The contribution of Nintendo *Wii Fit* series in the field of health: a systematic review and meta-analysis

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Background. *Wii Fit* was originally designed as a health and fitness interactive training experience for the general public. There are, however, many examples of *Wii Fit* being utilized in clinical settings. This article aims to identify the contribution of *Wii Fit* in the field of health promotion and rehabilitation by: 1) identifying the health-related domains for which the *Wii Fit* series has been tested, 2) clarifying the effect of *Wii Fit* in those identified health-related domains, and 3) quantifying this effect. **Method.** A systematic literature review was undertaken. The MEDLINE database and *Games for Health Journal* published content were explored using the search term “wii-fit”. Occurrences resulting from manual searches on Google and material suggested by experts in the field were also considered. Included articles were required to have measurements from *Wii Fit* activities for at least one relevant health indicator. The effect of *Wii Fit* interventions was assessed using meta-analyses for the following outcomes: activity-specific balance confidence score, Berg balance score, and time-up-and-go test. **Findings.** 115 articles highlighted that the *Wii Fit* has been tested in numerous healthy and pathological populations. Out of these, only a few intervention studies have focused on the prevention of chronic diseases. A large proportion of the studies focus on balance training (N=55). This systematic review highlights several potential benefits of *Wii Fit* interventions and these positive observations are supported by meta-analyses data (N=25). For example, the Berg balance score and the time-up-and-go test respond to a similar extend to *Wii Fit* interventions compared with traditional training. **Conclusions.** *Wii Fit* has the potential to be used as a rehabilitation tool in different clinical situations. However, the current literature includes relatively few randomized controlled trials in each population. Further research is therefore required.

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Abstract

Background. *Wii Fit* was originally designed as a health and fitness interactive training experience for the general public. There are, however, many examples of *Wii Fit* being utilized in clinical settings. This article aims to identify the contribution of *Wii Fit* in the field of health promotion and rehabilitation by: 1) identifying the health-related domains for which the *Wii Fit* series has been tested, 2) clarifying the effect of *Wii Fit* in those identified health-related domains, and 3) quantifying this effect. **Method.** A systematic literature review was undertaken. The MEDLINE database and *Games for Health Journal* published content were explored using the search term "wii-fit". Occurrences resulting from manual searches on Google and material suggested by experts in the field were also considered. Included articles were required to have measurements from *Wii Fit* activities for at least one relevant health indicator. The effect of *Wii Fit* interventions was assessed using meta-analyses for the following outcomes: activity-specific balance confidence score, Berg balance score, and time-up-and-go test. **Findings.** 115 articles highlighted that the *Wii Fit* has been tested in numerous healthy and pathological populations. Out of these, only a few intervention studies have focused on the prevention of chronic diseases. A large proportion of the studies focus on balance training (N=55). This systematic review highlights several potential benefits of *Wii Fit* interventions and these positive observations are supported by meta-analyses data (N=25). For example, the Berg balance score and the time-up-and-go test respond to a similar extend to *Wii Fit* interventions compared with traditional training. **Conclusions.** *Wii Fit* has the potential to be used as a rehabilitation tool in different clinical situations. However, the current literature includes relatively few randomized controlled trials in each population. Further research is therefore required.

Introduction

The past decade saw the emergence of home-based active video games (AVG), with the *Wii* (Nintendo Co. Ltd, Japan) being released in 2006, followed by the PlayStation *Move* (Sony Corp, Japan) and the *Kinect* (Microsoft, Washington, USA) in 2010. These systems take advantage of accelerometry and video camera-mediated motion detection technologies to track the player's movements and convert them into gaming commands. The *Wii* offers an original game modality with the *Wii Balance board* accessory, which can be used as a weighing scale or as a gamepad sensitive to body sway [1].

Among the home-based AVG, the well-known *Wii Fit* series (Nintendo, Japan) runs on the *Wii* console and consists of a combination of both serious and entertaining activities requiring body movement to fulfill gaming commands. The software displays various kinds of health metrics (body mass index, number of kilocalories burned over a given period) encouraging the players to improve their physical fitness. Whilst the *Wii Fit* was primarily designed to be used in homes by healthy individuals for health and fitness purposes, an overview of the literature indicates that physical therapists and physicians from different medical fields include the use of *Wii Fit* in their clinical practice. For instance, the *National Stroke Audit: Rehabilitation Services Report* recently indicated that 76% of Australian hospitals have a *Wii* console available to aid with the rehabilitation of stroke patients (the *National Stroke Foundation*, 2012 in [2]).

Many reviews have focused on AVG and their effects on health and describe mitigated outcomes [3, 4]. However, the distinction between *Wii Fit* and other AVG was not always clear, resulting in the inability to ascertain an objective picture of the contribution from the *Wii Fit*. The goals for this systematic review are as follows:

- Goal 1: Identifying the health-related domains (i.e. populations and clinical situations) in which the *Wii Fit* series has already been tested or used. A scientific database search with reasoned exclusion criteria was undertaken.
- Goal 2: Understanding the effect of *Wii Fit* in the identified populations (cf. Goal 1). A qualitative systematic review of studies including *Wii Fit* interventions was performed, with particular attention given to health and physical activity outcomes.
- Goal 3: When possible, quantification of the effect *Wii Fit* has on selected health-related domains was achieved by conducting meta-analyses.

Methods

Literature search

The selection process is summarized in a PRISMA flow diagram (Figure 1). Several strategies were adopted: 1) The MEDLINE database was used to conduct a systematic search using the following keywords: “wii fit”, “wii-fit” and “wiifit” (occurrences: N=122). 2) The same keywords were used to search for additional articles in the Mary Ann Liebert, Inc. *Games and Health Journal* (N=121). 3) Additional peer-reviewed articles were identified during manual searches *via* Google Search (Google Inc., California, USA) (N=1). 4) Articles suggested by authors active in the field of AVG (N=10) or identified in the reference section of eligible papers (N=46). 5) Only papers in English, French or Japanese were eligible for this review. The search and data extraction were performed by two independent researchers (Murakami H and Tripette J) and any discrepancies were resolved by a third contributor (Miyachi M).

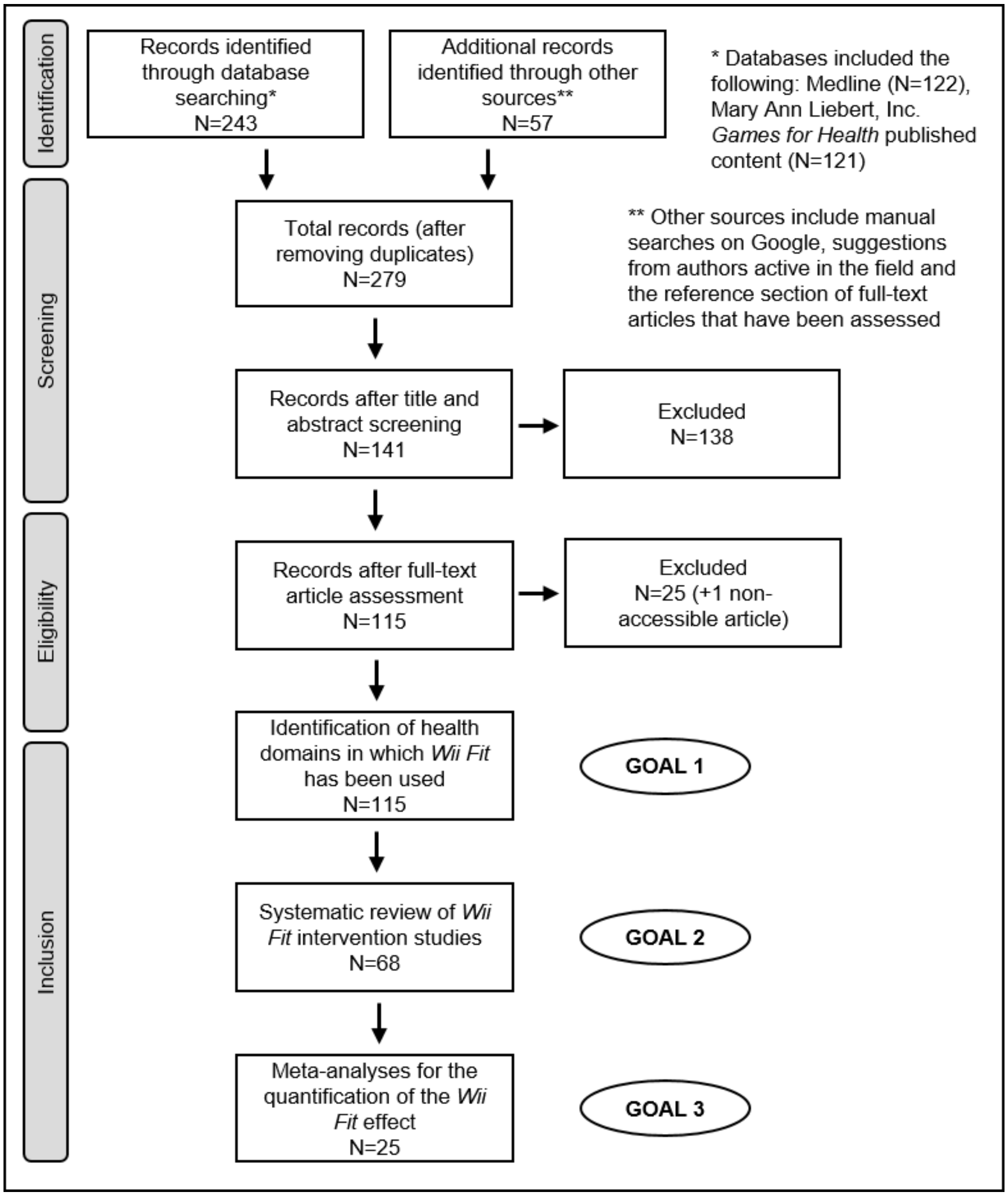

Figure 1. Flow diagram for the selection of studies included in the systematic review and the meta-analyses. Details about exclusion criteria and the selection process can be found in Table 1 and the Methods section.

The literature search was completed in June 2015. A total of 200 articles were identified. In order to meet the primary inclusion criteria, studies were required to: A) have a primary focus on any software of the *Wii Fit* series, and B) focus on a recognized health issue. 279 articles were screened after the identification and removal of 21 duplicates (Figure 1).

Goal 1: Identification of health domains

The exclusion criteria applied to identify medical domains in which the *Wii Fit* has already been tested or used are described in Table 1. The identification process involved screening titles and abstracts. The full texts were read when the abstracts provided insufficient details (Figure 1 & Table 1). The results are shown in Table 2.

Table 1. Summary of exclusion criteria

Literature review stage	Exclusion criteria
Screening	1) The study was not about any *Wii Fit* software. 2) The study does not focus on any health issue. 3) The article does not describe an original study. 4) The article was one of the following: letter, commentaries, symposium reports, interviews, conference abstracts, study protocols, reviews. 5) The article has not been peer-reviewed.
Goal 1	1) *Wii Fit* was not the main component of the intervention. 2) *Wii Fit* was used only to induce a stimulus without being the main object of the study. 3) The study focused on the *Wii Fit* avatar system rather than on its gaming content. 4) The article reports the development of software for the *Wii Balance Board.* 5) The study focuses on the *Wii Balance Board* capabilities not on the *Wii Fit* gaming content.
Goal 2	1) The article does not describe an intervention study. 2) The study does not include an objective assessment for at least one health or physical activity indicator, assessed quantitatively. 3) The protocol includes less than 5 subjects or does not report average or median values.
Goal 3	1) The study does not include numerical data for the activities-specific balance confidence test (ABC), Berg balance score (BBS), or the time-up-and-go test (TUG).[a] 2) The data reported for ABC, BBS and TUG were not mean ±SD, or does not allow the calculation of a mean values and the imputation of SD.[b] 3) The magnitude of changes in ABC, BBS or TUG, were expected to be important due to patients' initial condition and regardless of the chosen rehabilitation program (e.g. post-surgery orthopedic patients).[c] 4) The population sample's average age was less than 5-years old.[d]

[a] Examples of excluded studies for this selection criteria are [5, 6]. [b] Examples of excluded studies for this selection criteria are [7-10]. [c] An example of an excluded study for this selection criteria is [11]. [d] An example of an excluded study for this selection criteria is [12]. SD: standard deviation.

Goal 2: Systematic review, data extraction and synthesis

A qualitative systematic review was performed to understand the effect of *Wii Fit* in the previously identified health domains. This study followed the 2009 PRISMA guidelines for the conductance of systematic reviews and meta-analyses [13] (see, "S1 Checklist. PRISMA checklist"). The exclusion criteria which were applied at this stage are described in Table 1.

The content of each eligible article was extracted according to the following protocol: 1) Study identification (first author's name, year, and country), 2) methodological details (study design, sample size, population characteristics, etc.), 3) activities used, 4) description of each identified primary or secondary health and physical activity outcome, and 5) key findings (i.e. pre- and post-intervention as well as differences between *Wii Fit* and control groups) (Table 3 & 4).

Goal 3: Meta-analyses

The effects of *Wii Fit* were quantified for selected health-related domains. The most recurrent outcomes noted were the activities-specific balance confidence test (ABC), Berg balance score (BBS), and the time-up-and-go test (TUG). These three tests are frequently used to assess patients' balance abilities [14-16]. ABC is usually administered by a health care professional asking "How confident are you that you will not lose your balance or become unsteady when you…" for 16 different situations (e.g., "…walk around the house?", "…walk up or down stairs"…). For each item, the participant should answer by expressing confidence in percentage [14]. BBS is a scale able to measure balance in adults. The therapist asks participants to complete 14 different tasks (e.g., "sitting to standing", "turning to look behind them"…) and evaluates each of them using a 5-point score, ranging from 0 to 4 [15]. TUG is a simple measure of the time taken by a subject to stand up from a chair, walk a distance of 3 meters, turn, walk back to the chair, and sit down (time is expressed in seconds) [16]. Firstly, pre- and post-intervention meta-analyses were performed for each of these three outcomes. Secondly, *Wii Fit* vs. traditional therapy meta-analyses were completed, which only included results from randomized control (RCT) or two-arm trials. The exclusion criteria applied at this stage are described in Table 1. Only studies that used the 3-meter version of the TUG test were included. Groups submitted to a combination of *Wii Fit* activities and more traditional therapy exercises were excluded from the pre- and post-intervention meta-analysis (e.g., [17-19]). The pre- and post-intervention effect was calculated for the three selected outcomes. These meta-analyses used the mean difference between the reported pre-intervention and post-intervention values. For the *Wii Fit* vs. traditional therapy meta-analyses, the difference between the pre- and post- *Wii Fit* intervention changes and the pre- and post- traditional intervention changes were used as inputs in the meta-analysis. The variance imputation methods described by Follmann et al. were used to estimate the standard deviations of effect size when the authors did not report them [20]. Heterogeneity between studies was assessed using the homogeneity test. A fixed-effect model was used when the I^2 statistic, which is the index of heterogeneity, was under 75%. Sub-analyses were conducted in patients and healthy subjects. For ABC, because only two studies included a comparison between *Wii Fit* and traditional therapy [19, 21], only the pre- and post-intervention meta-analysis was performed. The risk of bias in each individual study included in the *Wii Fit* vs. traditional therapy meta-analysis was also assessed (Figure 2). Meta-regression analyses were performed to assess the impact of intervention duration and volume (i.e. session duration*number of session) on ABC, BBS and TUG. $p<0.05$ indicates statistical significance. Meta-analysis was performed using STATA 12.1 (StataCorp, Texas, USA).

