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Does an exercise programme integrating the Nintendo Wii Fit Balance Board improve balance in ambulatory children with Cerebral Palsy?

--Manuscript Draft--

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Abstract:	Background: Cerebral palsy is a common childhood movement disorder with balance impairment a common complaint. Active video games such as the Nintendo Wii-Fit have been found to be a valuable therapeutic tool, enjoyed by a variety of populations including children with CP but a synthesis of the research investigating its specific use for balance in children with CP is yet to be conducted. Objectives: To determine the effectiveness of a Nintendo Wii-Fit Balance board programme in improving balance in children with CP. Methods: A systematic search of the literature was conducted. A total of 6 studies matching inclusion and exclusion criteria were found and critically appraised by a modified version of Downs and Black Checklist. Results: All studies used the Nintendo Wii-Fit software, with variable programme length and frequency of sessions. All but one study demonstrated a significant improvement in at least one balance outcome post intervention with dynamic balance appearing to be greater influenced. Discussion: The impact of age on the results were inconclusive. Children with cognitive, visual or vestibular impairments may show less of an improvement. A 6 week programme appears sufficient providing training frequency remains high. Overall there is moderate evidence to suggest that a Nintendo Wii-Fit Balance Board programme can improve balance in children with CP. Conclusions: Balance training with a Nintendo Wii-Fit Balance Board can enhance balance in individuals with ambulatory CP. Due to limited evidence investigating ataxic or dyskinetic CP, results from this study should be generalised with caution to these subtypes. Future research should aim to further investigate the long term effects of the intervention.
Funding Information:	

Does an exercise programme integrating the Nintendo Wii Fit Balance Board improve balance in ambulatory children with Cerebral Palsy?

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Abstract

Background: Cerebral palsy is a common childhood movement disorder with balance impairment a common complaint. Active video games such as the Nintendo Wii-Fit have been found to be a valuable therapeutic tool, enjoyed by a variety of populations including children with CP but a synthesis of the research investigating its specific use for balance in children with CP is yet to be conducted.
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Discussion: The impact of age on the results were inconclusive. Children with cognitive, visual or vestibular impairments may show less of an improvement. A 6 week programme appears sufficient providing training frequency remains high. Overall there is moderate evidence to suggest that a Nintendo Wii-Fit Balance Board programme can improve balance in children with CP.
Conclusions: Balance training with a Nintendo Wii-Fit Balance Board can enhance balance in individuals with ambulatory CP. Due to limited evidence investigating ataxic or dyskinetic CP, results from this study should be generalised with caution to these subtypes. Future research should aim to further investigate the long term effects of the intervention.

Introduction

Cerebral palsy (CP) is the most common childhood movement disorder, with a prevalence of 2-2.5 per 1000 live births per year worldwide.[19] CP can be categorised into three groups based on the predominant neuromuscular abnormality; spastic, dyskinetic/athetoid and ataxic.[7] A common clinical problem in individuals with CP is impaired balance.[47] Previous research has demonstrated balance deficits ranging from 28%-43% depending on the nature of the balance task in individuals with CP

compared to controls.[21] As balance is critical for underlying normal movement, improvements in static and dynamic balance are important goals in rehabilitation for ambulatory children with CP.[34]

A variety of populations, including children with CP, enjoy the therapeutic use of active video games (AVG) such as the Nintendo Wii-Fit.[37] Significant improvements in balance have been demonstrated in individuals with Parkinson's Disease,[26] incomplete spinal cord injuries[43] and in individuals following a stroke.[3] Therefore it appears that AVG's might offer a promising intervention tool for therapy, however to date a synthesis of the literature pertaining to their impact on balance in individual with CP has yet to be published. The aim of this review is to determine the effectiveness of a Nintendo Wii-Fit Balance Board programme in improving the balance of ambulatory children with CP.

Methods

Search Strategy

A systematic literature search of electronic databases including MEDLINE, EMBASE, CINAHL, PEDro and Scopus was completed in September 2016 using the key terms and Boolean logic as listed in Table 1. The search was limited to peer-reviewed articles published in the English language. A total of 28 articles of interest were retrieved after duplicates were removed. Articles were screened by title and abstract, and when necessary full text, against inclusion and exclusion criteria. A detailed search strategy and a flow chart of the search can be seen in Table 2 and Figure 1 respectively.

Inclusion and exclusion criteria

Studies involving children aged 5 to 18 years with a formal diagnosis of CP and graded level 1, 2 or 3 in the Gross Motor Function Classification System (GMFCS) or the Expanded and Revised Gross Motor Function Classification System (GMFCS-ER) were included. Studies were only included if the intervention used a Nintendo Wii-fit Balance Board with the Nintendo Wii-Fit software and used a specific objective balance outcome measure. See Table 3 for detailed inclusion and exclusion criteria.

Quality index

To assess the methodological quality of the studies, a modified version of the Downs and Black checklist was used as it can be applied to both randomised controlled trials and non-randomised studies.[1, 12] Modifications were made to question 25 to weight it equally in the questionnaire as has been done previously.[46] Appraisal was completed by the lead author with uncertainty resolved by consensus. Results can be seen in Table 4.

