	Manipulation	Dependent variable	Size (n)	Mean Age (years)	Characteristics	
Widman et al. ⁶⁵	>20 minutes, 3 ×/week, 16 weeks	AVG only	Peak VO ₂ , maximum work output, aerobic endurance, peak heart rate, rating of perceived exertion, user satisfaction	8	15.5 (girls), 17.5 (boys)	Spina bifida	<ul style="list-style-type: none"> • Six reached 50% VO₂. • Seven reached 50% heart rate. • Seven increased work capacity.
Stroke Acosta et al. ⁷⁷	3 minutes, one session	AVG only	Reaching distance, upper limb motor assessment	7	50–80	Chronic unilateral stroke, 2–15 years poststroke	<ul style="list-style-type: none"> • Improved reaching distance across subjects, support levels, and targets
Celinder and Peoples ⁶⁷	1–9 sessions, 3 weeks	AVG only	Qualitative interviews and field notes on patients' experiences	9		Stroke patients	<ul style="list-style-type: none"> • Reported variety, engagement, and obstacles and challenges
Combs et al. ⁷⁶	18 sessions, 6 weeks	AVG only	Upper extremity reaching, function, stroke impact	9		3 years poststroke	<ul style="list-style-type: none"> • Reaching improved • No improvement in function or stroke impact
Flynn et al. ⁷³	1 hour, 20 sessions, 4.5 weeks	AVG only	Gait, balance, motor function, motor activity, depression	1	76	A woman 17 months poststroke in home	<ul style="list-style-type: none"> • Improved gait • Trended toward improvements in balance, function, motor activity, depression
Hijmans et al. ⁷²	45–60 minutes, 8–10 sessions, 2.5 weeks	Within subjects: 1. AVG 2. Control	Upper limb functionality, motor performance	14	71	6 months poststroke	<ul style="list-style-type: none"> • Group 1 improved upper limb functionality.
Hurkmans et al. ⁶⁸	Two 15-minute sessions	AVG only	VO ₂	10		In rehab center	<ul style="list-style-type: none"> • Mean energy expenditure for both games met criteria for moderate physical activity.
Mouawad et al. ⁶⁹	1–3 hours, 5 ×/week, 2 weeks	AVG only	Functional ability, upper extremity range of motion	12	41–83	1–38 months poststroke versus healthy controls	<ul style="list-style-type: none"> • Stroke patients improved functional ability, upper extremity range of motion, and activity log. • No changes in balance, dexterity • No changes for healthy controls • High presence and enjoyment
Rand et al. ⁷⁵	3 minutes/game	AVG only	Presence, enjoyment, control, success, perceived exertion, suitability for older adults, feasibility for use by individuals with stroke	56	19–80	Stroke patients versus healthy young adults versus healthy older adults	<ul style="list-style-type: none"> • Mean energy expenditure for both games met criteria for moderate physical activity. • Stroke patients improved functional ability, upper extremity range of motion, and activity log. • No changes in balance, dexterity • No changes for healthy controls • High presence and enjoyment
Saposnik et al. ⁷⁰	60 minutes, 4 ×/week, 2 weeks	1. AVG 2. Recreational therapy	Time exposure, adverse events, motor function test, stroke impact	22	61.3	Within 6 months poststroke	<ul style="list-style-type: none"> • Group 1 significantly improved motor function.
Yavuzer et al. ⁷⁴	30 minutes, 5 ×/week, 4 weeks, follow-up at 3 months	1. AVG plus usual care 2. Control group (mental practice—watched games without playing; plus usual care)	Functional independence, hand and upper extremity function	20	61.1	Hemiparetic inpatients 12 months poststroke	<ul style="list-style-type: none"> • Group 1 improved functional independence more than Group 2. • No group differences for hand and upper extremity function
Yong Jojo et al. ⁷¹	30 minutes, 3 ×/week, 2 weeks	AVG plus conventional rehab	Upper limb motor function, upper limb pain	20	64.5	Within 3 months poststroke	<ul style="list-style-type: none"> • Sixteen completers reported AVG as enjoyable and comparable or better than conventional therapy. • Small but significant improvements in motor function

^aKey findings reported were statistically or clinically significant unless otherwise noted. AVG, active videogame; COP, center of pressure; TUG, Timed Up and Go; VO₂, oxygen uptake.

played included "Wii Sports" and "Wii Fit,"³⁵ a virtual reality "SpiderWorld" game,³⁶ and "Chicken Little" and "Need for Speed."³⁷ AVG play proved to be an entertaining and distracting experience during the pain of burn treatment, increasing patients' tolerance³⁶ and decreasing pain and anxiety in adolescents³⁵ and young adults.^{35,36}

Cancer. One study examined 5 days of 30 minutes of "Wii Sports" play among seven cancer inpatients 47–70 years of age and found improved mood state, relaxation, and decreased negative emotions.³⁸ The authors concluded that AVG play may be helpful to combat cancer-related fatigue in hospital patients who otherwise have numerous barriers to exercise.