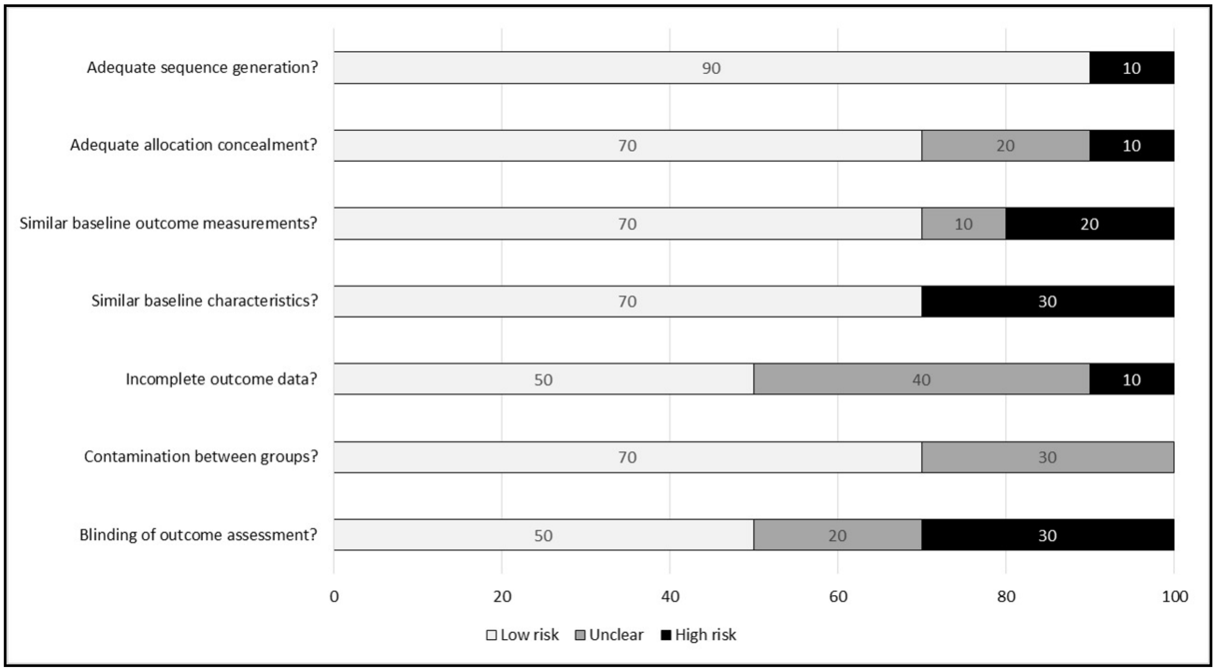

Figure 2. Assessment of risk of bias in individual studies included in the *Wii Fit* vs. traditional therapy meta-analyses. The absence of ABC, BBS or TUG excluded *de facto* the studies from the meta-analyses. Therefore the usually reported "reporting bias" was not included in this assessment. No "other bias" was identified.

Results

The literature search provided a total of 279 references of interest (Figure 1). Following the title and abstract screening process 138 studies were discarded, as they did not meet the selection criteria. 1 article was not accessible so was also discarded at this stage. An additional 25 references were removed after reading the full-text. Finally, 115 studies were included in the qualitative analysis, covering an approximately 6-year period from July 2009 to June 2015.

Goal 1: Health domains and populations of interest

The 115 selected studies focused on *Wii Fit* as a novel tool to improve physical function, fitness or health status. The content of the 115 articles was used to determine the different health domains in which *Wii Fit* may have potential benefits (Table 2).

Table 2. *Wii Fit* studies, health domains and populations of interest

Juvenile population
• Healthy children / adolescents[a] [2, 23[b], 24[b], 25, 26[b]]
• Overweight children / adolescents [24, 26][b]
• Children with developmental delay [12, 27-30]
• Children with migraine [31]
• Children with Raynaud disease [32]
• Children with cystic fibrosis [33, 34]
• Children with cerebral palsy [35-38]
• Adolescents with autism spectrum disorders [39]
Young adults & middle-age adults
• Healthy adults [a,c] [22, 23[b], 24[b], 40, 41-44, 45[b], 46[b], 47-58]
• Healthy women [59, 60, 61[b], 62, 63[d], 64]
• Overweight adults [24[b], 45[b], 46[b], 61[b], 65, 66]
• Depressed soldiers [67]
• Adults with drug dependency [68]
• Women with systemic lupus erythematosus [69, 70]
• Adults with vestibular disorders [21, 71[e],]
• Patients in orthopedic rehabilitation [11, 72-75]
• Amputees [76]
• COPD patients [77]
• Diabetic patients [78]
• Hemodialysis patients [79]
• Lower back pain patients [80]
• Adults with multiple sclerosis [81-86]
• Cancer patients [f] [87, 88]
• Stroke patients [f] [5, 17, 19, 89-92]
• Spinal cord injury patients [6]
Senior populations
• Healthy seniors [7, 8, 9[b], 93, 94[b] , 95-98, 99[b], 100-106]
• Senior with balance impairment [g] [8, 9[b], 10, 18, 99[b], 107-109, 94[b], 110, 111]
• Seniors with cognitive impairments [h] [112-120]
• Seniors with peripheral neuropathy [121]
• Other senior population [122]

[a] Not including overweight populations; [b] Some papers focused on various populations may appear in several fields; [c] Not including studies that focus on healthy adult women only; [d] The study included healthy subjects but targeted women with urinary incontinence; [e] Patients with « other neurological disorders » were included as well; [f] Includes both middle-age adults and seniors; [g] Includes subjects referred for rehabilitation, presenting a history of accidental falls, having fear of falling or described as frail or pre-frail; [h] Includes both Parkinson's and Alzheimer's patients. Intervention studies eligible for inclusion in the systematic review are described in further detail in Table 3 & 4.

Goal 2: Systematic review of Wii-Fit interventions

From the 115 selected *Wii Fit* articles, 68 were intervention studies and met the selection criteria for inclusion in the systematic qualitative review. Overall, these studies involved 2183 participants from both sexes (females: 1161, males: 844, not specified: 178), with a wide age range (49 ±6 months - 86 ±6 years [12, 100]), and various medical conditions. Primary and secondary outcomes, intervention content, as well as observation period vary from study to study. The intervention durations vary from 2 to 20 weeks [89, 99], frequencies from 1 to 7 sessions per week (respectively, [99, 110] and [64, 78]), and session time from 10 to 60 minutes (respectively, [8, 97] and [72, 81, 99]).

6 papers reported adverse effects: In young adults, light to moderate adverse effects (muscle soreness, pain, sprain, etc.) were observed [55]. Among seniors, hip strain, neck strain, lower back pain as well as one fall were reported [105, 108, 109]. In multiple sclerosis patients, knee pain and lower back pain were also reported [84]. Bower et al. (2014) observed a relatively high rate of falls in stroke patients (4 events over a group of 30 patients, [89]).

Table 3 describes the characteristics and main results from studies with a primary focus on the effects of *Wii Fit* interventions on physical activity level, physical fitness or patients' health status. Among 13 studies, 10 observed positive effects [8, 18, 64, 68, 79, 77-80, 87, 88, 110] and 3 presented more contrasted results [24, 60, 77]. Interestingly, 4 intervention studies were conducted in patients with chronic diseases. They all reported a significant improvement in health status and well-being (chronic obstructive pulmonary disease, type two diabetes mellitus, chronic kidney disease, and lower back pain) [77-80]. 2 reports described *Wii Fit* interventions as both feasible and effective methods for improving the overall physical fitness, mobility and independence of senior subjects [8, 18, 110].

Table 3. *Wii Fit* interventions for health status and well-being improvement [a]

Authors Year Country	Population characteristics	Study design	*Wii Fit* activities (or other video games)	Outcomes and measures	Key findings **& Data used for the meta-analyses**
Healthy population					
Nitz et al. 2010 Australia [60]	Women (N=10) *Age range:* 30-60 yrs *Mean age:* 47 ±10 yrs	Intervention *1 group* *Duration:* 10 wks (30 min, 2 sessions /wk) *Location:* Home (supposedly)	Not specified, possibly all the *Wii Fit's* activities	Physical fitness (6-min walk test, lower limb strength), body composition, balance and functional mobility (TUG, TUG_{cog}, step test, CTSIB, basic balance master test), well-being (home-made scale), adherence (attendance)	Improvement for some balance tests and lower limb strength. The overall attendance was 70%. *Adverse events:* No **<u>TUG (sec):</u>** ***Wii Fit group*** **Pre-intervention: 4.93 ±0.76** **Post-intervention: 5.00 ±0.73**
Owens et al. 2011 USA [24]	Eight Families (parents and children, *F/M*, *N*=13/8) *Age range:* 8-44 yrs	Intervention *1 group* (statistical analysis: children *vs.* adults) *Duration:* 13 wks (no further specifications: naturalistic approach) *Location:* Home	Not specified (subjects used the four categories of activities: *yoga, strength, aerobics, balance*)	PA (accelerometry), body composition, balance (SOT), physical fitness (VO_2max, upper limb strength, flexibility), adherence (playing time)	No significant change was noted in most of the physical fitness outcomes. Peak VO_2 increased in children only. Adherence declined over time. In realistic conditions *Wii Fit* may not provide sufficient stimulus for fitness improvement. *Adverse events:* No
Tripette et al. 2014 Japan [64]	Postpartum women (N=34) *Mean age:* 32 ±5 yrs	Intervention (RCT) *2 groups: Wii Fit vs.* passive control *Duration*: 5 wks (30 min, daily) *Location:* Home	All activities included in the *Wii Fit Plus* software	Body composition, physical fitness (flexibility and strength), energy intakes (questionnaire), adherence (playing time)	Women playing *Wii Fit* lost more weight than their passive control counterpart. They expended an average 4700 ±2900 kcal playing *Wii Fit* and decrease their energy intakes. *Adverse events:* lower back pain (N=1), ankle twist (N=1) and wrist tendinitis (N=1)
Chronic diseases					
Albores et al. 2013 USA	COPD patients (*F/M, N*=14/6) *Mean age:* 68 ±10 yrs	Intervention *1 group* *Duration:* 12 wks (30 min, daily)	*Aerobics:* Basic Run, Free Step; *training plus:* Bird's Eye Bull's-Eye, Obstacle	*Primary:* physical fitness (ESWT and other tests) *Secondary:* health	Home-based *Wii Fit* training improved physical fitness and overall health status but not dyspnea in COPD patients. *Adverse events:* No

[77]		*Location:* Home	Course	status (CRQ-SR, dyspnea assessment)	
Kempf & Martin 2013 Germany [78]	T2DM patients (*F/M, N*=119/101) *Age range:* 50-75 yrs *Mean age:* 61 ±8 yrs	Intervention (RCT) *2 groups: Wii Fit*-traditional care *vs.* traditional care-*Wii Fit* *Duration:* 12 wks (30 min/day) *Location:* Home	Not specified (supposedly, all the activities included in *Wii Fit Plus*)	*Primary:* glycemic variations (HbA1c) and various blood markers *Secondary:* body composition, blood pressure, PA (questionnaire), adherence (retention), health status (SF-12, PAID) and well-being & quality of life (WHO-5, CESD)	Subjects adhered to the *Wii Fit* intervention (retention rate: 80%). Playing *Wii Fit* on a daily basis significantly decreased HbA1c in T2DM patients (-0.3 ±1.1). Fasting glucose, weight, BMI, PA, as well as other well-being outcomes were also improved. *Adverse events:* No
Cho & Sohng 2014 Korea [79]	Hemodialysis patients (*F/M, N= 18/28*) *Mean age:* 59 ±8 yrs	Intervention (RCT) *2 groups:* Wii Fit vs. passive control *Duration:* 8 wks (30 min, 3 sessions/wk) *Location:* Hospital	*Yoga:* Chair, Half Moon, Standing Knee (supposedly); *strength:* Torso Twist, Triceps Extension (supposedly); *balance:* Balance Bubble, Tightrope Walk; *aerobics*: Basic Steps (supposedly), Hula Hoop; *training plus*: Big Top Juggling, Bird's-Eye Bulls-Eye, Rhythm Kung Fu, Rhythm Parade (+5 other activities that were not explicitly named)	Physical Fitness (back strength, handgrip, leg strength, sit-and-reach, single leg stance test), body composition (bioimpedancemetry), fatigue (analogue scale)	Significant improvements were noted for physical fitness, body composition and fatigue in the *Wii Fit* group but not the control group, suggesting that this software could be used for health promotion program in hemodialysis patients. *Adverse events:* No
Kim et al. 2014 Korea [80]	Middle-aged women with lower back pain (*N=30*) *Mean age:* 47 yrs	Intervention (RCT) *2 groups: Wii Fit vs.* traditional therapy *Duration:* 4 wks (30 min, 3 sessions/wk) *Location:* not specified	*Yoga:* Chair, Deep Breathing, Half Moon, Palm Tree, Sun Salutation (supposedly), Tree, Warrior	Pain (visual analogue scale, pressure algometry), disability (ODI, RDQ, FABQ)	Both interventions induced lower pain and self-perceived disability. *Wii Fit* induced significantly higher improvements for all outcomes except for deep tissue mechanical pain sensitivity (pressure algometry). *Adverse event*: No