Results

Six studies were identified through the search. A data extraction table can be seen in Table 5. The studies were undertaken in Sweden, Chile and South Africa and involved 90 participants in total. Participants were diagnosed with spastic or dyskinetic CP, aged five to 18 years. All studies used the Nintendo Wii-Fit Balance Board and software with a variety of games selected. Play time ranged from 20 to 40 minutes per session, two to five times a week for three to 12 weeks. Balance was measured by a variety of outcomes including Timed Up and Go (TUG), a timed Single Leg Stand (SLS) and Functional Reach Test (FRT). All but one study demonstrated a significant increase in at least one balance outcome post intervention.

All of the studies were scored on a checklist with a maximum of 27 points. All studies scored between 16 and 21 and demonstrated similar methodological flaws such as justification of sample size and blinding of participants.

Overall, there is moderate evidence to suggest a Nintendo-Wii Fit Balance Board exercise programme can improve balance in ambulatory children with CP.[41]

Methodological Analysis

All studies only partially described major confounding variables and no study made adjustments for the principal confounders in their results, making it difficult to establish their effect. Due to the natural variance of the presentation of an individual with CP, reporting of common confounding variables such as cognitive impairment,[9] and visual or vestibular disorders[5, 32] would aid in the clarity of interpretation of the results as well as determine whether the conclusions made can be generalised to the wider population.

None of the studies justified their sample size, which ranged from four to thirty participants. As such it could be speculated that there is a threat of being

underpowered, however five of the six studies did demonstrate at least a significant difference in one of the outcomes demonstrating sufficient power for this dependent variable.

Blinding of participants and outcome assessors was attempted in only one study[19] potentially reducing the risk of bias and improving the internal validity of the study. However the nature of the outcome measures used to assess balance are computationally automated and thus threat to bias from lack of outcome assessor bias is limited. In addition the lack of blinding of the intervention (balance exercises) mirrors clinical practice, therefore the results remain highly relevant to practice.

All studies used convenience sampling meaning studies may be influenced by selection bias. Therefore caution is advised when considering whether conclusions can be generalised to the wider population as the included samples may not be representative of the source population.

Discussion

Participants

Sub-Type of Cerebral Palsy

Four of the six studies[15, 16, 19, 29] only involved children with spastic CP, with only 3.3% of the total participants presenting with dyskinetic CP and none with ataxic CP. This is an important consideration as different subtypes are associated with different symptoms and impairments[7] and so interventions may have differing effects between CP subtypes. However, similar results from TUG have been found in participants with spastic CP[15] as well as dyskinetic CP[40] suggesting that perhaps the subtype of CP has little influence on those specific results. This could be explained by the inclusion criteria of grade 1, 2 or 3 GMFCS ensuring participants all had a similar level of mobility pre-intervention. Furthermore, the relevance of under-representing the ataxic subtype is questionable as they account for only 4.3% of the CP population[38] thus this subtype breakdown is typically of the wider population.

Age

The participant age's ranged from five to 18 years across the studies included in this review. Balance maturation is reached between the ages of ten and 12.[17, 23] Prior to this, children rely more upon their visual system as the vestibular system is last to develop.[23] This may explain why Gatica-Rojas et al.[16] found insignificant results in

their eyes closed condition as 80% of participants were younger than ten. Additionally, continually changing biomechanics caused by periods of rapid growth during puberty, forces sensory input systems to constantly recalibrate[8] perhaps affecting balance ability. The average age for pubertal peak height velocity is 11 to12 in females and 13 to 14 in males[31] therefore you may expect that participants of this age perform worse. Furthermore, although the brain remains 'plastic' throughout life, neural plasticity is maximal in the first few years of life, and then continues to decrease, suggesting that younger children may show greater improvements with balance interventions. [22,24] Due to the amalgamation of results across the studies and failure of the studies to report individual data, it is difficult to distinguish the effect of age on improvement within this review. However, when directly comparing mean ages to standing balance outcomes, results do suggest a relationship. Ramstrand and Lygnegard[29] demonstrated no significant improvement in CoP velocity with a mean participant age of 13.4 years, however Gatica-Rojas et al.[16] produced a mean improvement of 40.4% in participants with a mean age of 9.6 years. A similar relationship is not seen across the other balance measures suggesting this is not a universal pattern.

Participant Characteristics

In children with CP, 30-50% have a level of cognitive impairment, [9] 20% have visual disturbances,[5] and there is a high incidence of vestibular disorders.[32]Despite this, Ramstrand and Lygnegard[29] did not include cognitive impairment in their exclusion criteria or those with visual or vestibular disturbances. Therefore, there is a strong possibility that participants within this study would have displayed some of these traits. This may have affected some children's ability to fully engage and thus show improvements, whilst others may not have fully understood the requirements of the intervention or game instructions, perhaps contributing to the insignificant findings reported. In contrast, Jelsma et al.[19] also did not exclude cognitive impairment but demonstrated an improvement post intervention. However, unlike Ramstrand and Lygnegard[29], Jelsma et al.[19] had formally supervised sessions which may help to explain the difference in findings. This could suggest that balance intervention is most beneficial to those without visual or vestibular disorders, as well as suggesting

supervision may be required, especially for those with cognitive impairment in order to achieve an improvement in balance outcomes.