Cerebral palsy. Eleven studies assessed AVG play among individuals with cerebral palsy, all of whom were youth between 6 and 18 years of age. Studies assessed "Wii Sports,"^{39–42} "Wii Fit,"^{43,44} "Ultra Glove,"^{45,46} "Eye-Toy,"⁴⁷ and "Dance Dance Revolution."⁴¹ Seven of the studies observed increased fine and gross motor function,^{40,41,45–49} including during daily activities.⁴⁸ Two studies observed that while playing "Wii Sports," children attained a moderate physical activity level.^{41,42} AVGs were found to be a low-cost home-based or school-based solution for rehabilitation (specifically "Ultra Glove 3," "Wii Sports," and "Dance Dance Revolution").^{39,45,46} Children reported a high level of enjoyment playing a variety of AVGs (including "Wii Sports," "Wii Fit," "Dance Dance Revolution," and "Ultra Glove").^{41,43,46} In a 5-week AVG intervention study involving 35 gaming sessions per child, parents had a positive perception about Wii Fit for rehabilitation among children with cerebral palsy.⁴⁴

Down's syndrome. One case study examined Nintendo "Wii Sports" play in a 12-year-old with Down's syndrome.⁵⁰ The child was deemed to have the necessary attention and cognitive skills for intervention, which limits the generalizability of the study findings. Observed improvements in upper limb coordination, stability, and cognition may not be clinically significant. High compliance (85 percent) was achieved through free game choice, and the child's family was encouraged to participate to maintain the child's interest and enthusiasm.

Extremity limitations and amputations. Five studies examined AVG play among people with extremity dysfunction or amputations, using the "Wii Fit,"^{51–53} "Wii Sports,"^{54,55} and "Dance Dance Revolution" adapted for upper extremity play.⁵⁵ A case study of two older adult amputees found improved energy efficiency and reduced need for an assistive device,⁵³ and a case study of three young adults who used wheelchairs with a range of upper extremity limitations (none in a case of spina bifida and moderate to severe in cases of cerebral palsy) found a significant increase in energy expenditure.⁵⁵ Children and adolescents with unilateral lower limb amputation improved postural control compared with that of the age-matched typically developing control group.⁵¹ Using "Wii Fit" plus regular rehabilitation was as good as traditional rehabilitation for patients undergoing knee replacement in terms of length of rehabilitation, walk test, knee range of motion, balance confidence, lower ex-

trinity function, pain rating, and patient satisfaction.⁵² A study comparing "Wii Bowling" with standard exercise found that functional capacity, but not pain intensity, improved among long-term care patients with upper extremity dysfunction.⁵⁴ The long-term care patients in this study reported that Wii play was more enjoyable than the standard exercise.

Hospitalized care (unspecified cause). Three studies examined AVG play among hospitalized inpatients or long-term care residents, using "Wii Sports,"⁵⁶ "Wii Fit,"⁵⁷ and "Dance Dance Revolution."⁵⁸ AVG play was particularly effective in this setting by providing patients an opportunity to overcome boredom, to become physically and mentally active, and to be competitive (demonstrated in a study of long-term care patients using "Wii Sports").⁵⁶ High compliance and satisfaction were reported after eight 10-minute sessions of "Wii Fit" play among 30 elderly patients.⁵⁷ In contrast, a 3.5-week study among younger adults indicated lost interest in Wii and "Dance Dance Revolution" play over time and preference for walking with other patients over isolated solitary gameplay.⁵⁸

Lupus. One study examined 15 African American women with systemic lupus who played "Wii Fit" over a 10-week period and produced promising findings of alleviated fatigue and reduction of body weight, anxiety, and pain intensity.⁵⁹ Follow-up interviews ascertained the motivators of AVG play to be enjoyment, promised health benefits, a sense of accomplishment, convenience of being in the home, and the ability to customize the gameplay experience.⁶⁰