Drug dependency problems					
Cutter et al. 2014 USA [68]	Opioid- or cocaine-dependent subjects (*F/M, N=17/12*) *Mean age:* 43 ±9 yrs	Intervention (RCT) *2 groups: Wii Fit vs.* sedentary video games *Duration:* 8 wks (20-25 min, 5 sessions/wk) *Location:* Drug rehabilitation center	For each session, subjects were invited to choose, two *aerobics* activities, 1 *yoga* activity*,* 1 *balance* activity and 1 *strength* activity.	Acceptability (attendance, 4-item questionnaire), physical activity (in-session energy expenditure, IPAQ-L), substance use (diary, urine toxicology screening), well-being (PSS, BLSS, LOT)	Both interventions showed high level of acceptability, decreased substance use and increased well-being. *Wii Fit* participants reported high level of MVPA at the end of the intervention period. *Adverse events:* No
Cancer patients (fatigue management)					
Hoffman et al. [b] 2013 USA [87]	Post-surgical non-small lung cancer patients (*F/M, N*=5/2) *Age range:* 53-73 yrs *Mean age:* 65 ±7 yrs	Intervention (phase 1, cf. phase 2 below) *1 group* *Duration:* 6 wks (5-30 min "walking with the Wii (see elsewhere) + 3-4 *Wii Fit* balance activities, 5 sessions/wk) *Location:* Home	*Aerobics:* "walking with the Wii" (might described an *aerobics* – Free Run - activity played by walking instead of running); *balance:* Ski Slalom, Soccer Heading; *Training Plus*: Driving Range; and "other activities"	Acceptability (questionnaire), fatigue (BFI), Fatigue management (PSEFSM), balance and functional mobility (ABC, self-efficacy for walking duration instrument, step-count) and adherence (playing time)	Patients adhered to the *Wii Fit* intervention, which was rated as acceptable. Perceived efficacy for balance and functional mobility increased, perceived fatigue decreased, and perceived self-efficacy for fatigue self-management increased (No statistics however). Light intensity home-based exertion delivered via a game console was effective for fatigue self-management in cancer patients. *Adverse events:* No
Hoffman et al. 2014 [b] USA [88]	Same as for phase 1 (cf. above)	Intervention (phase 2, cf. phase 1 above) *1 group* *Duration:* 10 wks (30 min "walking with the Wii (see elsewhere) + 3-4 *Wii Fit* balance activities, 5 sessions/wk) *Location:* Home <u>Note:</u> phase 1 and phase 2 together: 16-wk intervention	Same as for phase 1 (cf. above)	Same as for phase 1 (cf. above)	Positive outcomes noted at the end of phase 1 (cf. the above) were maintained or reinforced at the end of the phase 2. Light intensity home-based exertion delivered via a game console was effective for fatigue self-management in cancer patients (even for those undergoing an adjuvant therapy) for a period as long as 16 weeks at least. *Adverse events:* No **<u>ABC (no unit):</u>** ***Wii Fit group*** **Pre-intervention: 72.8 ±20.5** **Post-intervention: 88.9 ±24.8**
Systemic lupus erythematosus					

Yuen et al. 2011 USA [69]	African American women with systemic lupus erythematosus (*N*=15) *Age range:* 25-67 yrs *Mean age:* 47 ±14 yrs	Intervention *1 group* *Duration:* 10 wks (30min, 2 sessions/wk) *Location:* Home	*Yoga*, *strength* and *aerobics* activities	*Primary:* fatigue (FSS) *Secondary:* anxiety level, pain intensity, body composition, step-count, physical fitness, adherence	Fatigue, anxiety and pain were reduced. Body composition and physical fitness improved. Good adherence. *Adverse events:* No
Seniors					
Chan et al. 2012 China [110]	Elderly referred for rehabilitation (*F/M, N*=22/8, 13 of them having acquired neurological disorders) *Mean age:* 80 ±7 yrs	Intervention *1 group* (+ comparison with a historic pool of 60 patients) *Duration:* 5-9 wks (10 min, 1-2 sessions/wk, total of 8 *Wii Fit* sessions) *Location:* Geriatric center	*Aerobics:* 2P Run	*Primary:* feasibility (Borg scale, HR), adherence (playing time), acceptability (questionnaire) *Secondary:* functional ability (FIM)	Participants completed an average of 72 ±7 min of *Wii Fit* during their 5-9-wk rehabilitation period (instructions: about 80 min). No difference was noted in exertion rate between the *Wii Fit* activity and a traditional arm ergometer exercise. *Wii Fit* participants exhibited a higher improvement in functional abilities compared to historic controls and wanted to continue the game at home. *Adverse events:* No
Daniel USA 2012 [18]	Pre-frail elderly (*F/M, N*=14/9) *Mean age :* 77 ±5 yrs	Intervention (RCT) *3 groups :* passive control *vs.* seated exercise training *vs. Wii Fit* + weight vest *Duration:* 15 wks (45 min, 3 sessions/wks) *Location:* Laboratory	Not specified (supposedly, all activities included in *Wii Fit* and *Wii Sports*)	Physical fitness (SFT, CHAMPS) body composition, balance & functional mobility (ABC, LLFDI, 8-feet TUG), adherence (attendance)	Authors described an improvement in physical fitness and balance confidence in the *Wii Fit* group, but no statistical significance was indicated. Same attendance rate (86%) in both seated exercising and *Wii Fit* groups. *Adverse events:* No

[a] When balance outcomes were included concomitantly with other outcomes, and were not described as a primary outcome alone, the study was only included in Table 3. [b] Hoffman et al. (2013 & 2014) report results from two different phases of the same project [87, 88].

%: percentage; ABC: activities-specific balance confidence scale; BFI: brief fatigue inventory; BLSS: brief life satisfaction scale; BMI: body mass index; CESD: center for epidemiologic studies depression scale; CHAMPS: community healthy activities model program for seniors; COPD: chronic obstructive pulmonary disease; CRQ-SR: chronic respiratory questionnaire; CTSIB: clinical test of sensory interaction and balance ; EE: energy expenditure; ESWT: endurance shuttle walk test; FABQ: fear avoidance beliefs questionnaire; FIM: functional independence measure; FFS: Fatigue Severity Scale; HR: hear rate (beats/min); IMI: Intrinsic Motivation Inventory; LLFDI: late life function and disability index; IPAQ-L: physical activity questionnaire-long version; LOT: life orientation test; METs: metabolic equivalent; MVPA: moderate-to-vigorous physical activity; PSEFSM: perceived self-efficacy for fatigue self-management; RPP: rate pressure product; PAID: problem areas in diabetes scale; sec: second; SEES: subjective exercise experience scale; SFT: senior fitness test; PA: physical activity; PACES: physical activity and exercise questionnaire; ODI: Oswestry low-back pain disability index; PSS: perceived stress scale; RDQ: Roland Morris disability questionnaire; SF-12:

short form-12 health survey; SOT: sensory organization test; TD2M: type 2 diabetes mellitus; TUG: time up and go; VPA: vigorous physical activity; VO_2: oxygen consumption; VO_2max: maximal oxygen consumption; WHO-5: five-item WHO well-being index.

For the same test, unit may vary from one paper to another.

For each population, Table 4 summarizes study characteristics and the main results for protocols with a primary focus on the effect of *Wii Fit* intervention on balance activities and related physical functions. Overall, the qualitative review of these studies supports a positive effect of *Wii Fit* interventions on balance outcomes. Among the 55 studies, 50 observed a positive effect of *Wii Fit* on at least one parameter [5-7, 9-12, 17, 19, 21, 27-31, 36, 37, 42, 43, 52, 57, 72, 74, 75, 81, 82, 84, 86, 90, 92, 93, 95, 98-102, 105, 106, 108, 109, 111, 113-120]. There were numerous examples were balance–related parameters improved to a similar or even higher extent when using *Wii Fit* compared to traditional therapies [5, 11, 17-19, 21, 42, 43, 52, 72, 74, 75, 81, 96, 90, 95, 99, 105, 111, 116, 120]. Only 5 papers described contrasted results or expressed some reservations about the ability of the software to induce benefits in balance skills [8, 35, 58, 89, 97], with 3 of these studies being conducted in healthy populations [8, 58, 97].

213 **Table 4. *Wii Fit* interventions for functional balance training**

Authors Year Country	Population characteristics	Study design	*Wii Fit* activities (or other video games)	Outcomes and measures	Key findings **& Data used for the meta-analyses**
Healthy young adults or middle-aged adults					
Gioftsidou et al. 2013 Greece [42]	Healthy young adults (*F/M, N*=18/22) *Age range*: 20-22 yrs *Mean age:* 20 ±1 yrs	Intervention (RCT) *2 groups: Wii Fit vs.* BOSU ball-based therapy *Duration*: 8 wks (14 min, 2 sessions/wk) *Location:* Laboratory (supposedly)	*Balance:* Balance Bubble, Penguin Slide, Snowboard Slalom, Ski Slalom, Soccer Heading, Table Tilt; *Training plus*: Balance Bubble Plus, Skateboard Arena, Table Tilt Plus	Balance (single leg stance tests[a] and various indexes using *Biodex* system)	Balance improvements for both BOSU ball and *Wii Fit* intervention. Only one test (the balance board anterior-posterior single-limb stance test) showed greater improvement for the BOSU ball training. *Adverse events:* No
Melong & Keats 2013 Canada [43]	Healthy young adults (*F/M, N*=12/8) *Mean age:* 20 ±1 yrs	Intervention (RCT) *2 groups: Wii Fit vs.* BOSU ball-based therapy *Duration:* 4 wks (20 min, 3 sessions/wk) *Location:* Laboratory	*Balance:* Ski Jump, Ski Slalom, Soccer Heading, Table Tilt (+ a other activities played with the Wii balance board)	*Primary:* adherence (attendance and playing time) *Secondary:* enjoyment (PACES), balance (stabilometry)	Balance improvement were noted in both groups. While the *Wii Fit* group showed higher levels of enjoyment, this did not lead to a significantly higher attendance or playing time. This study may have been underpowered. *Adverse events:* No
Lee et al. 2014 Korea [52]	Healthy young adults (*N*=24) *Mean age:* 20 ±1 yrs	Intervention (RCT) *2 groups: Wii Fit* vs. indoor horseback riding exercise *Duration:* 6 wks (25 min, 3 sessions/wk) Location: not specified (« indoor »)	*Balance:* Balance Bubble, Ski Slalom, Table Tilt	Balance (dynamic tests using *Biodex* system: anteroposterior, mediolateral, and overall stability)	Both the *Wii Fit* and indoor horseback riding programs induce significant improvement in all three dynamic balance tests. *Adverse events:* No
Cone et al. 2015 USA [57]	Healthy young adults (*F/M, N*=16/24) *Age range:* 18-35 yrs *Mean age*: 23 ±3 yrs	Intervention (RCT) *2 groups: Wii Fit vs.* passive control *Duration:* 6 wks (30-45 min, 2-4 sessions/wk) *Location:* Laboratory (supposedly)	*Balance:* Balance Bubble, Penguin Slide, Snowboard Slalom, Ski Slalom, Soccer Heading, Table Tilt, Tightrope Walk	Balance (SOT, LOF)	Significantly higher improvements in both LOS and SOT scores were noted for the *Wii Fit* group. Because those tests respectively focus on dynamic stability and sensory weighting, the results suggest that individuals with vestibular system alterations or dynamic balance control impairments may benefit from *Wii Fit* training.

					Adverse events: No
Naumann et al. 2015 Germany [58]	Healthy young adults (*F/M, N*=29/8) *Age range:* 20-34 yrs *Mean age*: 23 ±3 yrs	Intervention (RCT) *3 groups: Wii Fit vs.* MFT Challenge Disc® *vs.* passive control *Duration:* 4 wks (30 min, 3 sessions/wk) + follow-up after 4 weeks *Location:* Laboratory (supposedly)	*Balance:* Balance Bubble, Ski Slalom, Snowboard Slalom, Table Tilt	Balance (game scores, single- or two-leg stance COP excursion)	The performance on trained games increased in both intervention groups. No changes were noted for the COP excursion tests. Similarly, the *Wii Fit* group did not show any increase in MFT Challenge Disc® scores, and *vice-versa*. These data suggest that the training effect of *Wii Fit* was highly specific and may not be transferred to real life balance-related tasks. *Adverse events*: No
Healthy seniors					
Williams et al. 2011 USA [93]	Elderly (*F/M, N*=18/4) *Age range:* 74-84 yrs *Mean age:* 84 ±5 yrs	Intervention *1 group* *Duration:* 4 wks (20 min, 1 session/wk) *Location:* Geriatric center-based	*Balance* and *aerobics* activities	Balance (BBS)	*Wii Fit* induced improvement in balance skills. The post-intervention BBS scores (49 ±5) were significantly higher than pre-intervention scores (39 ±6). *Adverse events:* No **<u>BBS (no unit):</u>** ***Wii Fit group*** **Pre-intervention: 39.41 ±6.28** **Post-intervention: 48.55 ±4.58**
Bateni 2012 USA [95]	Elderly (*F/M, N*=9/8) *Age range:* 53-91 yrs *Mean age:* 73 ±14 yrs	Intervention (RCT) *3 groups: Wii Fit vs. Wii Fit* + traditional physical therapy *vs.* traditional physical therapy alone *Duration:* 4 wks (15 min – estimation, 3 sessions/wk) *Location:* Rehabilitation center	*Balance:* Balance Bubble, Ski Jump, Ski Slalom; *training plus:* Table Tilt plus	Balance (BBS and *Wii Fit* Balance Bubble score)	Improvements in both BBS and Balance Bubble score in all 3 groups were observed. However, subjects who underwent traditional therapy exercises performed better at the BBS compared to subjects who only play *Wii Fit* alone. *Adverse events:* No
Franco et al. 2012 USA [97]	Elderly (*F/M, N*=25/7) *Mean age:* 78 ±6 yrs	Intervention (RCT) *3 groups: Wii Fit* + strength training *vs.* traditional balance training *vs.* passive control	*Balance:* Ski Jump, Ski Slalom, Soccer Heading, Table Tilt, Tightrope Walk	Balance and gait (BBS, Tinetti test), functional health and well-being (SF-36), enjoyment (home-made questionnaire)	*Wii Fit* did not induce any balance and gait improvements. Same outcomes were observed in the traditional training group. Subjects playing *Wii Fit* reported high level of enjoyment. *Adverse events:* No