Intervention

Compliance

Only one study within this review included unsupervised intervention sessions.[29] Although this study concluded insignificant results, they were unable to account for compliance or choice of games as participants completed the intervention at home. However, this could be more reflective of clinical practice thereby highlighting supervision as an important factor to consider within intervention programmes.

Programme duration and frequency

Both the duration and frequency of the balance exercise programmes varied across the studies. Significant improvement in balance outcomes have been shown in both a 12 week programme with two sessions per week[40] and a shorter three week programme of 12 sessions.[19] Furthermore, although no statistical significance was shown, Gatica-Rojas et al.[15]
demonstrated a larger improvement in a shorter programme of six weeks with three sessions per week in both SLS compared to Tarakci et al.[40] and TUG compared to Tarakci et al.[39, 40] This could suggest that shorter programmes are sufficient to yield significant improvements in balance, providing the frequency remains high (multiple sessions per week). In addition, no relationship was found when comparing duration per session or total weekly training time in all outcome measures, suggesting that shorter sessions can produce similar results when frequency remains high. By increasing the frequency of sessions, the training stimulus needed to achieve neuroplasticity, as well as physiological and structural changes, is reached more readily, achieving a successful training effect and resulting in performance improvement.[30]This could explain why results suggest a trending between frequency of sessions and improvement in balance outcomes, more so than the duration of the exercise programme.
The same relationship between training frequency and balance improvement was not seen when comparing data between the studies using the static standing balance. Despite the increased training frequency, Ramstrand and Lygnegard[29] failed to show a significant improvement in static standing balance when using 5

sessions a week, however Gatica-Rojas et al's[16] programme of 3 sessions a week showed significant improvements. Ramstrand and Lygnegard's[29] possible compliance issues relating to their intervention may explain these findings. Furthermore, programmes with similar training frequency showed large differences in results when using Functional Forward Reach[39, 40]. However, the inclusion of additional treatments may have influenced these findings, such as Neurodevelopmental treatment (NDT) included within Tarakci et al.[39]

Game selection and level

The games selected for the intervention varied between studies, however according to a game analysis by Deutch et al[11] all selected games within this review trained aspects of balance and therefore suggest that the specific balance games selected is not highly important. In addition, within this review there seems to be no apparent relationship between the games selected and the outcome of the study.

Despite progression being a well-established principle within exercise in order to improve performance, only Tarakci et al.[40] directly stated that the training programme will be updated to higher levels of games every four weeks. No other study stated whether or not progression was considered within their training programmes and therefore it is assumed it was not. This could limit the amount of improvement seen through the intervention as a ceiling effect may prevent further balance improvement.

Outcome measures

The outcome measures used differ between the studies involved in this review, assessing static and dynamic balance. These include using a force plate to measure centre of pressure sway and velocity during static standing,[16 , 29] timed single leg stance,[15, 40] timed up and go,[15 , 39, 40] functional reach,[39 , 40] and Subtest 5 (balance) of the modified Bruininks-Oseretsky test of Motor Proficiency 2nd edition (BOT-2).[19] TUG is a widely used, quick, practical test of dynamic balance, requiring participants to rise from a seat, walk three meters, turn, return to the seat and sit down.[28] It is being increasingly used in paediatrics and has been found to be a reliable measure of dynamic balance in children with CP[18]. Although falls risk is multifaceted with balance being one of numerous factors, a decrease in falls post intervention can be used to determine whether an increase in TUG score is reflective of a functional balance improvement. However, there is currently no evidence supporting the

predictive ability of TUG in children with CP. Literature in adults is inconclusive, with some suggesting that three meters is insufficient for detecting subtle balance deficits,[5] whilst others concluding it can predict risk of falls in the elderly.[7, 36, 45] However, due to the functional nature of TUG, it could be suggested that an improvement in TUG score is applicable to a functional balance improvement in children with CP.

The FRT assesses dynamic standing balance,[14] by measuring the distance one can reach forwards whilst maintaining a fixed base of support in standing.[39] Some evidence concludes the FRT to be a valid and reliable measure of dynamic balance in children with CP[15] whereas others conclude it a weak measure, suggesting the need to consider compensatory mechanisms such as trunk movement.[20] Modifications to include sideways reaching also are suggested, which have demonstrated good validity and reliability[4] and were included within Tarakci et al.[39] Therefore it could be suggested that FRT is a good test of dynamic standing balance, however it is important to consider the effect of compensatory mechanisms upon this outcome measure.