Parkinson's disease. Four studies assessed multiple sessions of "Wii Fit" play among individuals diagnosed with Parkinson's disease. One 8-week intervention with 10 patients that did not include a control group observed improved balance, gait, and postural sway, although there were no effects on mood, depression symptoms, or balance confidence.⁶¹ Because there was no control group, it is not clear if AVG play attenuated the decline in these psychosocial outcomes. Two studies compared AVG play among individuals with Parkinson's disease versus healthy elderly individuals.^{62,63} Both those with Parkinson's disease and the healthy elderly participants improved in physical ability, mobility, and balance. An RCT compared 7 weeks of "Wii Fit" play versus a control group without feedback or cognitive stimulation and found that both groups improved in activities of daily living.⁶⁴ In this case, the "Wii Fit" did not offer advantages for motor or cognitive training, but because both groups improved similarly, the more enjoyable activity that sustains attention and motivation to play may be preferred.

Spinal injury. Two studies examined AVG play among individuals with spinal cord injuries or impairments, both involving 16-week interventions either on the GameCycle⁶⁵ or on a custom-made game.⁶⁶ The GameCycle study of adolescents with spina bifida observed that the majority reached the target energy expenditure, with high enjoyment.⁶⁵ The second study was a case study in which a 57-year-old man improved strength and endurance from 180 minutes/week of gameplay and reported that the adjustments made to suit his needs motivated him to continue playing and

improving.⁶⁶ AVG play was successful in motivating adherence to training in people with spinal injuries or spina bifida, although the literature is limited to two studies.

Stroke. Eleven studies assessed AVG play among patients recovering from stroke, from 1 month to 15 years poststroke, using “Wii Sports,”^{67–71} a CyWee Z remote similar to the Wii remote,⁷² the “EyeToy,”^{73–75} “Hand Dance Pro,”⁷⁶ and a custom-made air hockey game.⁷⁷ Short bouts of “Wii Sports Tennis” and “Wii Sports Boxing” met levels of moderate-intensity activity among stroke patients.⁶⁸ It is interesting that in a comparison of 2 weeks of “Wii Sports” play among patients recovering from stroke versus healthy young and healthy old people, only the patients recovering from stroke improved on functional ability and upper extremity range of motion, and they also reported higher daily activity and improved activities of daily living.⁶⁹

Participants reported that AVGs were enjoyable, safe, easy to operate, and immersive, particularly when games were sensitive to varied physical limitations due to the stroke recovery (specifically “Wii Sports” and “EyeToy”).^{70,75} Many patients favored AVG play (“Wii Sports” and “EyeToy”) to the highly repetitive therapy in usual care.^{71,75} In fact, one study examining “Wii Sports” and “Wii Fit” reported AVGs as ubiquitous in rehabilitation practice.⁴⁹ Patients undergoing a 2-week “Wii Sports” intervention reported finding AVG play as very enjoyable and as likely to continue gameplay and recommend to other patients.⁷¹ AVG interventions also demonstrated transfer effects that improved activities of daily living. For instance, after a brief 3-minute AVG intervention using a customized air hockey table game, patients’ reaching distance improved even beyond that needed for the gameplay.⁷⁷

Discussion

Overall, the vast majority of studies demonstrated promising results for improved health outcomes related to therapy, including significantly greater or comparable effects of AVG play versus usual care. Games that focused on specific skills or deficits proved particularly useful in helping patients achieve rehabilitation goals.^{28,31,45,46,63,74} Findings were somewhat equivocal for balance, with several studies indicating significant improvement in balance following AVG play and others indicating no improvement. AVG play lessened the burden of traditional therapy by increasing tolerance for burn wound treatment, improving the mood state for patients undergoing cancer treatment, battling boredom among inpatients, and alleviating fatigue and anxiety among women with lupus. AVG play produced additional physiological benefits for a variety of patients undergoing rehabilitation or therapy, by providing moderate-intensity activity for children with cerebral palsy, improving coordination for a child with Down’s syndrome (although improvements may not have reached clinically significant levels), improving postural control and energy efficiency in individuals with extremity limitations and amputations, improving balance and gait among people with Parkinson’s disease, and reaching target energy expenditure among individuals with spinal injuries or impairments.

It is important that AVG play was acceptable and enjoyed by nearly all populations included in this review, including elderly

populations with little or no prior exposure to videogame play and pediatric populations with serious physical limitations. No serious adverse events were reported in the studies reviewed. The entertaining and distracting nature of AVG play may be just as useful to completing therapy and restoring positive mood as the actual physical improvements attained.