		Duration: 3 wks (10-15 min, 2 sessions/wk) *Location:* Community dwelling		and adherence (playing time)	<u>**BBS (no unit):**</u> ***Wii Fit group*** **Pre- and post-intervention delta: 3.55 ±5.03** ***Traditional therapy group*** **Pre- and post-intervention delta: 3.45 ±2.50**
Orsega-Smith et al. 2012 USA [98]	Elderly (F/M, N=30/4) *Age range:* 55-86 yrs *Mean age:* 72 ±8 yrs	Intervention (No-RCT) 3 groups: playing *Wii Fit* for 4 wks vs. playing *Wii Fit* for 8 wks vs. passive controls *Duration:* 4 or 8 wks (30 min, 2 sessions/wk) *Location:* Community dwelling	*Yoga:* Deep Breathing, Half Moon, Palm Tree; *aerobics:* Hula Hoop; *balance:* Balance Bubble, Penguin Slide, Snowboard Slalom, Ski Jumping, Ski Slalom, Table Tilt	Balance (BBS), mobility (8-feet TUG), leg strength (STST), balance confidence (ABC, FES), autonomy (ADL)	Balance, and ability to complete activities of daily living were improved in the two *Wii Fit* groups. Leg strength increased in the 4-wk intervention group only, while balance confidence increased in the 8-wk intervention group only. No change was noted in the control group *Adverse events:* No <u>**ABC (no unit):**</u> ***Wii Fit group (A: 4-week)*** **Pre- and post-intervention delta: 3.20 ±13.88** ***Wii Fit group (B: 8-week)*** **Pre- and post-intervention delta: 6.07 ±7.04** <u>**BBS (no unit):**</u> ***Wii Fit group (A: 4-week)*** **Pre- and post-intervention delta: 1.44 ±2.34** ***Wii Fit group (B: 8-week)*** **Pre- and post-intervention delta: 1.22 ±1.09**
Rendon et al. 2012 USA [9]	Elderly (*F/M, N*=26/14; 6 using an assistive devise) *Age range:* 60-95 yrs *Mean age:* 85 ±5 yrs	Intervention (RCT) *2 groups: Wii Fit vs.* passive control *Duration:* 6 wks (35-45 min, 3 sessions/wk) *Location:* Community dwelling	*Strength:* Lunge, Single Leg Extension, Single Leg Twist	*Primary:* balance (ABC, 8ft up and go test) *Secondary:* depression (GDS)	*Wii Fit* improved dynamic balance and balance confidence. No effect on depression score. *Adverse events:* No

Toulotte et al. 2012 France [99]	Elderly (some had an history of falling; *F/M, N*=22/14) *Age range:* >60 yrs *Mean age:* 75 ±10 yrs	Intervention (RCT) *4 groups:* passive control *vs. Wii-Fit*, adapted physical activities *vs. Wii Fit* + adapted physical activities *Duration:* 20 wks (60 min, 1 session/wk) *Location:* Fitness room	*Yoga* activities and some *balance* activities (Soccer Heading, Ski Jump, Ski Slalom, Tightrope Walk, and another activity identified as "game balls")	Balance (static tests only: a single leg stance test[a] and the *Wii Fit* balance test; static and dynamic test: Tinetti test)	*Wii Fit* significantly improved static balance but not dynamic balance. The conventional adapted PA training improved both. Combining both interventions did not induce additional benefits. *Adverse events:* No
Bieryla & Dold 2013 USA [7]	Elderly (*F/M, N*=10/2) *Age range:* 70-92 yrs *Mean age:* 82 ±6 yrs	Intervention (RCT) *2 groups: Wii Fit vs.* passive control *Duration:* 3 wks (30 min, 3 sessions/wk) + follow-up at 4-wk *Location:* Community dwelling (supposedly: "supervised")	*Yoga:* Chair, Half Moon, Warrior; *aerobics:* Torso Twists; *balance:* Ski Jump Soccer, Heading	Balance (BBS, TUG, FAB, functional reach test) and adherence (retention rate)	In the *Wii Fit* group, the retention rate was 4/6 at the 4-wk follow-up. The *Wii Fit* training induced an improvement in the BBS only. *Adverse events:* No
Chao et al. 2013 USA [100]	Assisted living residents *(F/M, N*=5/2, 3 of them having acquired neurological disorders) *Age range:* 80-94 yrs *Mean age:* 86 ±5 yrs	Intervention *1 group* *Duration:* 8 wks (30 min, 2 sessions/wk) *Location:* Assisted living dwelling	*Yoga*: Chair, Deep Breathing; *strength*: Lunge; *aerobics*: Basic Run; *balance*: Penguin Slide, Table Tilt	Balance & mobility (BBS, TUG, 6-min walk test, FES), perceived efficacy (SSE, OEE), acceptability (questionnaire), safety	The *Wii Fit* intervention was acceptable and safe, and induced significant improvements in BBS. Trends only (p= 0.06) were noted for improvement in other balance and mobility indexes. *Adverse events:* No **<u>BBS (no unit):</u>** ***Wii Fit group*** **Pre-intervention: 40.9 ±8.5** **Post-intervention: 45.1 ±8.3** **<u>TUG (sec):</u>** ***Wii Fit group*** **Pre-intervention: 19.4 ±5.5** **Post-intervention: 15.8 ±5.1**
Janssen et al. 2013 The Netherland [8]	Home nursing residents (*F/M, N*=20/9, some had a history of falling) *Average age:* 65-90	Intervention (No-RCT) 3 groups: *Wii Fit* (without history of playing) *vs. Wii Fit*	Table Tilt Plus (*Training Plus*) and 2 other games of participants' choice	*Primary:* balance (BBS) *Secondary:* physical activity (LASAPAQ)	No significant balance improvements in either *Wii Fit* intervention groups. However, subjects increased their volume of physical activity by about 60 min/day.

	yrs *Mean age*: 82 ±9 yrs	(with an history of playing) *vs.* passive control *Duration:* 12 weeks (10-15 min, 2 sessions/wk) *Location:* Assisted living dwelling			*Adverse events:* No
Chao et al. 2014 USA [101]	Assisted living resident (*F/M, N=24/8*) *Mean age:* 85 ±6 yrs	Intervention (RCT) *2 groups: Wii Fit vs.* "education" semi-passive control *Duration:* 4 wks (30 min, 2 sessions/wk) *Location:* Assisted living dwelling	*Yoga:* Chair, Deep Breathing; *strength:* Lunge; *balance*: Penguin Slide, Table Tilt; aerobics: Basic Run	Balance and physical function (BBS, TUG, 6-min walk test, FES, SEE), depression (GDS), quality of life (SF-8)	Significant improvements in balance related-function and depression parameters were found in the *Wii Fit* group only. *Wii Fit* might be considered as a potential activity for older adults in assisted living dwellings. *Adverse events:* No **BBS (no unit):** ***Wii Fit group*** **Pre-intervention: 40.53 ±6.59** **Post-intervention: 43.93 ±6.34** **TUG (sec):** ***Wii Fit group*** **Pre-intervention: 18.52 ±5.60** **Post-intervention: 15.27 ±4.68**
Cho et al. 2014 Korea [102]	Elderly (*N=32*) *Mean age:* 78 ±1 yrs	Intervention (RCT) *2 groups*: *Wii Fit vs.* passive control *Duration:* 8 wks (30 min, 3 sessions/wk) *Location:* not specified	*Balance:* Balance Bubble, Ski Slalom, Table Tilt	Balance (Romberg test)	Significant improvements were noted in the *Wii Fit* group only. *Adverse events:* No
Nicholson et al. 2015 Australia [105]	Elderly (*F/M, N=14/27*) *Age range:* 65-84 yrs *Mean age:* 75 ±5 yrs	Intervention (RCT) *2 groups: Wii Fit vs.* usual exercise *Duration:* 6 wks (30 min, 3 sessions /wk) *Location:* Community dwelling	*Balance:* Penguin Slide, Ski Jump, Ski Slalom, Soccer Heading, Table Tilt, Tightrope Walk; *training plus*: Snowball Fight, Perfect 10	Balance and mobility (TUG, functional reach tests, single leg stance test[a], STST, Icon-typed FES, walking speed), enjoyment (PACES), adherence (playing frequency)	The *Wii Fit* group showed more improvement compared to the control group for the followings: TUG, lateral reach, left-leg single leg stance test and gait speed. Interestingly, enjoyment increased during the intervention and the adherence was very high (average attendance: 17.5 out of 18 recommended sessions)

					Adverse events: exacerbations of lower back pain (N=2) **<u>TUG (sec):</u>** ***Wii Fit group*** **Pre- and post-intervention delta: -0.61 ±0.79** ***Traditional therapy group*** **Pre- and post-intervention delta: -0.14 ±0.88**
Roopchand-Martin et al. 2015 Jamaica [106]	Elderly (*F/M, N=26/7*) *Mean age:* 70 ±7 yrs	Intervention *1 group* *Duration:* 6 wks (30 min, 2 sessions/wk) *Location:* Community dwelling	*Yoga:* Tree; *balance:* Balance Bubble, Penguin Slide, Snowboard Slalom, Soccer Heading, Table Tilt; *training plus:* Obstacle Course, Skateboard	Balance and function (BBS, MCTSIB, MDRT, SEBT)	Significant balance and functional improvements were noted at the end of the *Wii Fit* intervention (i.e. for BBS, MDRT, SEBT, but not for MCTSIB) *Adverse events*: No **<u>BBS (no unit):</u>** ***Wii Fit group*** **Pre- and post-intervention delta: 1.54 ±2.60**
Seniors presenting balance impairments					
Williams et al. 2010 UK [108]	Elderly with an history of falling (*N*=21) Mean age: 77 ±5 yrs	Intervention (RCT) 2 groups: *Wii Fit vs.* standard care *Duration:* 12 wks (2 sessions/wk) *Location:* Rehabilitation center	*Yoga:* Deep Breathing; *aerobics:* Basic Step, Hula Hoop, Running activities; *Balance:* Ski Jump, Ski Slalom, Soccer Heading, Table Tilt,	Functional balance (BBS, Tinetti test), static balance (*Wii Fit age* test) Balance confidence (FES), acceptability (retention, playing frequency, interviews)	The intervention met a high rate of acceptability. Balance improved in the *Wii Fit* group only. *Adverse events:* fall (N=1, no injury) **<u>BBS (no unit):</u>** ***Wii Fit group*** **Pre-intervention: 43.7 ±9.5** **Post-intervention: 44.8 ±11.8** ***Traditional therapy group*** **Pre-intervention: 36.3 ±9.9** **Post-intervention: 39.0 ±10.2**
Agmon et al. 2011 USA [109]	Elderly with balance impairment (*F/M, N*=4/3) *Age range:* 78-92 yrs *Mean age:* 84 ±5 yrs	Intervention *1 group* *Duration:* 13 wks (30 min, 3 sessions/wk) *Location:* Home	*Balance:* Basic Step, Ski Slalom, Soccer Heading, Table Tilt	*Primary:* Balance (BBS) Secondary: mobility (4-meter walk test), enjoyment (PACES), feasibility (playing time), safety	The *Wii Fit* intervention increased balance and mobility. Some activities were more enjoyable than the others. Adherence was associated with enjoyment. *Adverse events:* hip and neck strain (N=1 and 2, respectively)

				(interviews)	**<u>BBS (no unit):</u>** ***Wii Fit group*** **Pre-intervention: 49.0 ±2.1** **Post-intervention: 53.0 ±1.8**
Bainbridge et al. 2011 USA [10]	Elderly with perceived balance deficit (*F/M, N*=7/1) *Age range:* 65-87 yrs *Mean age:* 75 ±8 yrs	Intervention *1 group* *Duration:* 6 wks (30 min, 2 sessions/wk) *Location:* Community dwelling	*Yoga:* Half Moon, Warrior*; Balance:* Penguin Slide, Ski Jump, Ski Slalom, Soccer Heading, Table Title, Tightrope Walk	Balance (BBS, ABC, MDRT), COP excursion measurements) and other parameters (ankle range of motion tests…)	No statistically significant changes, but 4 patients (over the 6 who finished the intervention) demonstrated improvements on the BBS, based on established clinical guidelines. *Adverse events:* No
Jorgensen et al. 2012 Denmark [111]	Elderly with perceived balance deficit (*F/M, N*=40/18) *Mean age*: 75 ±6 yrs	Intervention (RCT) *2 groups: Wii Fit vs.* passive control *Duration:* 10 wks (35 min, 2 sessions/wk) *Location:* Community dwelling	*Balance:* Penguin Slide, Ski Slalom, Table Tilt, Tightrope Walk; *training plus:* Perfect 10	*Primary:* strength (maximal voluntary contraction of leg extensors (MVC), Rate of Force Development (RFD), static balance (COP velocity moment) *Secondary:* mobility (TUG, STST), balance confidence (FES), motivation (questionnaire)	Compared to controls, the *Wii Fit* group exhibited increased strength after 10 weeks of training. Mobility and balance confidence parameters also showed an improvement in the *Wii Fit group* only. Motivation for *Wii Fit* training was found to be high. *Adverse events:* No **<u>TUG (sec):</u>** ***Wii Fit group*** **Pre-intervention: 10.3 ±3.8** **Post-intervention: 9.0 ±3.2**
Seniors with acquired neurological alterations					
dos Santos et al. 2012 Brazil [114]	Patients with Parkinson's disease (stages 1 and 2 on Hoehn & Yahr scale, *N*=16) *Mean age:* 69 ±8 yrs	Intervention *2 groups:* patients *vs.* healthy controls, *N*=11) *Duration:* 7 wks (20-30 min, 2 sessions/wk) + follow-up after 2 months *Location:* Rehabilitation center (supposedly: « Overseen by a physiotherapist »)	*Strength:* Single Leg Extension, Torso Twists; *aerobics:* Basic Step*; balance:* Penguin Slide, Soccer Heading, Table Tilt*; training plus:* Basic Run Plus, Obstacle Course, Rhythm Parade, Tilt City	Stability (functional reach test) and motor learning (score performed in the selected games before and after the intervention)	7 of the 10 tested games induced the same learning in Parkinson's disease patients compared with healthy subjects. These patients were also able to transfer and retained (+2-mths follow-up) their learning on a similar but untrained functional task. *Adverse events:* No
Esculier et al. [c]	Patients with	Intervention	*Yoga:* Deep	Functional balance	Improvements in every outcome (except