Both Gatica-Rojas et al.[16] and Ramstrand and Lygnegard[29] measured posturography by recording CoP velocity to determine a participant's static balance pre and post intervention. Posturography has been shown to be sensitive to small changes,[42] effective at measuring therapeutic efficiency[25] and able to predict falls risk.[27] Participants were asked to stand still for 20 or 30 seconds in Gatica-Rojas et al.[16] and Ramstrand and Lygnegard[29].However, a literature review investigating the reliability of CoP measures suggests that a minimum of 90 seconds with three to five repetitions is required to achieve reliable data[33] inferring that both studies may have failed to comply with such recommendations questioning the reliability of the data.

The SLS or timed one leg stand (TOLS) is a common balance measure used to assess static balance and postural stability.[40] Participants are timed how long they are able to stand on one leg.[13] Gatica-Rojas et al.[15] demonstrated an average increase of 28.0%, the equivalent of 6.2 seconds, although results were not deemed statistically significant. Conversely, Tarakci et al.[40] demonstrated a significant improvement in SLS. Although Shimada et al.[35] consider the SLS potentially useful for predicting functional improvement, there is very limited evidence investigating the reliability and validity of SLS for measuring static balance in any population, including children with CP. Therefore it is questionable whether changes seen in

SLS within the included studies would accurately represent a functional improvement.

Jelsma et al.[19] used a modified version of subtest-5 of the BOT-2, which focuses on balance, including tasks such as standing heel-toe on a balance beam.[10] The BOT-2 as a whole has shown moderate to high reliability in healthy children[10] as well as in those with learning difficulties,[44] however children with CP were excluded from this study. No other studies have evaluated the use of BOT-2 in children with CP, like those in Jelsma et al.[19] Furthermore, when specifically looking at 'body coordination', which includes subtest-5, highly variable reliability coefficients have been found[10] further suggesting that results from Jelsma et al.[19] may be unreliable. Although all but one participant showed an improvement in their scores post-intervention, due to being tested a total of 12 times, it can be questioned whether these results are due to a practice effect which has been found to be prevalent within this balance subtest.[10] Therefore due to its questionable reliability and possible practice effect, Jelsma et al.[19] results may not truly represent balance improvement post-intervention.

It is important to consider the validity and reliability of each outcome measure as well as evidence supporting its use within the target population. Evidence supports the use of TUG and FRT in children with CP, both of which found significant improvement post-intervention across the studies, suggesting a positive relationship between Nintendo Wii-Fit Balance Board intervention and an improvement in dynamic balance. Results from measures of static balance, such as SLS and TOLS, may be more variable. Furthermore, due to the lack of evidence to support the use of these outcome measures in children with CP, it can be questioned as to whether these results can be relied upon as a true representation of balance improvement.

Only Jelsma et al[19] completed post-intervention follow up, demonstrating a significant improvement in the BOT-2 Subtest 5 (Balance) after intervention, and two months post-intervention. However, as no other study investigated the retention of the balance skills developed, it is not possible to draw conclusions of whether the balance improvement is retained after intervention as stopped.

Conclusion

Overall, there is moderate evidence to suggest a Nintendo Wii-Fit Balance Board intervention can improve balance in children with CP. However, when applying these results to clinical practice, there are many factors to consider. There is a lack of evidence within this review to include ataxic or dyskinetic CP, and so conclusions applied to these subtypes must be done with caution. Results regarding the impact of age upon balance improvement are inconclusive, however it can be suggested that older children, or those undergoing a pubescent growth spurt may show less improvement. Children with cognitive, visual or vestibular impairments may also show less improvement. It appears that a 6 week programme is sufficient to show balance improvement, however training frequency should remain high. Only one study within this review investigated the long term effects of balance intervention and so further research is needed in this area. The game selection from the balance range on the Nintendo Wii-Fit software appears to have no impact on results although it was not clear whether regularly increasing game levels would influence improvement. Results suggest greater improvements in balance outcomes when sessions are supervised, ensuring good compliance to the programme. Intervention appears more beneficial for dynamic balance than static balance, with evidence suggesting TUG and FRT are more appropriate outcome measures to use in children with CP than SLS and static balance.

Limitations

As grey literature was not included within this search, as well as non-English-language studies being excluded there is possible publication bias resulting in the risk of quality evidence being missed from this review.[2] None of the articles within this review included participants from all three sub-types of CP, possibly limiting the generalisability of the results to the entire population of children diagnosed with CP.