Study designs varied in rigor, with 38 percent using a between-subjects design often comparing AVG play with a control group (usual care) and an additional 6 percent using a within-subjects crossover design. However, this leaves 56 percent of studies that tested AVG play only without a comparator group, including 12 case studies. Perhaps because of limited access to patients undergoing therapy or limited time to intervene following an illness or accident, investigators chose to only examine AVG play. However, having outcome data for only the treatment condition limits the ability to assess efficacy, so more RCTs are needed.

The majority of studies examining therapeutic uses of AVGs focused on older adults, primarily driven by the high volume of studies assessing balance. Only 22 percent of studies examined youth, indicating a need for further research in this age range. Finally, the studies predominantly used the Nintendo Wii console (69 percent of the studies reviewed), most likely because this console had earlier commercial success compared with the Sony PlayStation or Xbox Kinect consoles. Five studies tested custom-designed games for the specific population of interest, indicating the potential capability to tailor AVGs based on the players’ unique abilities and therapy needs. For instance, games designed for children with cerebral palsy were adapted to allow children with limited hand functions and in wheelchairs to engage in AVG play.⁶⁰ Game features of commercially available AVGs may limit the ability of individuals with disabilities to play the game.^{47,78}

Although the majority of studies showed promising results for the use of AVGs for therapeutic purposes in rehabilitation and illness management, the studies were predominantly pilot trials with relatively few RCTs. Much of the AVG technology is still relatively new; therefore, many studies were small pilot or feasibility studies and lacked the sample size needed for an adequately powered efficacy trial. Therefore, the chief limitations of the studies reviewed were small sample size and a lack of control group or inappropriate comparison group, both of which lessened the power to detect significance differences. The settings were typically laboratory-based, which limited understanding the real-world effectiveness of AVG interventions, although some studies were conducted in clinical settings or at home.

Several trials tested multiweek or multimonth interventions among populations at high risk for inactivity and health problems, although few included follow-up assessments to examine effects of AVG play after the intervention ended. Although the majority of the reviewed studies showed significant or comparable effects of AVG play versus usual care or a control group, publication bias likely biased results, and it is unclear how many trials have not observed changes from AVG play.

Limitations of the review

This systematic review was limited to therapeutic populations undergoing interventions that involved AVGs. However,

the review was broad in scope and included a range of conditions and outcome measures. Because of the diversity of populations, effects, and outcomes, a meta-analysis to produce mean effect sizes was not possible, and it was also difficult to summarize overall significant findings. However, the aim of this systematic review was to survey the variety of therapeutic uses of AVG play; therefore limiting the review was not appropriate. A second limitation is that relevant studies may have been unintentionally excluded because of the range of search terms and the specific databases selected.

Implications for clinicians

One overarching suggestion for clinicians is that AVGs may need to be adapted to the needs of the gameplayer, providing appropriate challenges as the player improves.²⁹ With the appropriate technical expertise, AVGs can be modified or adapted depending on the illness or injury (e.g., for upper extremity use)⁵⁵ and can promote rehabilitation for these populations.^{51–53} One study of children with cerebral palsy provided an appendix detailing the therapeutic goal, rationale, and feedback for each activity mode of the AVG studied,³⁹ which may be helpful for clinicians.

A key limitation of current commercially available AVGs is a lack of performance feedback that can translate to a clinical rating of improvement or deterioration, as the game performance scores are typically deemed insufficient.^{49,75} The role of the supervisor or trainer to provide personal feedback proved important, particularly in translating laboratory-based interventions to home-based programs.⁵¹

Home-based balance programs that incorporate AVG may be effective in improving functional abilities among individuals with disabilities,⁶³ particularly when tailored toward the interests and motivations of the patient population.⁶² Because AVGs can be played in the home, AVGs may remove obstacles to traditional exercise training, including cost, transportation, time restraints, and attire that are associated with other activity options.¹⁹

Clinicians should bear in mind that although the studies reported here show promise for improved physical outcomes for therapeutic purposes, these populations were often self-selected and may be biased toward patients who already have AVG experience or are motivated to use AVGs or alternative treatment options. For example, in a study of patients in a rehabilitation center, three were unable to play because of disabilities.⁶⁸ In a study of AVG play among individuals recovering from stroke, although the AVG play was feasible, patients reported fatigue in upper extremities and also reported frustration during gameplay.⁷⁵ Nonetheless, AVG enjoyment ranked high among patients,^{41,46} with many patients reporting preferring the AVG therapy over traditional therapy.⁴³ Compliance and attendance were also high particularly among pediatric patients, including 85 percent compliance among a study of a child with Down's syndrome⁵⁰ and nearly all patients having 100 percent attendance among children with cerebral palsy.⁴⁰ In fact, a study of children with balance problems due to lower limb amputation indicated that children exceeded the minimum prescribed AVG play time during the first 3 weeks of the intervention.⁵¹ Healthy older adults also appear to be able to easily operate AVGs.⁷⁵