2012 Canada [113]	Parkinson's disease (*F/M, N*=5/6) *Age range:* 48-80 yrs *Mean age:* 62 ±11 yrs	*2 groups:* patients *vs.* healthy controls, *F/M, N*=4/5) *Duration:* 6 wks (40 min, 3 sessions/wk) *Location:* Home	Breathing; *aerobics:* Hula-Hoop; *balance:* Balance Bubble, Penguin Slide, Ski Jump, Ski Slalom, Table Tilt	and mobility (ABC, STST, TUG, Tinetti test, 10-m walk test, CBM), static balance (single leg stance test[a], COP excursion)	for ABC) in the two groups. A home-based *Wii Fit* improved static and dynamic balance, mobility and functional abilities of people affected by Parkinson's disease *Adverse events:* No
Pompeu et al. 2012 Brazil [116]	Patients with Parkinson's disease (stages 1 and 2 on Hoehn & Yahr scale, *F/M, N*=15/17) *Age range:* 60-85 yrs *Mean age:* 67 ±8 yrs	Intervention (RCT) *2 groups: Wii Fit vs.* traditional balance training *Duration:* 7 wks (30 min, 2 sessions/wk) + follow-up 60 days after *Location:* Rehabilitation center	*Strength:* Single Leg Extension, Torso Twist; *aerobics:* Basic Step, Basic Run; *balance:* Penguin Slide, Soccer Heading, Table Tilt; *training plus:* Obstacle Course, Rhythm Parade, Tilt City	*Primary:* performance in daily activities *Secondary:* balance (static: single leg stance test [a], dynamic: BBS), cognition (Montreal cognitive assessment)	Same improvements in *Wii Fit* and traditional balance training groups (maintained at 60 days follow-up). No additional advantage for the *Wii Fit* group. *Adverse events:* No **<u>BBS (no unit)</u>** ***Wii Fit group*** **Pre- and post-intervention delta: 1.4 ±2.6** ***Traditional therapy group*** **Pre- and post-intervention delta: 1.1 ±2.1**
Padala et al. 2012 USA [115]	Patients with an history of mild Alzheimer's Dementia (*F/M, N*=16/6) *Mean age:* 80 ±7 yrs	Intervention (RCT) *2 groups: Wii Fit vs.* walking *Duration:* 8 wks (30 min, 5 sessions/wk) *Location:* Assisted living center	*Yoga:* Chair, Half moon, Sun Salutation Warrior; *strength:* Lunge, Single Leg Extension, Torso Twist; *balance:* Balance Bubble, Penguin Slide, Ski Jump, Ski Slalom, Soccer Heading, Table Tilt	*Primary:* balance (BBS, TUG, Tinetti test) *Secondary:* functional ability (ADL & instrumental ADL), quality of life (quality of life in Alzheimer's disease scale), cognition (mini mental state examination)	Significant improvements for balance outcomes in the *Wii Fit* group only (trends for the walking group). No significant changes in other outcomes, except for quality of life (walking group only). *Adverse events:* No **<u>BBS (no unit)</u>** ***Wii Fit group*** **Pre-intervention: 43.4 8.9** **Post-intervention: 47.5 5.9** ***Traditional therapy group*** **Pre-intervention: 41.3 ±7.6** **Post-intervention: 46.9 ±6.3** **<u>TUG (sec)</u>** ***Wii Fit group*** **Pre-intervention: 14.7 ±7.2** **Post-intervention: 14.3 ±6.8** ***Traditional therapy group***

					Pre-intervention: 14.9 ±4.7 **Post-intervention: 12.8 ±3.2**
Barcala et al. 2013 Brazil [17]	Hemiplegic stroke patients (*F/M, N*=11/9) Age range: *Mean age:* 64 ±14 yrs	Intervention (RCT) *2 groups:* conventional therapy + *Wii Fit vs.* conventional therapy + balance training *Duration:* 5 wks (30 min, 2 sessions/wk) *Location:* Rehabilitation center	*Balance:* Penguin Slide, Table Tilt, Tightrope Walk	Functional balance (BBS), static balance (stabilometry), functional mobility, independence (TUG, functional independence test)	Both groups showed significant improvements in all parameters. No statistical differences were noted between the two groups emphasizing the efficacy of the *Wii Fit* therapy for functional recovery in hemiplegic stroke patient. *Adverse events:* No **<u>BBS (no unit)</u>** ***Wii Fit group*** **Pre-intervention: 39.6 ±6.43** **Post-intervention: 41.9 ±6.91** ***Traditional therapy group*** **Pre-intervention: 37.2 ±5.22** **Post-intervention: 42.2 ±4.8** **<u>TUG (sec)</u>** ***Wii Fit group*** **Pre-intervention: 27.9 ±8.22** **Post-intervention: 24.3 ±8.64** ***Traditional therapy group*** **Pre-intervention: 28.1 ±3.10** **Post-intervention: 25.2 ±2.78**
Mhatre et al. 2013 USA [117]	Patients with Parkinson's disease (stages 2.5 or 3 on Hoehn & Yahr scale, *F/M, N*=6/4) *Age range:* 44-91 yrs *Mean age:* 67 yrs	Intervention 1 group Duration: 8 wks (30 min, 3 sessions/wk) *Location:* Rehabilitation center	*Balance:* "marble tracking", "skiing", "bubble rafting" (possibly: Table Tilt, Ski Slalom and Balance Bubble)	*Primary:* Balance (BBS; DGI; Sharpened Romberg; *Wii Balance Board*-assisted postural sway tests) *Secondary:* Balance (ABC) and depression (GDS)	Significant improvements in BBS (3.3) and some other balance & gait outcomes, but not in balance confidence (ABC) or mood (GDS). *Adverse events:* No **<u>ABC (no unit)</u>** ***Wii Fit group*** **Pre-intervention: 83.5 ±5.3** **Post-intervention: 82.5 ±3.6** **<u>BBS (no unit)</u>** ***Wii Fit group*** **Pre-intervention: 48.8 ±3.2** **Post-intervention: 52.1 ±2.3**
Bower et al.	Stroke inpatients	Intervention (RCT)	A selection of 18	*Primary:* adherence	The recruitment rate (21%), eligibility

2014 Australia [89]	(*F/M, N*=13/17) *Mean age:* 64 ±15 yrs	*2 groups: Wii Fit* balance training vs. *Wii Sports* upper limb training *Duration:* 2-4 weeks (45 min, 3 sessions/wk) *Location:* Rehabilitation center	activities among the 66 activities proposed in the *Wii Fit Plus* software (including Deep Breathing, Ski Slalom, Basic Run and others…)	(retention, attendance, playing time), acceptability (recruitment rate, questionnaire), safety (questionnaire) *Secondary:* Balance (Step Test, *Wii Balance Board* Test), Functional autonomy (functional reach test, upper limb – motor assessment scale), mobility (TUG, STREAM), balance confidence (FES),	rate (86%), retention rate (90 and 70% respectively at 2 and 4 wks) and adherence rate (99 and 87%) indicated that a *Wii Fit* intervention would be feasible in stroke inpatients. All the patients enjoyed the intervention, which was described as safe. However, trends only were noted for improvements in some of the balance tests. *Adverse events:* Falls (N=4), no subsequent injury **TUG (sec):** ***Wii Fit group*** **Pre- and post-intervention delta: -11.2 ±10.3**
Esculier et al. [c] 2014 Canada [118]	Patients with Parkinson's disease (stages 3.5 or more on Hoehn & Yahr scale, *F/M, N*=3/5) *Mean age:* 64 ±12 yrs	Intervention *2 groups:* patients *vs.* healthy controls (*F/M, N*=3/5) *Duration:* 6 wks (40 min, 3 sessions/wk) *Location:* Home	A selection of *balance* and *strength* activities involving lower limb muscles (i.e. using semi-squats Positions)	Lower limb corticomotor excitability (transcranial magnetic stimulation)	*Wii Fit* training improved lower limb corticomotor excitability in Parkinson's patients. Depending on the experimental conditions, these improvements were similar or more important when compared to healthy subjects. Home-based interventions including visual feedbacks could be beneficial for functional improvement in Parkinson's patients. *Adverse events:* No
Gonçalves et al. 2014 Brazil [119]	Patients with Parkinson's disease (stages 2 to 4 on Hoehn & Yahr scale, *F/M, N=8/7*) *Mean age:* 69 ±10 yrs	Intervention *1 group* *Duration:* 7 weeks (40 min, 2 sessions/wk) *Location:* Hospital (supposedly, not specified)	*Balance:* Ski Jump, Ski Slalom, Soccer Header; *aerobics*: Free Step, Rhythm Boxing; *training plus*: Island Cycling, Rhythm Parade (supposedly), Segway Circuit (+2 other activities that were not explicitly named)	Functional mobility (UPDRS, SE, FIM), gait (number of steps, walking speed)	The *Wii Fit* program induced gait improvement, but statistical significance was not indicated. Functional mobility was significantly improved (i.e. decrease in UPDRS score, and increase in SE and FIM scores) *Adverse events:* No
Hung et al.	Chronic stroke	Intervention (RCT)	*Yoga:* Warrior;	Balance (a series of	At the end of the intervention, *Wii Fit*

2014 China [90]	patients (*F/M, N=10/18*) *Mean age:* 54 ±10 yrs	*2 groups: Wii Fit vs.* traditional weight-shift training *Duration:* 12 wks (30 min, 2 sessions/wk) + follow-up at 3 months *Location:* rehabilitation center (supposedly: according to pictures, "supervised by an occupational therapist")	*balance:* Balance Bubble, Penguin Slide, Ski Slalom, Soccer Heading, Table Tilt; *aerobics*: Basic Step	COP excursion tests, FES), function (forward reach, TUG), enjoyment (PACES)	induced a higher increase in some COP excursion tests compared to the traditional weigh-shift training group. However, at a 3-month follow-up, these effects were not maintained, while the traditional weight-shift group showed higher improvements. Both types of intervention showed significant improvements in balance and functional outcomes, and the enjoyment was higher in the *Wii Fit* group. *Adverse events:* No **TUG (sec):** ***Wii Fit group*** **Pre-intervention: 26.06 ±12.05** **Post-intervention: 20.88 ±7.77** ***Traditional therapy group*** **Pre-intervention: 29.45 ±16.22** **Post-intervention: 26.61 ±12.92**
Liao et al. 2014 China [120]	Patients with Parkinson's disease (stages 1 to 2 on Hoehn & Yahr scale; *F/M, N=19/17*) *Mean age:* 66 ±7 yrs	Intervention (RCT) 3 groups: *Wii Fit vs.* traditional therapy *vs.* passive control *Duration:* 6 weeks (45 min, 2 sessions/wk + follow-up after 1 month *Location:* Rehabilitation center (supposedly: "administrated by the same physical therapist")	*Yoga (10 min):* Chair, Sun Salutation, Tree; *strength (15 min)*; *balance (20 min):* Balance Bubble, Soccer Heading, Ski Slalom, Table Tilt	*Primary*: mobility (obstacle crossing performance tests measured with the *Liberty* system), dynamic balance (LOS) *Secondary:* balance (SOT, FES), mobility (TUG), quality of life (PDQ-39).	When compared with the passive control group, *Wii Fit* induced significant increases for the mobility, balance and quality of life outcomes. Interestingly, movement velocity evaluated with LOS test showed significantly greater improvement in the *Wii Fit* group compared to traditional therapy. These results should encourage the implementation of *Wii Fit* activities in patients with Parkinson's disease. *Adverse events:* No **TUG (sec):** ***Wii Fit group*** **Pre- and post-intervention delta: -2.9 ±2.2** ***Traditional therapy group*** **Pre- and post-intervention delta: -1.1 ±0.1**

					Passive control group **Pre- and post-intervention delta: +0.7 ±1.7**
Morone et al. 2014 Italy [5]	Subacute stroke patients (*N=50*) *Mean age:* 60 ±10 yrs	Intervention (RCT) *2 groups: Wii Fit* + traditional therapy *vs.* traditional balance exercises + traditional therapy *Duration:* 4 wks (20 min, 3 sessions/wk) + follow-up after 1 month *Location:* Rehabilitation center	*Balance:* Balance Bubble, Ski Slalom; *aerobics:* Hula Hoop	*Primary:* balance (BBS) *Secondary:* mobility (10-m walk test, functional ambulatory category), independency (Barthel index)	*Wii Fit* was more effective than traditional balance exercises to improve balance and independency in subacute stroke patients. No significant differences were noted between groups for mobility outcomes (increase in both groups). Interestingly, benefits in balance ability were maintained 1 month after the intervention. *Adverse events:* No
Omiyale et al. 2015 USA [92]	Hemiparetic stroke patients (*F/M, N=4/6*) *Age range:* 41-73 yrs Mean age: 67 ±8 yrs	Intervention *1 group* *Duration:* 3 wks (60 min, 3 sessions/wk) Location: not specified, but “supervised by a physical therapist”	*Balance:* Balance Bubble, Penguin Slide, Ski Slalom, Table Tilt, Tightrope Walk	Neural plasticity (interhemispheric symmetry through tibialis anterior corticomotor excitability using transcranial magnetic stimulation), balance, motor response and function (COP distribution and dynamic weight shifting, Soccer Heading’s score, BBS, TUG, and dual TUG, gait speed, ABC)	Interestingly, the *Wii Fit* intervention significantly improved the interhemispheric symmetry. Overall, but not for all parameters, patients also improved their balance abilities, motor responsiveness, and balance related functions. These results suggest that *Wii Fit* rehabilitation may be able to influence positively neural plasticity and functional recovery in chronic stroke patients. *Adverse events*: No **<u>ABC (no unit):</u>** ***Wii Fit group*** **Pre-intervention: 65.9 ±13.49** **Post-intervention: 73.4 ±13.32** **<u>BBS (no unit):</u>** ***Wii Fit group*** **Pre-intervention: 51.6 ±5.97** **Post-intervention: 53.6 ±2.95** **<u>TUG (sec):</u>** ***Wii Fit group*** **Pre-intervention: 21.0 ±12.18** **Post-intervention: 19.4 ±9.10**

Yatar & Yildirim 2015 Cyprus/Turkey [19]	Chronic stroke patients (*F/M, N*=13/17) *Mean age:* 60 ±14 yrs	Intervention (RCT) *2 groups:* neurodevelopmental training + *Wii Fit vs.* neurodevelopmental training + progressive balance training *Duration:* 4 wks (30 min, 3 sessions/wk) *Location:* Rehabilitation center (supposedly)	*Balance:* Balance Bubble, Ski Slalom, Soccer Heading	*Primary:* static balance (*Wii Balance Board*-assisted postural sway tests), dynamic balance (BBS, DGI, functional reach test, TUG) *Secondary*: balance confidence (ABC, ADL)	Primary and secondary outcomes increased in both *Wii Fit* and progressive balance training groups. The increment was statistically higher in the *Wii Fit* group for: DGI. Functional reach test and ABC. Large differences in baseline values between the two groups limits the interpretation. *Adverse events*: No **BBS (no unit):** ***Wii Fit group*** **Pre-intervention: 45.60 ±5.26** **Post-intervention: 50.33 ±4.09** ***Traditional therapy group*** **Pre-intervention: 39.60 ±9.31** **Post-intervention: 44.80 ±7.48** **TUG (sec):** ***Wii Fit group*** **Pre-intervention: 17.96 ±7.77** **Post-intervention: 16.17 ±8.23** ***Traditional therapy group*** **Pre-intervention: 26.36 ±11.60** **Post-intervention: 22.11 ±11.88**
Orthopedic population					
Fung et al. 2011 Canada [11]	Adult outpatients following knee replacement (*F/M, N*=33/17) *Mean age:* 68 ±11 yrs	Intervention (RCT) *2 groups:* traditional therapy + *Wii Fit vs.* traditional therapy + additional lower limb exercise *Duration*: until discharge (≈ 6wks, 15 min/session) *Location:* Rehabilitation center	*Yoga:* Deep Breathing, Half Moon; *Strength:* Torso Twist; *Aerobics:* Hula Hoop; *Balance:* Balance Bubble, Penguin Slide, Ski Slalom, Table tilt, Tightrope Walk	Function (range of motion), 2-min walk test, LEFS), pain (NPRS), Balance confidence (ABC) and length of rehabilitation	From baseline to discharge, the improvements were similar between the two groups for all the outcomes. The *Wii Fit* intervention might induce higher improvement for the LEFS. But the study was not powerful enough to obtain significance. *Adverse events:* No
Baltaci et al. 2012 Turkey [72]	Young adults with anterior cruciate ligament reconstruction (N=30)	Intervention (RCT) *2 groups: Wii vs.* conventional rehabilitation	Not clear. Probably a combination of *Wii Sports* games (Bowling, Boxing)	Balance (SEBT), function (functional squat test including coordination,	No difference between *Wii Fit* and conventional physical therapy. *Wii Fit* may be able to address rehabilitation goals for patients with anterior cruciate