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Table 1 – Search Terms

Key Concept	**Combinations**
Cerebral Palsy	Cerebral Palsy
Nintendo Wii	Nintendo Wii
Balance	Balanc*
Children	child* or adolescent* or youth* or teen* or p*diatric*

Table 2 – Detailed Search Strategy using MySearch

Key Concept	Combinations
Cerebral Palsy	Search 1 – Cerebral Palsy **= 56,354**
Nintendo Wii	Search 2 – Cerebral Palsy AND Nintendo Wii **= 54**
Balance	Search 3 – Cerebral Palsy AND Nintendo Wii AND Balanc* **= 29**
Children	Search 4 – Cerebral Palsy AND Nintendo Wii AND Balanc* AND child* or adolescent* or youth* or teen* or p*diatric* **= 41**

Figure 1 - PRISMA Flow diagram of search

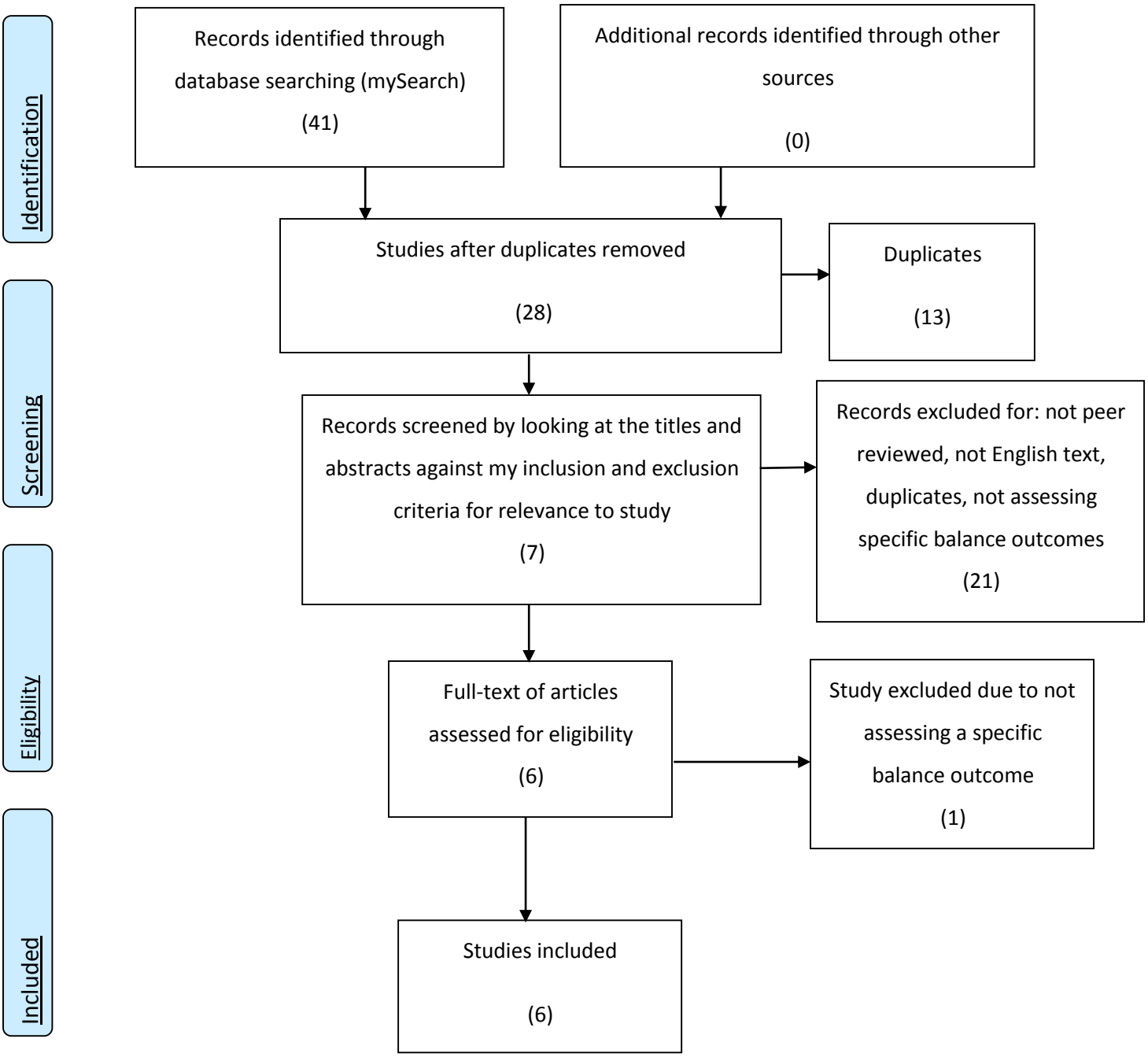

Table 3 – Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
▪ Diagnosis of any subtype of cerebral palsy ▪ Grade 1, 2 or 3 on the Gross Motor Function Classification System (GMFCS) or Expanded and Revised Gross Motor Function Classification System (GMFCS-ER) ▪ Intervention using a Nintendo Wii-Fit Balance Board with the Nintendo Wii-Fit software ▪ Balance as a specific outcome measure	▪ Aged <5 or >18 years ▪ Intervention using other interactive games other than the Nintendo Wii-Fit Balance Board ▪ Balance not a specific outcome measure