There are also potential limitations and challenges to AVG play, including fear of falling, lack of interest, and help

needed for set up, instructions, and gameplay.⁵⁶ Regardless, AVG play can be a safe opportunity for hospitalized patients to obtain regular physical activity,⁵⁸ and patients who were hospitalized report they would continue to play the AVG at home.⁵⁷

Conclusions

In conclusion, AVG play appears promising as a tool for physical health improvement among a variety of rehabilitation and illness populations. Although the findings from the studies are mostly positive for therapeutic and health benefits, more clinical trials are needed in order to assess AVGs as effective for therapeutic purposes. It will be important going forward to determine how best to incorporate AVG play into traditional rehabilitation programs and to determine the ideal prescription for the duration and frequency of gameplay for each patient. Researchers and clinicians should continue to harness the potential of AVGs to motivate physical activity in an entertaining manner among populations who are most in need of fun, sustainable options for activity and rehabilitation.

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References

1. Barnett A, Cerin E, Baranowski T. Active video games for youth: A systematic review. *J Phys Act Health* 2011; 8:724–737.
2. Biddiss E, Irwin J. Active video games to promote physical activity in children and youth: A systematic review. *Arch Pediatr Adolesc Med* 2010; 164:664–672.
3. Peng W, Lin J-H, Crouse J. Is playing exergames really exercising? A meta-analysis of energy expenditure in active video games. *Cyberpsychol Behav Soc Netw* 2011; 14:681–688.
4. LeBlanc AG, Chaput JP, McFarlane A, et al. Active video games and health indicators in children and youth: A systematic review. *PLoS One* 2013; 8:e65351.
5. Peng W, Crouse JC, Lin J-H. Using active video games for physical activity promotion. A systematic review of the current state of research. *Health Educ Behav* 2013; 40:171–192.
6. Primack BA, Carroll MV, McNamara M, et al. Role of video games in improving health-related outcomes: A systematic review. *Am J Prev Med* 2012; 42:630–638.
7. Van Diest M, Lamothe CJ, Stegenga J, et al. Exergaming for balance training of elderly: State of the art and future developments. *J Neuroeng Rehabil* 2013; 10:101.
8. Laver K, George S, Thomas S, et al. Virtual reality for stroke rehabilitation. *Stroke* 2012; 43:e20–e21.
9. Taylor MJ, McCormick D, Shawis T, et al. Activity-promoting gaming systems in exercise and rehabilitation. *J Rehabil Res Dev* 2011; 48:1171–1186.
10. Staiano AE, Calvert SL. Exergames for physical education courses: Physical, social, and cognitive benefits. *Child Dev Perspect* 2011; 5:93–98.