	Mean age: 29 ±5 yrs	*Duration:* 12 wks (60 min, 3 sessions/wk) *Location:* Rehabilitation center (supposedly)	and *Wii Fit* activities ("skiing games", "football", "balance board")	proprioception, time response and strength measurements)	ligament reconstruction. *Adverse events:* No
Sims et al. 2013 USA [74]	Young active adults with an history of lower limb injury within 1 yr (*F/M, N*=16/12) *Mean age:* 22 ±2 yrs	Intervention (RCT) *3 groups: Wii Fit*, traditional balance training, passive control *Duration:* 4 wks (15min, 3 sessions/wk) *Location:* Rehabilitation center	*Yoga:* Chair, Half Moon, Tree; *Balance:* Balance bubble, Penguin Slide, Ski Slalom, Soccer Heading, Table Tilt; *Strength:* Lunge, Sideways Leg Lift, Single Leg Extension; *Aerobics:* Basic Step, Hula Hoop, Super Hula Hoop	*Primary:* balance (static: Time to Boundary test, dynamic: SEBT) *Secondary:* function (LEFS)	*Wii Fit* improved static balance to a larger extend than the traditional balance training. Dynamic balance was improved in all groups. *Adverse events:* No
Punt et al. 2015 Switzerland [75]	Adults ankle sprain patients (*F/M, N*=39/51) *Mean age:* 34 ±11 yrs	Intervention (RCT) *3 groups: Wii Fit vs.* traditional balance training *vs.* passive control *Duration*: 6 wks (30 min, 2 sessions/wk) *Location:* Home	*Balance:* Balance Bubble, Penguin Slide, Ski Slalom, Table Tilt	Function (FAAM), pain (visual analogue scale), time to return to sport, satisfaction (questionnaire)	Foot and ankle ability score increased and pain decreased in all groups. A *Wii Fit* intervention was as effective as traditional therapy or no therapy. In the *Wii Fit* group, the average time to return to sport was 27 ±20 days and 82% of patients were satisfied. *Adverse events:* No
Multiple sclerosis					
Brichetto et al. 2012 Italia [81]	Patients with multiple sclerosis (*F/M, N*=22/14) *Mean age:* 42 ±11 yrs	Intervention (RCT) *2 groups: Wii Fit vs.* traditional rehabilitation *Duration:* 4 wks (60 min, 3 sessions/wk) *Location:* Rehabilitation center	*Balance :* Lotus Focus, Ski Slalom, Snowboard Slalom, Soccer Heading, Table Tilt, Tightrope Walk	*Primary:* balance (BBS) *Secondary:* fatigue (MFIS), posture (stabilometry)	More important balance improvements in the *Wii Fit* group. Fatigue was reduced and posture improved. A *Wii Fit*-based program might be more efficient than the standard rehabilitation procedure in multiple sclerosis patients. *Adverse events:* No **BBS (no unit):** ***Wii Fit group*** **Pre-intervention: 49.6 ±4.9** **Post-intervention: 54.6 ±2.2** ***Traditional therapy group*** **Pre-intervention: 48.7 3.3**

					Post-intervention: 49.7 ±3.9
Nilsagard et al. 2013 Sweden [82]	Patients with multiple sclerosis (*F/M, N*=64/20) *Mean age:* 50 ±11 yrs	Intervention (RCT) *2 groups: Wii Fit vs.* passive control *Duration:* 6-7 wks (30 min, 2 sessions /wk) *Location:* Rehabilitation Center ("physical therapist supervised session")	*Aerobics:* Skateboard Arena *Balance:* Balance Bubble, Penguin Slide, Ski Slalom, Soccer Heading, Snowboard Slalom, Table Tilt, Tightrope Walk; *Training plus:* Balance Bubble plus, Perfect 10, Table Tilt Plus	*Primary:* balance (TUG) *Secondary:* other functional tests ($TUG_{cognitive}$, four square step test, 25-foot walk test, DGI, MSWS-12, ABC, STST)	Improvement in several balance-related outcomes for the *Wii Fit* group. However, same improvements were observed in the controls (because of spontaneous exercise). *Wii Fit* can be recommended in adults with multiple sclerosis *Adverse events:* No **ABC (no unit):** ***Wii Fit group*** **Pre- and post-intervention delta: 5.0 ±14.4** **TUG (sec):** ***Wii Fit group*** **Pre- and post-intervention delta: -0.8 ±2.4**
Prosperini et al. 2013 Italy [84]	Patients with multiple sclerosis (*F/M, N*=25/11) *Mean age:* 36 ±9 yrs	Intervention (cross-over RCT) *2 groups: Wii Fit vs.* passive control *Duration*: 12 wks (30 min, 5 sessions/wk) *Location:* Home	Supposedly all balance activities included in *Wii Fit Plus* (for the 4 first weeks, patients were allowed to play Zazen, Table Tilt and Ski Slalom only)	Balance (COP excursion, 4-step square test), mobility (25-foot walk test), self-perceived disability (MSIS-29)	*Wii Fit* was effective in improving balance, mobility and self-perceived health status and quality of life. *Adverse events:* knee pain (N=2), lower back pain (N=3)
Robinson et al. 2015 UK [86]	Patients with multiple sclerosis (*F/M, N*=38/18) *Mean age:* 52 ±6 yrs	Intervention (RCT) *3 groups: Wii Fit vs.* traditional therapy *vs.* passive control *Duration*: 4 wks (40-60 min, 2 sessions/wk) *Location:* Rehabilitation center	*Balance:* Heading Soccer, Ski Slalom, Table Tilt, Tightrope Walk; *Strength:* Rowing Squats, Torso Twist; *aerobics*: Boxing, Hula Hoop, Advanced Steps (supposedly)	*Primary:* balance (postural sway), gait (gait speed), acceptability (UTAUT, FSS) *Secondary:* self-perceived disability (MSWS-12, WHODAS)	Balance but not gait was improved by both the *Wii Fit* and traditional therapy interventions. *Wii Fit* was acceptable and induced positive changes in self-perceived disability. *Adverse events:* No
Spinal cord injury patients					
Wall et al. 2015 USA [6]	Individuals with incomplete spinal cord injury (> 1-yr post-injury, *M, N=5*)	Intervention *1 group* *Duration:* 7 wk (60 min, 2 sessions/wk) +	*Balance:* Balance Bubble, Basic Run (or another running activity), Penguin	Walking ability (gait speed), balance (TUG, functional reach), well-being (SF-36)	Gait speed and functional reach tests score both significantly increased after the *Wii Fit* intervention and the effects were maintained at a 4-week follow-up.

	Age range: 50-64 yrs *Mean age:* 59 ±5 yrs	follow up after 4 wks *Location:* Home or University (and "supervised")	Slide, Ski Slalom, Ski Jump, Tightrope Walk, Table Tilt; *training plus*: Island Bike, Obstacle Course, Segway Circuit,		However, the program failed to induce statistical improvements in wellness (SF-36) and TUG. *Adverse events:* No
Children with developmental delay					
Salem et al. 2012 USA [12]	Children with developmental delay (*F/M*, *N=18/22*) *Age range:* 39 to 58 mths *Mean age:* 49 ±6 mths	Intervention (RCT) *2 groups: Wii vs.* passive control *Duration:* 10 wks (30min, 2 sessions/wk) *Location:* Rehabilitation center	*Strength:* Lunges, Single Leg Stance; *aerobics:* Basic Run, Basic Step, Hula Hoop; *balance*: Penguin Slide, Soccer Heading, Tightrope Walk; *Wii Sports'* Baseball, Bowling and Boxing games were also used	*Primary:* balance and gait (gait speed, TUG, single leg stance test[a], STST, TUDS, 2-min walk test) *Secondary:* grip strength (dynamometer)	*Wii Fit* induced significant improvements for the single leg stance test and grip strength only *Adverse events:* No
Esposito et al. 2013 Italia [31]	Children with migraine without aura (*F/M, N*=32/39) *Mean age:* 9 ±2 yrs	Intervention 2 groups: patients *vs.* healthy controls, *F/M, N*=44/49) Duration: 12 wks (30 min, 3 sessions/wk) *Location:* Home	A choice of 18 *balance* oriented *Wii Fit Plus* activities (e.g. Balance Bubble, Hula Hoop, Obstacle Course, Penguin Slide, Rhythm Activities, Segway Circuit, Snowboard Slalom, Skateboard Arena, Ski Jump, Ski Slalom, Soccer Heading, Table Tilt, Tilt City…)	Motor coordination (MABC), fine visuomotricity (Berry-VMI)	3-month *Wii Fit* training in children with migraine without aura improved all parameters: motor coordination (including balance skills), and fine visuomotricity. *Wii Fit* could be used in this population to counterbalance associated developmental delays or other deleterious effects. *Adverse events:* No
Ferguson et al. 2013 South Africa [27]	Children with developmental coordination disorders (*F/M, N*=22/24) *Age range:* 6-10 yrs Mean age: 8 ±1 yrs	Intervention *2 groups: Wii Fit vs.* established neuromotor task training *Duration:* 6 wks (30 min, 3 sessions/wk)	18 of the *Wii Fit* games mimicking the act of cycling, soccer, skateboarding and skiing or played with the hand controller	Motor coordination (MABC), physical fitness (functional strength, strength measured with dynamometer, muscle power sprint test, 20-	Motor performance improved in the two groups, but more important changes were noted in the traditional training group. The latter was also true for functional strength and cardiorespiratory fitness measurements. Adherence was near 100% in both

		Location: School		m shuttle run test, adherence	groups. The choice of one or the other intervention may depend on resources and time constraints. *Adverse events:* No
Hammond et al. 2013 UK [28]	Children with developmental coordination disorders (*F/M*, *N=4/14*) *Age range:* 7-10 yrs *Mean age:* 8 ±1 yrs	Intervention (cross-over RCT) 2 groups: *Wii Fit*-regular motor training *vs.* regular motor training-*Wii Fit* *Duration:* 4 wks (3 sessions/wk) *Location:* School	A selection of 9 *Wii Fit* games focusing on coordination and balance	*Childs:* motor proficiency (BOT), self-perceived ability and satisfaction with motor task (coordination skills questionnaire) *Parents:* emotional and behavioral development (strengths and difficulties questionnaire)	*Wii Fit* induced significant gains in motor proficiency and other outcomes for many, but not all the children. Including *Wii Fit* therapy for children with developmental disorders could be considered. *Adverse events:* No
Mombarg et al. 2013 The Netherland [29]	Children with balance alterations (*F/M*, *N*=6/23) *Age range:* 7-12 yrs *Mean age:* 10 ±1 yrs	Intervention (RCT) *2 groups: Wii Fit vs.* passive control *Duration:* 6 wks (30 min, 3 sessions/wk) *Location:* School	18 activities identified as balance games (mainly from the *balance* and *training plus* categories: Ski Jump, Ski Slalom, Snowboard Slalom, Table Tilt, Obstacle Course, Segway Circuit, Skateboard Arena, Tilt City, Rhythm activities…)	Balance (MABC & BOT)	Significant improvements in the *Wii Fit* group. Effective intervention for children with poor motor development. *Adverse events:* No
Jelsma et al. 2014 The Netherlands [30]	Children with probable developmental coordination disorders and balance problems (*F/M=10/18*) *Age range:* 71-136 mths *Mean age:* 100 ±15 mths	Intervention *2 groups*: *Wii Fit vs.* waiting period-*Wii Fit* *Duration:* 6 weeks (30 min, 3 sessions/wk) *Location:* Laboratory (supposedly)	18 "balancing activities" from the *Wii Fit Plus* software (not including Ski Slalom, which was used for test)	Motor coordination (MABC), balance (BOT, Ski Slalom), enjoyment (home-made scale)	A *Wii Fit* intervention significantly increased motor and balance skills in children with coordination disorders and balance problems. After 6 weeks of intervention, 20 children (out of 28) still rated Wii Fit as "super fun" and 4 as "fun". *Adverse events:* No
Children with cerebral palsy					