Table 4 – Modified Downs and Black Checklist

Question	Gatica-Rojas et al (2016b)	Taraki et al (2016)	Taraki et al (2013)	Jelsma et al (2013)	Gatica-Rojas et al (2016a)	Ramastrand and Lyngnegard (2012)
1	1	1	1	1	1	1
2	1	1	1	1	1	1
3	1	1	1	1	1	1
4	1	1	1	1	1	1
5	1	1	1	1	1	1
6	1	1	1	1	1	1
7	1	1	1	1	1	1
8	1	0	0	1	0	0
9	1	1	1	1	1	1
10	1	1	0	1	0	1
11	UTD	UTD	1	UTD	UTD	UTD
12	UTD	UTD	1	1	UTD	UTD
13	1	1	1	1	1	1
14	0	0	0	0	0	0
15	0	0	0	1	0	0
16	1	1	1	1	1	1
17	1	1	UTD	1	1	1
18	1	1	1	1	1	1
19	1	1	1	1	1	0
20	1	1	1	1	1	1
21	UTD	1	1	UTD	1	0
22	UTD	1	1	1	UTD	UTD
23	0	1	0	1	0	1
24	0	UTD	0	UTD	0	UTD
25	0	0	0	0	0	0
26	1	1	1	1	1	1
27	0	0	0	0	0	0
TOTAL	**17**	**19**	**18**	**21**	**16**	**16**

Table 5 – Date Extraction Table

Authors and Design	Subjects	Exclusion criteria	Intervention	Results	D& B Score	Comments
Gatica-Rojas et al (2016b) Pilot Study	10 participants 6-17 yrs 2 female 8 male Spastic CP Hemiplegic, diplegic or monoplegic CP Level 1 or 2 on GMFCS	Cognitive impairment Epilepsy Grade 3 or more on MMAS in ankle plantar flexor muscles. Previous surgeries in LL over the last 2 years Botox in LL in last 10 months Uncorrected visual or vestibular impairment	18 sessions over 6 weeks 3 x a week 25mins each PT supervised/supported patients Snowboard, Penguin slide and Super Hula Hoop and Yoga game.	**I**mproved static standing balance; Significantly reduced the Centre of Pressure (CoP) Sway by mean of 2.18, eyes open condition – (40.370% decrease) Insignificantly reduced CoP by mean of 0.69 eyes closed condition – (13.45% decrease)	18	Only spastic subtype included Mean age; 9.61 years
Tarakci et al (2013) Pilot Study	14 participants 5-17 yrs 3 female 11 males Spastic/ Dyskinetic CP Hemiplegic or Diplegic CP Level 1, 2 or 3 on GMFMCS-ER Normal-mild level	Epilepsy Grade 3 or more on MAS in lower extremities -Inability to cooperate with exercise or measurement	24 sessions over 12 weeks 2 x a week Approx. 40 minutes each PT supervised/supported the patients Ski Slalom, Soccer Heading, Tilt Table and Walking a tight rope.	One leg standing test significantly improved; Mean Right increase 0.4s (6.06% increase) Mean Left increase 3.09 (57.12% increase) Mean Timed up and Go significantly decreased by 3.69s (20.21% decrease) Mean Functional reach test significantly increased by 1.72cm (8.28% increase)	19	Includes spastic and dyskinetic type CP Mean age; 12.07 years

	intellectual disability					
Ramstrand and Lyngnegard (2012) Randomised cross-over design	18 participants 10 females 8 males 8-17rs Hemiplegic or diplegic Level 1 or 2 on GMFCS Able to walk unaided for 10 minutes Not previously used NWBB		25 sessions over 5 weeks 5 x a week Minimum of 30 minutes each Played at home without PT supervision. Diary to record playing time Soccer Heading, Ski Slalom, Ski Jump, Table Tilt, Tightrope walk and Balance Bubble.	Standing balance (using the modified sensory organization test (mSOT)) found no significant difference in any condition. Reactive balance evaluated by investigating the latency response in the lower leg musculature following an external perturbation; found no significant difference (equipment failure)	15	Only spastic CP included Mean age; 13.41 years No exclusion criteria; Doesn't take into account main confounding variables including epilepsy, spasticity, and cognitive impairment, visual or vestibular disorders. Wii intervention within participants home and not supervised – reliable? Equipment failure during reactive balance testing
Gatica-Rojas et al (2016a) Pilot Case Series	4 males 8-16yrs Spastic CP Hemiplegic or diplegic CP Level 1 or 2 in GMFCS and GMFCS-ER	Cognitive impairment Epilepsy Previous surgeries in the LL over the last 2 years Uncorrected visual or vestibular impairment	18 sessions over 6 weeks 3 x a week 25 minutes per session PT supervise/supported patients Snowboard, Penguin Slide and Super Hula Hoop, Yoga game	Mean Timed up and Go significantly decreased by 2.81s (22.50% decrease) Mean Timed one leg standing showed no significant improvement increasing by 6.22s (27.96% increase) however the average post-training time was higher than the average pre-training time.	**17**	Only spastic CP included Mean age; 12 years