11. Agmon M, Perry CK, Phelan E, et al. A pilot study of Wii Fit exergames to improve balance in older adults. *J Geriatr Phys Ther* 2011; 34:161–167.
12. Bateni H. Changes in balance in older adults based on use of physical therapy vs the Wii Fit gaming system: A preliminary study. *Physiotherapy* 2012; 98:211–216.
13. Daniel K. Wii-hab for pre-frail older adults. *Rehabil Nurs* 2012; 37:195–201.
14. Franco JR, Jacobs K, Inzerillo C, Kluzik J. The effect of the Nintendo Wii Fit and exercise in improving balance and quality of life in community dwelling elders. *Technol Health Care* 2012; 20:95–115.
15. Griffin M, McCormick D, Taylor MJ, et al. Using the Nintendo Wii as an intervention in a falls prevention group. *J Am Geriatr Soc* 2012; 60:385–387.
16. Laver K, Ratcliffe J, George S, et al. Is the Nintendo Wii Fit really acceptable to older people? A discrete choice experiment. *BMC Geriatr* 2011; 11:64.
17. Meldrum D, Glennon A, Herdman S, et al. Virtual reality rehabilitation of balance: Assessment of the usability of the Nintendo Wii® Fit Plus. *Disabil Rehabil Assist Technol* 2012; 7:205–210.
18. Michalski A, Glazebrook CM, Martin AJ, et al. Assessment of the postural control strategies used to play two Wii Fit videogames. *Gait Posture* 2012; 36:449–453.
19. Pluchino A, Lee SY, Asfour S, et al. Pilot study comparing changes in postural control after training using a video game balance board program and 2 standard activity-based balance intervention programs. *Arch Phys Med Rehabil* 2012; 93:1138–1146.
20. Rendon AA, Lohman EB, Thorpe D, et al. The effect of virtual reality gaming on dynamic balance in older adults. *Age Ageing* 2012; 41:549–552.
21. Taylor MJ, Shawis T, Impson R, et al. Nintendo Wii as a training tool in falls prevention rehabilitation: Case studies. *J Am Geriatr Soc* 2012; 60:1781–1783.
22. Toulotte C, Tousel C, Olivier N. Wii Fit® training vs. Adapted Physical Activities: Which one is the most appropriate to improve the balance of independent senior subjects? A randomized controlled study. *Clin Rehabil* 2012; 26:827–835.
23. Gil-Gómez J-A, Lloréns R, Alcañiz M, Colomer C. Effectiveness of a Wii balance board-based system (eBaViR) for balance rehabilitation: A pilot randomized clinical trial in patients with acquired brain injury. *J Neuroeng Rehabil* 2011; 8:30.
24. McGough R, Paterson K, Bradshaw EJ, et al. Improving lower limb weight distribution asymmetry during the squat using Nintendo Wii Balance Boards and real-time feedback. *J Strength Cond Res* 2012; 26:47–52.
25. Lamothe CJ, Alingh R, Caljouw SR. Exergaming for elderly: Effects of different types of game feedback on performance of a balance task. *Stud Health Technol Inform* 2012; 181:103–107.
26. Lamothe CJ, Caljouw SR, Postema K. Active video gaming to improve balance in the elderly. *Stud Health Technol Inform* 2011; 167:159–164.
27. Betker AL, Szturm T, Moussavi ZK, Nett C. Video game-based exercises for balance rehabilitation: A single-subject design. *Arch Phys Med Rehabil* 2006; 87:1141–1149.
28. Chen PY, Wei SH, Hsieh WL, et al. Lower limb power rehabilitation (LLPR) using interactive video game for improvement of balance function in older people. *Arch Gerontol Geriatr* 2012; 55:677–682.
29. Szturm T, Betker AL, Moussavi Z, et al. Effects of an interactive computer game exercise regimen on balance impairment in frail community-dwelling older adults: A randomized controlled trial. *Phys Ther* 2011; 91:1449–1462.
30. Clark R, Kraemer T. Clinical use of Nintendo Wii bowling simulation to decrease fall risk in an elderly resident of a nursing home: A case report. *J Geriatr Phys Ther* 2009; 32:174–180.
31. Kim J, Nam KW, Jang IG, et al. Nintendo Wii remote controllers for head posture measurement: Accuracy, validity, and reliability of the infrared optical head tracker. *Invest Ophthalmol Vis Sci* 2012; 53:1388–1396.
32. Pichierri G, Coppe A, Lorenzetti S, et al. The effect of a cognitive-motor intervention on voluntary step execution under single and dual task conditions in older adults: A randomized controlled pilot study. *Clin Interv Aging* 2012; 7:175–184.
33. Schoene D, Lord SR, Verhoef P, Smith ST. A novel video game-based device for measuring stepping performance and fall risk in older people. *Arch Phys Med Rehabil* 2011; 92:947–953.
34. Smith ST, Sherrington C, Studenski S, et al. A novel Dance Dance Revolution (DDR) system for in-home training of stepping ability: Basic parameters of system use by older adults. *Br J Sports Med* 2011; 45:441–445.
35. Yohannan SK, Tufaro PA, Hunter H, et al. The utilization of Nintendo® Wii during burn rehabilitation: A pilot study. *J Burn Care Res* 2012; 33:36–45.
36. Hoffman HG, Doctor JN, Patterson DR, et al. Virtual reality as an adjunctive pain control during burn wound care in adolescent patients. *Pain* 2000; 85:305–309.
37. Kipping B, Rodger S, Miller K, Kimble RM. Virtual reality for acute pain reduction in adolescents undergoing burn wound care: A prospective randomized controlled trial. *Burns* 2012; 38:650–657.
38. Jahn P, Lakowa N, Landenberger M, et al. InterACTIV: An exploratory study of the use of a game console to promote physical activation of hospitalized adult patients with cancer. *Oncol Nurs Forum* 2012; 39:E84–E90.
39. Deutsch JE, Borbely M, Filler J, et al. Use of a low-cost, commercially available gaming console (Wii) for rehabilitation of an adolescent with cerebral palsy. *Phys Ther* 2008; 88:1196–1207.
40. Gordon C, Roopchand-Martin S, Gregg A. Potential of the Nintendo Wii as a rehabilitation tool for children with cerebral palsy in a developing country: A pilot study. *Physiotherapy* 2012; 98:238–242.
41. Howcroft J, Klejman S, Fehlings D, et al. Active video game play in children with cerebral palsy: Potential for physical activity promotion and rehabilitation therapies. *Arch Phys Med Rehabil* 2012; 93:1448–1456.
42. Hurkmans HL, van den Berg-Emons RJ, Stam HJ. Energy expenditure in adults with cerebral palsy playing Wii Sports. *Arch Phys Med Rehabil* 2010; 91:1577–1581.
43. Jelsma J, Pronk M, Ferguson G, Jelsma-Smit D. The effect of the Nintendo Wii Fit on balance control and gross motor function of children with spastic hemiplegic cerebral palsy. *Dev Neurorehabil* 2013; 16:27–37.
44. Ramstrand N, Lyngegård F. Can balance in children with cerebral palsy improve through use of an activity promoting computer game? *Technol Health Care* 2012; 20:501–510.
45. Golomb MR, Warden SJ, Fess E, et al. Maintained hand function and forearm bone health 14 months after an in-home