Ramstrand & Lygnegard 2012 Sweden [35]	Children with hemiplegic or diplegic cerebral palsy (*F/M, N*=10/8) *Age range:* 8-17 yrs *Mean age:* 13 ±3 yrs	Intervention (cross-over RCT) *2 groups*: *Wii Fit*-no intervention *vs.* no intervention-*Wii Fit* *Duration:* 5 wks (>30min, 5 sessions/wk) *Location:* Home	*Balance*: Balance Bubble, Ski Jump, Ski Slalom, Soccer Heading, Table Tilt, Tightrope Walk,	*Primary:* balance (modified SOT, reactive balance test, weight shift test) *Secondary:* adherence (playing time)	No improvements after the *Wii Fit* intervention period. A 30-min home-based *Wii Fit* intervention was not effective to improve balance in children with cerebral palsy. 4 children did not complete the required 30 min/day sessions. *Adverse events:* No
Jelsma et al. 2013 South Africa [36]	Children with spastic hemiplegic cerebral palsy (*F/M, N*=6/8) *Age range:* 7-14 yrs *Mean age:* 11 ±2 yrs	Intervention (A-B) *1 group* (*cf.* details in the paper) Duration: 3 wks (25min, 4 sessions/wk) + follow-up after 2 months *Location:* Rehabilitation center	*Aerobics*: Hula Hoop*; balance:* Balance Bubble, Penguin Slide, Snowboard Slalom, Slalom Ski, Soccer Heading	Balance (BOT), functional mobility (BOT and TUDS)	Balance score improved significantly (sustained at 2 months follow-up), but not the functional scores (BOT and TUDS). 10 children only preferred to play *Wii Fit* instead of conventional physiotherapy. *Wii Fit* may not be used in place of conventional therapy. *Adverse events:* No
Tarakci et al. 2013 Turkey [37]	Children with ambulatory cerebral palsy (*F/M, N*=3/11) *Mean age:* 12 ±3 yrs	Intervention *1 group* *Duration:* 12 wks (40min, 2 sessions/wk) *Location:* Rehabilitation center	*Balance:* Ski Slalom, Soccer Heading, Table Tilt, Tightrope Walk	Balance (single leg stance test[a], functional reach test, TUG, 6-min walk test)	Balance improved significantly (all outcomes) *Adverse events:* No **TUG (sec):** ***Wii Fit group*** **Pre-intervention: 18.26 ±8.95** **Post-intervention: 14,57 ±5.39**
Other populations with balance impairments					
Meldrum et al. 2015 Ireland [21]	Patients with unilateral peripheral vestibular loss (*F/M, N=27/44*) *Mean age:* 54 ±15 yrs	Intervention (RCT) *2 groups: Wii Fit vs.* traditional balance rehabilitation *Duration*: 6 wks (15 min, 5 sessions/wk) + follow-up after 6 months *Location:* Home	*Yoga:* Deep Breathing, Palm Tree, Standing Knee, Tree Pose; *strength*: Sideways Leg Lift, Single Leg Extension; *balance*: Balance Bubble, Ski Slalom, Heading Soccer, Penguin Slide, Table Tilt; *aerobics*: Advanced Step, Basic Step, Free Step;	*Primary:* Gait (self-preferred gait speed) *Secondary*: gait parameters (various tests performed eyes open or close, including DGI), balance (ABC, SOT), dynamic visual acuity (computerized dynamic visual acuity system), self-perceived benefit	Both the *Wii Fit* and traditional balance training induced improvement in gait speed. No difference was noted between the two groups for gait parameters and other outcomes at the end of the intervention. Adherence was high for the two interventions but *Wii Fit* was described as more enjoyable. *Adverse events*: low back pain (N=1) **ABC (no unit):** ***Wii Fit group*** **Pre-intervention: 64.82 ±18.74**

			training plus: Skateboard, Snowball Fight, Table Tilt Plus	(vestibular rehabilitation benefit questionnaire), mental health (Hospital Anxiety and depression Scale), adherence (diary)	**Post-intervention: 74.36 ±21.25**

[a] Many different single leg stance tests were used in the *Wii Fit* literature for balance assessment purposes. In this table “single leg stance test” describe any test requiring subjects to stand on one leg. [b] Many different sit-to-stand tests (STST) were used in the *Wii Fit* literature for balance, strength or functional assessment purpose. In this table, “STST” describes any test that requires the subject to sit and stand repeatedly. [c] Esculier et al. (2012 & 2014) report results obtained with the same group of subjects during the same trial [113, 118].

ABC: activities-specific balance confidence scale; BBS: Berg balance scale; BMI: body mass index; BOT: Bruininks-Oseretsky test; ADL: activities of daily living scale; CHAMPS: community healthy activities model program for seniors; CBM: community balance and mobility scale; COPD: chronic obstructive pulmonary disease; Beery-VMI: Beery visual-motor integration test; CRQ-SR: chronic respiratory questionnaire; CTSIB: clinical test of sensory interaction and balance; DGI: dynamic gait index; EE: energy expenditure; ESWT: endurance shuttle walk test; FAAB: foot and ankle ability measure; FAB: Fullerton advanced balance scale; FES: Falls Efficacy Scale; FIM: functional independence measure; FSS: flow state scale; GDS: geriatric depression scale; HR: hear rate (beats/min); IMI: Intrinsic Motivation Inventory; LASAPAQ: LASA Physical Activity Questionnaire; LEFS: lower extremity functional scale; LLFDI: late life function and disability index; LOS: limits of stability; MABC: movement assessment battery for children; MCTSIB: modified clinical test for sensory interaction in balance; MDRT: multidirectional reach test; METs: metabolic equivalent; MFIS: modified fatigue impact scale; MSIS-29: 29-item multiple sclerosis impact scale; MSWS-12: 12-items multiple sclerosis walking scale; MVC: maximal voluntary contraction of leg extensors; MVPA: moderate-to-vigorous physical activity; NPRS: numeric pain rating scale; OEE: Outcome expectations for exercise scale; PA: physical activity; PACES: physical activity and exercise questionnaire; PAID: problem areas in diabetes scale; PDQ-39: 39-question Parkinson’s disease questionnaire; RFD: rate of force development; RPP: rate pressure product; SE: Schwab & England daily living activities scales; SEE: self-efficacy exercise scale; SEES: subjective exercise experience scale; SF-8: short form-8 health survey; SF-36: short form-36 health survey; SFT: senior fitness test; SOT: sensory organization test; STREAM: stroke rehabilitation assessment of movement; STST: sit-to-stand-test; TD2M: type 2 diabetes mellitus; TUDS: time up and down stairs; TUG: time up and go; UPDRS: unified rating scale for Parkinson’s disease; UTAUT: unified theory of acceptance and use of technology questionnaire; VPA: vigorous physical activity; VO_2: oxygen consumption; VO_2max: maximal oxygen consumption; WHO-5: five-item WHO well-being index; WHODAS: world health organization disability assessment schedule

For the same test, unit may vary from one paper to another.

Goal 3: Outcomes of Meta-analyses

For the pre- and post-intervention meta-analyses, 7 groups out of 6 studies were included for ABC, 13 groups out of 12 studies for BBS, and 12 groups out of 12 studies for TUG. For the *Wii Fit* vs. traditional therapy meta-analyses, 14 groups out of 7 studies for BBS, and 12 groups out of 6 studies for TUG. Studies included in the different meta-analyses involved 595 participants from both sexes (females: 332, males: 242, not specified: 21), with a wide age range (12 ±3 – 86 ±5 years [37, 100]) and various medical conditions. Whilst these papers all included a measure of ABC, BBS or TUG, the interventions content and duration vary from study to study. The assessment of individual studies revealed a low risk of bias (Figure 2). Detailed results for ABC, BBS and TUG are presented in Figure 3, 4 and 5, and data included in the meta-analyses appears in Table 3 and 4. *Wii Fit* interventions did not induce any change in ABC (2.02, 95% CI: -4.01 – 8.04). For BBS, significant improvements were noted in both healthy subjects and patients (2.00, 95% CI: 0.41 – 3.60 and 2.99, 95% CI: 0.08 – 5.90, respectively; 2.23, 95% CI: 0.84 – 3.63, overall). In addition, there was no significant difference in changes induced by traditional training and those induced by *Wii Fit,* suggesting that *Wii Fit* was as valid as traditional training. Regarding TUG, no significant reduction was noted after the *Wii Fit* intervention in either healthy subjects or patients (-0.34 sec, 95% CI: -1.38 – 0.70 and -2.24 sec, 95% CI: -5.17 – 0.69, respectively; -0.55 sec, 95% CI: -1.53 – 0.43, overall). However, compared to traditional training programs, the *Wii Fit* did induced a more significant reduction in TUG, especially in patients (-1.76, 95% CI: -2.13 – -1.39, in patients; -1.31, 95% CI:-1.62 – -1.01, overall). The sets of studies included in both BBS and TUG pre- and post-intervention meta-analyses were statistically homogenous (I^2 = 0.0%, p=0.961 and I^2 = 0.0%, p=0.969, respectively for the overall analysis). Various levels of heterogeneity were observed in the *Wii Fit* vs. traditional therapy meta-analyses (I^2 = 60.0%, p = 0.040 for BBS in patients and I^2 = 74.3%, p = 0.002 for TUG overall

(Figure 4 and 5), indicating some inconsistencies in the literature. This was expected, however, since different populations were included in the analyses.

Meta-regression analyses revealed no significant results (not shown), suggesting no relationships between improvements in balance outcomes and intervention duration or volume.

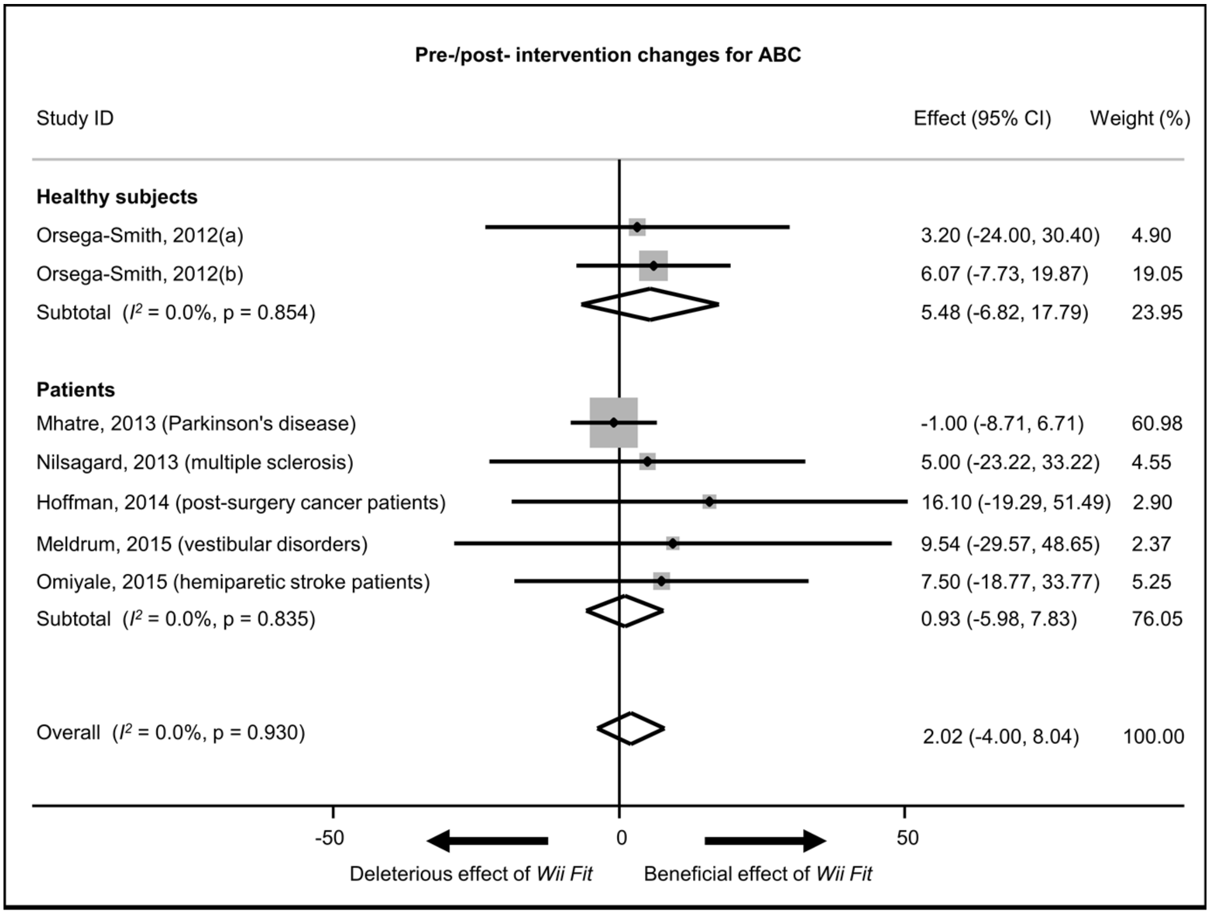

Figure 3. Pre- and post-intervention meta-analytic effect for the activities-specific balance confidence test (ABC). The black point shows the average change for each study. The diamonds describe the pooled values respectively for the change in healthy subjects, patients and the overall population. The vertical black line refers to no change. For each analysis (overall population) or sub-analysis (healthy subjects or patients), a significant effect is observed if the diamond does not touch the black line. The horizontal black line shows the 95% confidence interval and the grey square shows the study weight in percentage. Orsega et al. 2012(a): 4-week *Wii Fit* intervention group; Orsega et al. 2012(b): 8-week *Wii Fit* intervention group [98]. I^2: index of heterogeneity.

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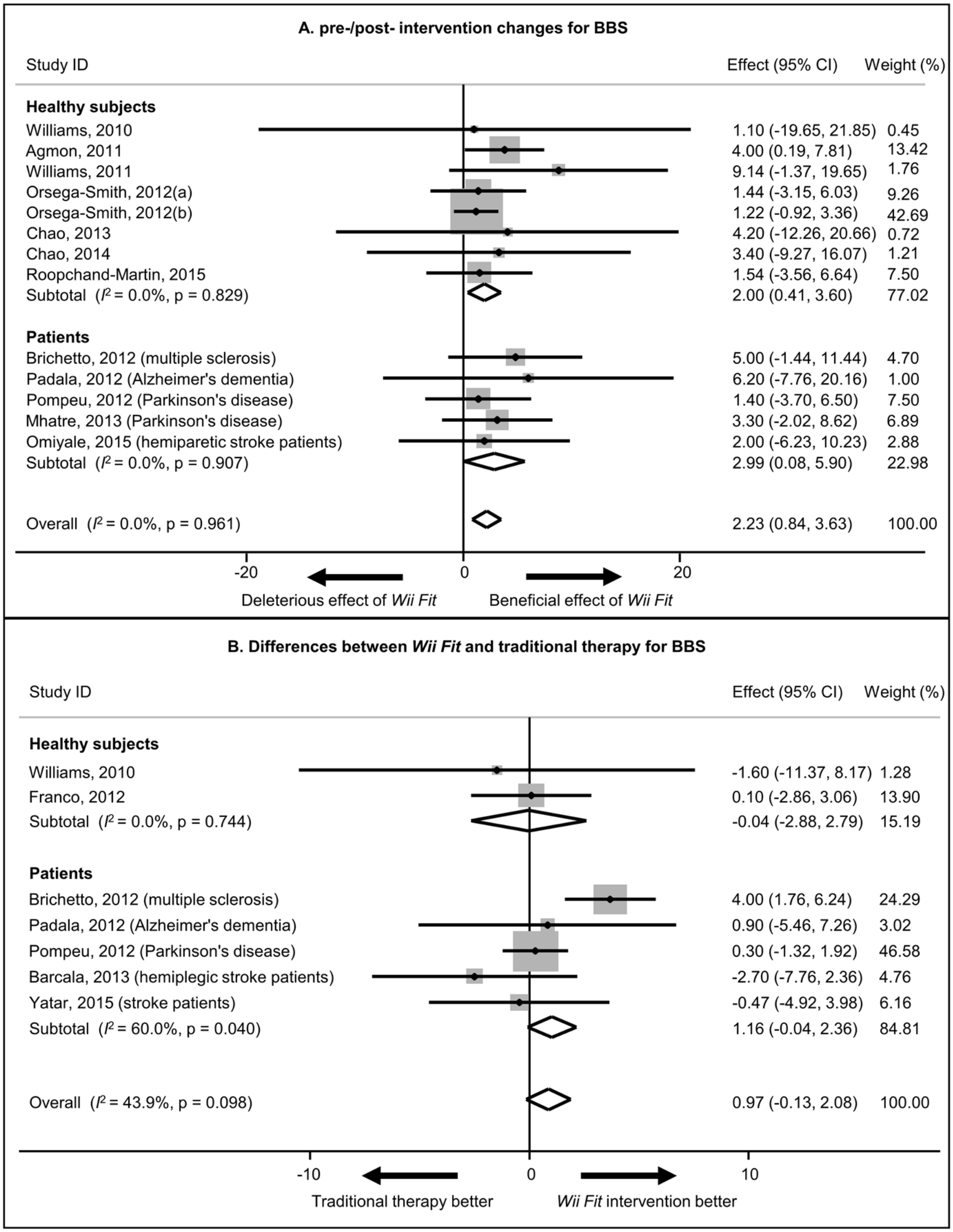