Jelsma et al (2013) AB, Single subject	14 participants 7-14yrs Spastic CP Hemiplegic Level 1 or 2 on the GMFCS	Epilepsy Visual or hearing impairments Undergoing orthopaedic surgery for serial plastering at the time of date collection Access to Wii Fit at home	12 sessions over 3 weeks 4 x a week 25mins each Research Assistant recorded game score, time, rest breaks and absenteeism. Snowboarding, Skiing, Penguin Game, Soccer, Bubble Game and Hula-hoop.	Significant difference in BOT-2 Subtest 5 (balance) after intervention, and after 2 months	**22**	Only spastic CP included Unable to determine mean age Not taking into account cognitive impairments Tested 9 times – training effect?
Taraki et al (2016) Randomised control trial	30 children 11 female 19 male 5-18yrs Diagnosis of spastic of dyskinetic type CP Diplegic or hemiplegic CP Level 1, 2 or 3 of GMFCS Confirmed mental ability to be able to adapt to exercise	Epilepsy Botulinum toxin A treatment for the lower extremities in the previous 6 months - excessive spasticity in any joint (score > 2 on the Modified Ashworth Scale	12 weeks 2 x a week 50 min session 30 mins of Neurodevelopment treatment (NDT) approach plus 20 mins of Wii or conventional balance programme PT supervised/supported the patients Slalom skiing, Walking on a rope, Tilt Table and Heading the ball	Significant increase in mean forward reach increased by 4.27cm (21.00% increase) Significant increase in mean leftward reach increased by 3.2cm (20.96% increase) Insignificant increase in the mean rightward reach, increased by 3.6cm (22.42%) Significant decrease found in mean Timed up and Go, decreased by 2.34s (18.05% decrease)	**20**	Spastic and dyskinetic type CP included Mean age; 10.46 years NDT and Nintendo Wii-Fit Balance Board programme well defined

KEY: CP, Cerebral Palsy; LL, Lower limb; MMAS, Modified Modified Ashworth Scale; BOT-2, Modified Bruininks-Oseretsky test of Motor Proficiency 2nd edition; NDT, Neurodevelopmental treatment; GMFCS, Gross motor function classification system.

Response to Reviewers

Reviewer #1: Major Comments:

Page 6, Age: The author suggests a potential increased benefit for younger children, but only sites the differences in COP velocity between studies as evidence. More evidence or explanation is needed to suggest that younger children would have more benefit (or removal of suggested conclusion).

I have amended the manuscript by removing the original citation and adding in two alternatives evidencing my suggestion of a greater benefit to younger children.

Page 7, Programme duration and frequency: Was the duration per session examined? For example, were there trends towards greater improvement with longer sessions (ex 30 minutes compared to 15 minutes)? Or perhaps considering total training time per week instead?

The duration of sessions and total training time per week have now been examined and no relationship has been found between increased training time/training time per week and the amount of improvement shown in the outcome measures within this review.

I have amended the manuscript to include a sentence stating that this has been considered but no relationship has been found.

Page 8, Outcome Measures, TUG: TUG is a reliable and valid measure of what in children with CP? The paragraph later describes how it is not a reliable measure of fall risk.

TUG has been found to be a reliable measure of dynamic balance in children with cerebral palsy.

I have amended the manuscript to state it is a reliable measure of dynamic balance and have included a more current reference more suited to my target population

Page 10: Retention should also be discussed, though it appears only one study did additional post-intervention follow up (Jelsma et al 2013).

I have amended the manuscript to include a sentence regarding the post-intervention follow up demonstrated by Jelsma et al (2013), and that conclusions cannot be drawn from this review regarding retention due to the other five studies failing to discuss longer term follow up.

Minor Comments:

Page 3, Introduction: misspelling of "stroke"

I have amended the manuscript to the correct spelling of stroke.

Figure 2: Box with "records excluded" is cut off at the bottom

I have amended the table so that all text can be seen within the boxes.

Page 4, Inclusion and exclusion criteria: Wii-Fit Balance Board should all be capitalized (or title changed to be consistent)

I have amended the text so that Nintendo Wii-Fit Balance Board is consistently capitalized throughout.

Page 5, top of page: A discussion on possible confounding variables that may have been present is warranted. For example, discussion of the concurrence of visual disturbances and vestibular disorders with CP would be an appropriate confounding variable to mention here.

I have added in a sentence stating the major confounding variables of visual and vestibular disorders and cognitive impairment – which is explained in more detail, with concurrence rates, on page 6 under participant characteristics.

Page 9, mid of top paragraph: "be a valid a reliable" should be "be a valid and reliable"

I have amended the manuscript so that it now reads ‘be a valid and reliable’

Does an exercise programme integrating the Nintendo Wii-Fit Balance Board improve balance in ambulatory children with Cerebral Palsy?