- virtual-reality videogame hand telerehabilitation intervention in an adolescent with hemiplegic cerebral palsy. *J Child Neurol* 2011; 26:389–393.
46. Huber M, Rabin B, Docan C, et al. Feasibility of modified remotely monitored in-home gaming technology for improving hand function in adolescents with cerebral palsy. *IEEE Trans Inf Technol Biomed* 2010; 14:526–534.
 47. Jannink MJ, van der Wilden GJ, Navis DW, et al. A low-cost video game applied for training of upper extremity function in children with cerebral palsy: A pilot study. *Cyberpsychol Behav* 2008; 11:27–32.
 48. Winkels DG, Kottink AI, Temmink RA, et al. Wii-habilitation of upper extremity function in children with cerebral palsy. An explorative study. *Dev Neurorehabil* 2013; 16:44–51.
 49. Deutsch JE, Brettler A, Smith C, et al. Nintendo Wii Sports and Wii Fit game analysis, validation, and application to stroke rehabilitation. *Top Stroke Rehabil* 2011; 18:701–719.
 50. Berg P, Becker T, Martian A, et al. Motor control outcomes following Nintendo Wii use by a child with Down syndrome. *Pediatr Phys Ther* 2012; 24:78–84.
 51. Andrysek J, Klejman S, Steinnagel B, et al. Preliminary evaluation of a commercially available videogame system as an adjunct therapeutic intervention for improving balance among children and adolescents with lower limb amputations. *Arch Phys Med Rehabil* 2012; 93:358–366.
 52. Fung V, Ho A, Shaffer J, et al. Use of Nintendo Wii Fit in the rehabilitation of outpatients following total knee replacement: A preliminary randomised controlled trial. *Physiotherapy* 2012; 98:183–188.
 53. Miller CA, Hayes DM, Dye K, et al. Using the Nintendo Wii Fit and body weight support to improve aerobic capacity, balance, gait ability, and fear of falling: Two case reports. *J Geriatr Phys Ther* 2012; 35:95–104.
 54. Hsu JK, Thibodeau R, Wong SJ, et al. A “Wii” bit of fun: The effect of adding Nintendo Wii® Bowling to a standard exercise regimen for residents of long-term care with upper extremity dysfunction. *Physiother Theory Pract* 2011; 27:185–193.
 55. Rowland JL, Rimmer JH. Feasibility of using active video gaming as a means for increasing energy expenditure in three nonambulatory young adults with disabilities. *PM R* 2012; 4:569–573.
 56. Brandt K, Paniagua MA. The use of Nintendo Wii with long-term care residents. *J Am Geriatr Soc* 2011; 59:2393–2395.
 57. Chan TC, Chan F, Shea YF, et al. Interactive virtual reality Wii in geriatric day hospital: A study to assess its feasibility, acceptability and efficacy. *Geriatr Gerontol Int* 2012; 12:714–721.
 58. Rosipal NC, Mingle L, Smith J, Morris GS. Assessment of voluntary exercise behavior and active video gaming among adolescent and young adult patients during hematopoietic stem cell transplantation. *J Pediatr Oncol Nurs* 2013; 30:24–33.
 59. Yuen HK, Holthaus K, Kamen DL, et al. Using Wii Fit to reduce fatigue among African American women with systemic lupus erythematosus: A pilot study. *Lupus* 2011; 20:1293–1299.
 60. Yuen HK, Breland HL, Vogtle LK, et al. The process associated with motivation of a home-based Wii Fit exercise program among sedentary African American women with systemic lupus erythematosus. *Disabil Health J* 2013; 6:63–68.
 61. Mhatre PV, Vilares I, Stibb SM, et al. Wii Fit balance board playing improves balance and gait in Parkinson disease. *PM R* 2013; 5:769–777.