281 **Figure 4. Pre- and post-intervention meta-analytic effect (A) and *Wii-Fit* vs. traditional**
282 **therapy meta-analytic effect (B) for the Berg balance score (BBS).** A. The black point shows

the average change for each study. The diamonds describe the pooled values respectively for the change in healthy subjects, patients and the overall population. The vertical black line refers to no change. For each analysis (overall population) or sub-analysis (healthy subjects or patients), a significant effect is observed if the diamond does not touch the black line. B. The black point shows the difference of effect between *Wii Fit* and traditional therapy for each study. The diamonds describe the pooled values respectively for the difference of effect in healthy subjects, patients and the overall population. The vertical black line refers to no difference between *Wii Fit*-induced change and traditional therapy-induced change. For each analysis (overall population) or sub-analysis (healthy subjects or patients), a significant difference is observed if the diamond does not touch the black line. A and B. The horizontal black line shows the 95% confidence interval and the grey square shows the study weight in percentage. Orsega et al. 2012(a): 4-week *Wii Fit* intervention group; Orsega et al. 2012(b): 8-week *Wii Fit* intervention group [98]. I^2: index of heterogeneity.

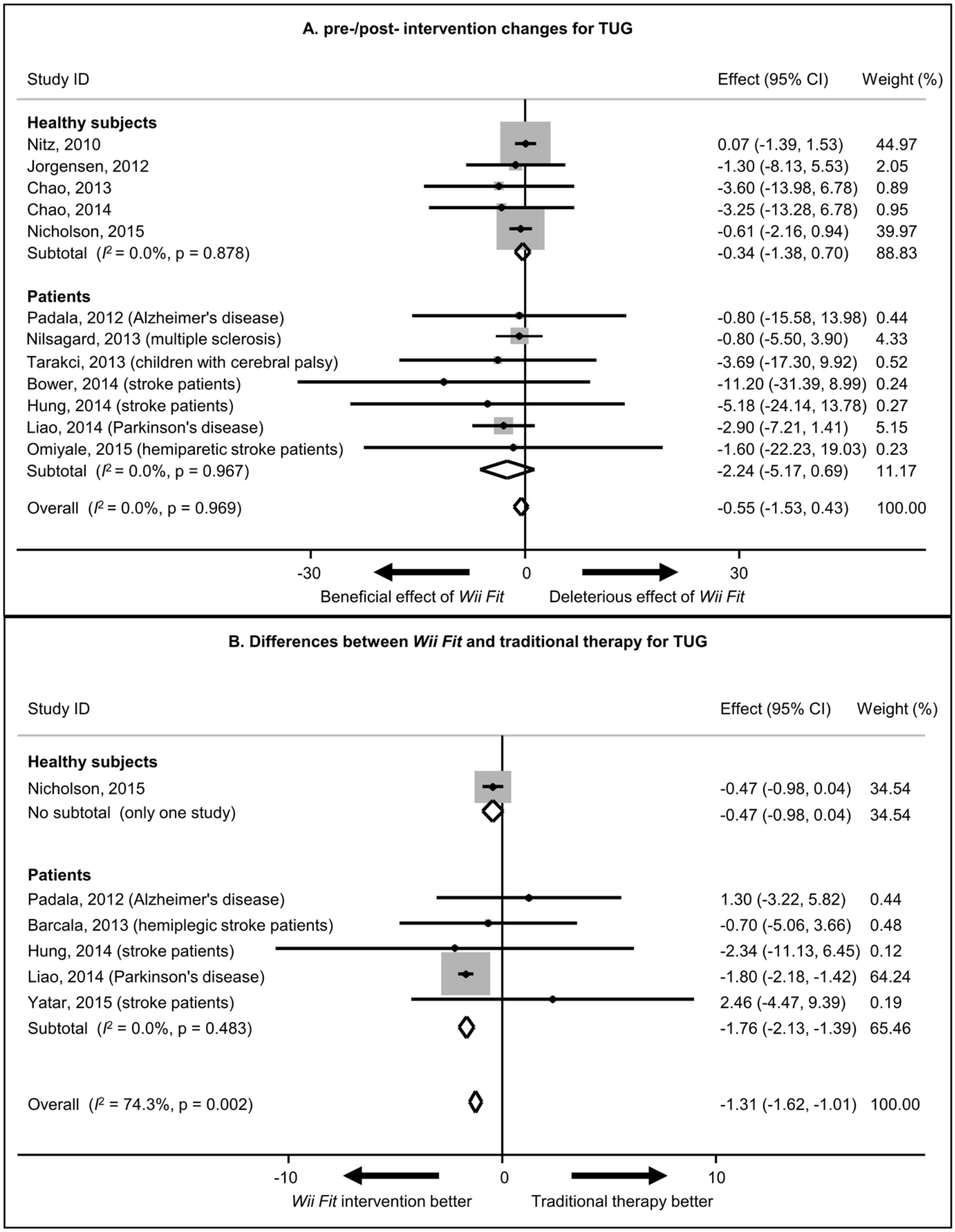

Figure 5. Pre- and post-intervention meta-analytic effect (A) and *Wii-Fit* vs. traditional therapy meta-analytic effect (B) for the time-up-and-go test (TUG). A. The black point

shows the average change for each study. The diamonds describe the pooled values respectively for the change in healthy subjects, patients and the overall population. The vertical black line refers to no change. For each analysis (overall population) or sub-analysis (healthy subjects or patients), a significant effect is observed if the diamond does not touch the black line. B. The black point shows the difference of effect between *Wii Fit* and traditional therapy for each study. The diamonds describe the pooled values respectively for the difference of effect in healthy subjects, patients and the overall population, the vertical black line refers to no difference between *Wii Fit*-induced change and traditional therapy-induced change. For each analysis (overall population) or sub-analysis (healthy subjects or patients), a significant difference is observed if the diamond does not touch the black line. A and B. The horizontal black line shows the 95% confidence interval and the grey square shows the study weight in percentage. I^2: index of heterogeneity. Unlike ABC and BBS, which are scores, the TUG test results are expressed in time. A negative difference therefore indicates a higher performance.

Discussion

The three main goals set for this review were as follows:

- Goal 1: Identify the health-related domains in which the *Wii Fit* series has been tested or used. A scientific database search was undertaken with reasoned exclusion criteria. We identified that the *Wii Fit* has been used for numerous health purposes and in various populations (Table 2). Balance training was identified as being the most recurrent topic in the literature and appears to be the field of predilection for the usage of the *Wii Fit* software. Another notable focus was the prevention of metabolic disorders as well as the improvement of health status in people with chronic disease.
- Goal 2: Understand the effect of *Wii Fit* in the identified populations (cf. Goal 1). A qualitative systematic review of studies including *Wii Fit* interventions was performed, with particular attention given to health and physical activity outcomes. *Wii Fit* was employed to prevent falls, to induce functional improvements in seniors or in subjects presenting neurodegenerative diseases, to treat orthopedic populations, *etc.* (Table 4). Overall, the effects of using *Wii Fit* were mainly positive, with the software being recurrently described as being able to induce similar benefits to traditional therapies. In addition, *Wii-Fit* interventions were linked to an improvement of health status in several different patients types (diabetic subjects, cancer patients...), however its preventive effect remains to be demonstrated.
- Goal 3: To conduct meta-analyses when possible to quantify the effect *Wii Fit* had on selected health-related domains. In regards to balance training, the results of meta-analyses revealed that *Wii Fit* interventions had a positive impact on BBS and TUG. Interestingly, *Wii Fit* interventions also appear very safe, with very low levels of injuries being reported.

Wii Fit for the prevention of metabolic disorders and health status improvement in patients

From light physical activity to moderate-to-vigorous physical activity, AVG elicit a wide range of intensities [23, 26, 41, 44, 45, 46, 48, 55, 56, 62, 64-66, 123]. However, it is difficult to state whether playing *Wii Fit* on a regular basis would allow one to meet the *American College of Sports Medicine's* recommendations for physical activity or could induce beneficial effects on health. Intervention studies reviewed in this article indicate that playing *Wii Fit* is not a strategy to consider in young adults (and children) for the prevention of cardio-metabolic disease, because it does not induce any significant increase in physical activity or any improvement in physical fitness [24, 60]. However, one study showed a significant and rapid weight loss during a *Wii Fit* intervention in postpartum women [64]. *Wii Fit* may also be a promising tool to aid seniors in maintaining a healthy lifestyle. Intervention studies have reported an increase in physical activity [8], physical fitness [18], and functional skills [110]. Playing *Wii Fit* also clearly appeared to be beneficial for various types of patients: Some studies have reported improvements to health status in chronic obstructive pulmonary disease, hemodialysis patients, diabetic subjects, and cancer patients [77-79, 87, 88]. While the preventive effects of *Wii Fit* remain to be demonstrated, the software may be of value in other clinical settings.

Wii Fit for balance training

Many of the intervention studies (55/68) were related to balance training or to the improvement of related functions, with a large majority of them (50/55, Table 4) describing a beneficial effect. The meta-analytic results supported these promising observations. Significant improvements were observed for BBS in both healthy subjects and patients, while a trend was noted for TUG improvements in patients. Interestingly, the meta-analyses also revealed no difference in improvements induced by traditional therapies and *Wii Fit* interventions for BBS, while TUG showed greater improvements following the *Wii Fit* intervention compared to after traditional therapy. Taken together, these outcomes suggest a possible therapeutic application for the software, with *Wii Fit* potentially being as valid as traditional training in some situations. However, a careful look at the qualitative analysis outcome (Table 4) mitigates the overall positive impression for some populations. For instance, *Wii Fit* intervention outcomes in children with cerebral palsy appeared somewhat contrasted, sometimes being successful [37], sometimes unsuccessful [35], or sometimes inducing improvements in some but not all of the parameters [36]. In addition, BBS evaluates balance in isolated balance-related tasks, and TUG combines a limited set of very simple actions (standing-up, walking and sitting-down). *Wii Fit*-induced improvements were only observed in BBS score and TUG, in a clinical setting, and were not associated with improvements in self-confidence in balance abilities (no changes in ABC), therefore it is unclear whether these improvements can be transferred to activities that occur during daily-life and positively impact the quality of life. The general impressions about *Wii Fit* interventions are, however, currently positive. Our review should therefore encourage further research in order to assist physiotherapists and health professionals in their decision to incorporate the use of *Wii Fit* into their treatment regimes. Considering that contrasted observations do exist, prescribing *Wii Fit* should still be considered with caution.

Wii Fit therapeutic content and Wii balance Board

It is unsurprising that *Wii Fit* has been the object of much attention among physical therapists. The specificities of the *Wii Fit* games taken together with the technical features of the *Wii Balance Board* tend to promote medial-lateral and anterior-posterior movements, mimicking exercises that are commonly used in physical rehabilitation programs [2, 47, 96]. The board is composed of multiple pressure sensors able to work together to follow the displacement of the vertical projection of the center of gravity on the floor. Moreover, the device has been validated against the "gold standard" laboratory-grade force platform for assessing standing balance [1]. In addition, high levels of adherence have frequently been reported in the reviewed studies (Table 3 & 4). One may therefore hypothesize that key features of the *Wii Fit* are the ludic elements that promote adherence in individuals who are not interested in traditional training programs. However, Deutsch et al. emphasizes one limitation of the *Wii Fit*, which favors the "knowledge of results" rather than the "knowledge of performance" model, i.e. subjects focus on scores rather than on the quality of movements [41]. This is an important finding, since this would limit the relevance of using *Wii Fit* at home without the supervision of a therapist checking the quality of movement. One difference with the traditional proprioceptive rehabilitation material is that the *Wii Balance Board* is unable to tilt. Medial-lateral and anterior-posterior displacements are the result of exteroceptive adaptive mechanisms triggered by visual and auditory feedback stimuli that depend on the game scenario.

Limitations

Firstly, the sub-analyses performed in patients included various pathologies. This was highlighted by the high level of heterogeneity between studies in the *Wii Fit vs*. traditional therapy meta-analyses (see I^2 in Fig 4B and 5B). While the overall meta-analyses described a positive effect, the results cannot be predictive of *Wii Fit* intervention-related changes in one specific population. This emphasizes the requirement for more research in order to determine the optimum usage of *Wii Fit* for each medical domain. Secondly, the attention given to AVG and other virtual reality devices for the purpose of promoting health has been constantly growing, even after the screening period of this review (July 2009-June 2015). Therefore we encourage readers to also review the new literature on the subject.

Conclusions

Originally designed as a ludic health and fitness promotion software, the *Wii Fit* series grabbed the attention of physical therapists due to the panel of features favoring body movements. Initial promising observations encouraged physicians, from various medical fields, to test the *Wii Fit* software on numerous populations. The literature still remains contrasted on the preventive effects of *Wii Fit* on chronic diseases. However, *Wii Fit* interventions were shown to be effective for the improvement of health status in various types of patients (chronic obstructive pulmonary disease, hemodialysis, renal complications, diabetes, cancer, etc.). Our review identified that the most notable focus of *Wii Fit* interventions were balance training. The *Wii Fit* has indeed been successfully used to prevent falls or to induce functional improvements in a wide range of healthy or pathologic populations (e.g. seniors, subjects with neurodegenerative diseases, orthopedic patients, children with developmental delay, multiple sclerosis patients, etc). Our meta-analysis supports the general positive impressions about *Wii Fit*, suggesting promising applications in a wide range of medical fields. The unexpected entry of a video game into the health device market could create innovative healthcare strategies, however, more research is required to validate these claims.

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