 62. dos Santos Mendes FA, Pompeu JE, Modenesi Lobo A, et al. Motor learning, retention and transfer after virtual-reality-based training in Parkinson’s disease—Effect of motor and cognitive demands of games: A longitudinal, controlled clinical study. *Physiotherapy* 2012; 98:217–223.
 63. Esculier JF, Vaudrin J, Beriault P, et al. Home-based balance training programme using Wii Fit with balance board for Parkinson’s disease: A pilot study. *J Rehabil Med* 2012; 44:144–150.
 64. Pompeu JE, Mendes FA, Silva KG, et al. Effect of Nintendo Wii-based motor and cognitive training on activities of daily living in patients with Parkinson’s disease: A randomised clinical trial. *Physiotherapy* 2012; 98:196–204.
 65. Widman LM, McDonald CM, Abresch RT. Effectiveness of an upper extremity exercise device integrated with computer gaming for aerobic training in adolescents with spinal cord dysfunction. *J Spinal Cord Med* 2006; 29:363–370.
 66. Sayenko DG, Masani K, Milosevic M, et al. Video game-based neuromuscular electrical stimulation system for calf muscle training: A case study. *Med Eng Phys* 2011; 33:249–255.
 67. Celinder D, Peoples H. Stroke patients’ experiences with Wii Sports® during inpatient rehabilitation. *Scand J Occup Ther* 2012; 19:457–463.
 68. Hurkmans HL, Ribbers GM, Streur-Kranenburg MF, et al. Energy expenditure in chronic stroke patients playing Wii Sports: A pilot study. *J Neuroeng Rehabil* 2011; 8:38.
 69. Mouawad MR, Doust CG, Max MD, McNulty PA. Wii-based movement therapy to promote improved upper extremity function post-stroke: A pilot study. *J Rehabil Med* 2011; 43:527–533.
 70. Saposnik G, Teasell R, Mamdani M, et al. Effectiveness of virtual reality using Wii gaming technology in stroke rehabilitation: A pilot randomized clinical trial and proof of principle. *Stroke* 2010; 41:1477–1484.
 71. Yong Joo L, Soon Yin T, Xu D, et al. A feasibility study using interactive commercial off-the-shelf computer gaming in upper limb rehabilitation in patients after stroke. *J Rehabil Med* 2010; 42:437–441.
 72. Hijmans JM, Hale LA, Satherley JA, et al. Bilateral upper-limb rehabilitation after stroke using a movement-based game controller. *J Rehabil Res Dev* 2011; 48:1005–1013.
 73. Flynn S, Palma P, Bender A. Feasibility of using the Sony PlayStation 2 gaming platform for an individual poststroke: A case report. *J Neurol Phys Ther* 2007; 31:180–189.
 74. Yavuzer G, Senel A, Atay MB, Stam HJ. “Playstation Eyetoy Games” improve upper extremity-related motor functioning in subacute stroke: A randomized controlled clinical trial. *Eur J Phys Rehabil Med* 2008; 44:237–244.
 75. Rand D, Kizony R, Weiss PT. The Sony PlayStation II EyeToy: Low-cost virtual reality for use in rehabilitation. *J Neurol Phys Ther* 2008; 32:155–163.
 76. Combs SA, Finley MA, Henss M, et al. Effects of a repetitive gaming intervention on upper extremity impairments and function in persons with chronic stroke: A preliminary study. *Disabil Rehabil* 2012; 34:1291–1298.

77. Acosta AM, Dewald HA, Dewald JP. Pilot study to test effectiveness of video game on reaching performance in stroke. *J Rehabil Res Dev* 2011; 48:431–444.
78. Sandlund M, Dock K, Hager CK, Waterworth EL. Motion interactive video games in home training for children with cerebral palsy: Parents' perceptions. *Disabil Rehabil* 2012; 34:925–933.

Address correspondence to:
Amanda E. Staiano, PhD
Pennington Biomedical Research Center
6400 Perkins Road
Baton Rouge, LA 70808
E-mail: amanda.staiano@pbrc.edu