Abstract

Background: Cerebral palsy is a common childhood movement disorder with balance impairment a common complaint. Active video games such as the Nintendo Wii-Fit have been found to be a valuable therapeutic tool, enjoyed by a variety of populations including children with CP but a synthesis of the research investigating its specific use for balance in children with CP is yet to be conducted.
Objectives: To determine the effectiveness of a Nintendo Wii-Fit Balance board programme in improving balance in children with CP.
Methods: A systematic search of the literature was conducted. A total of 6 studies matching inclusion and exclusion criteria were found and critically appraised by a modified version of Downs and Black Checklist.
Results: All studies used the Nintendo Wii-Fit software, with variable programme length and frequency of sessions. All but one study demonstrated a significant improvement in at least one balance outcome post intervention with dynamic balance appearing to be greater influenced.
Discussion: The impact of age on the results were inconclusive. Children with cognitive, visual or vestibular impairments may show less of an improvement. A 6 week programme appears sufficient providing training frequency remains high. Overall there is moderate evidence to suggest that a Nintendo Wii-Fit Balance Board programme can improve balance in children with CP.
Conclusions: Balance training with a Nintendo Wii-Fit Balance Board can enhance balance in individuals with ambulatory CP. Due to limited evidence investigating ataxic or dyskinetic CP, results from this study should be generalised with caution to these subtypes. Future research should aim to further investigate the long term effects of the intervention.
Keywords: Balance; Exercise; Systematic review; Intervention; Outcome Measures

Introduction

Cerebral palsy (CP) is the most common childhood movement disorder, with a prevalence of 2-2.5 per 1000 live births per year worldwide.[19] CP can be categorised into three groups based on the predominant neuromuscular abnormality; spastic, dyskinetic/athetoid and ataxic.[7] A common clinical problem in individuals with CP is impaired balance.[47] Previous research has demonstrated balance deficits ranging

from 28%-43% depending on the nature of the balance task in individuals with CP compared to controls.[21] As balance is critical for underlying normal movement, improvements in static and dynamic balance are important goals in rehabilitation for ambulatory children with CP.[34]

A variety of populations, including children with CP, enjoy the therapeutic use of active video games (AVG) such as the Nintendo Wii-Fit.[37] Significant improvements in balance have been demonstrated in individuals with Parkinson's Disease,[26] incomplete spinal cord injuries[43] and in individuals following a stroke.[3] Therefore it appears that AVG's might offer a promising intervention tool for therapy, however to date a synthesis of the literature pertaining to their impact on balance in individual with CP has yet to be published. The aim of this review is to determine the effectiveness of a Nintendo Wii-Fit Balance Board programme in improving the balance of ambulatory children with CP.

Methods

Search Strategy

A systematic literature search of electronic databases including MEDLINE, EMBASE, CINAHL, PEDro and Scopus was completed in September 2016 using the key terms and Boolean logic as listed in Table 1. The search was limited to peer-reviewed articles published in the English language. A total of 28 articles of interest were retrieved after duplicates were removed. Articles were screened by title and abstract, and when necessary full text, against inclusion and exclusion criteria. A detailed search strategy and a flow chart of the search can be seen in Table 2 and Figure 1 respectively.

Inclusion and exclusion criteria

Studies involving children aged 5 to 18 years with a formal diagnosis of CP and graded level 1, 2 or 3 in the Gross Motor Function Classification System (GMFCS) or the Expanded and Revised Gross Motor Function Classification System (GMFCS-ER) were included. Studies were only included if the intervention used a Nintendo Wii-fit Balance Board with the Nintendo Wii-Fit software and used a specific objective balance outcome measure. See Table 3 for detailed inclusion and exclusion criteria.

Quality index

To assess the methodological quality of the studies, a modified version of the Downs and Black checklist was used as it can be applied to both randomised controlled trials and non-randomised studies.[1, 12] Modifications were made to question 25 to weight it equally in the questionnaire as has been done previously.[46] Appraisal was completed by the lead author with uncertainty resolved by consensus. Results can be seen in Table 4.

Results

Six studies were identified through the search. A data extraction table can be seen in Table 5. The studies were undertaken in Sweden, Chile and South Africa and involved 90 participants in total. Participants were diagnosed with spastic or dyskinetic CP, aged five to 18 years. All studies used the Nintendo Wii-Fit Balance Board and software with a variety of games selected. Play time ranged from 20 to 40 minutes per session, two to five times a week for three to 12 weeks. Balance was measured by a variety of outcomes including Timed Up and Go (TUG), a timed Single Leg Stand (SLS) and Functional Reach Test (FRT). All but one study demonstrated a significant increase in at least one balance outcome post intervention.

All of the studies were scored on a checklist with a maximum of 27 points. All studies scored between 16 and 21 and demonstrated similar methodological flaws such as justification of sample size and blinding of participants.

Overall, there is moderate evidence to suggest a Nintendo-Wii Fit Balance Board exercise programme can improve balance in ambulatory children with CP.[41]

Methodological Analysis

All studies only partially described major confounding variables and no study made adjustments for the principal confounders in their results, making it difficult to establish their effect. Due to the natural variance of the presentation of an individual with CP, reporting of common confounding variables such as cognitive impairment,[9] and visual or vestibular disorders[5, 32] would aid in the clarity of interpretation of the results as well as determine whether the conclusions made can be generalised to the wider population.

None of the studies justified their sample size, which ranged from four to thirty participants. As such it could be speculated that there is a threat of being

underpowered, however five of the six studies did demonstrate at least a significant difference in one of the outcomes demonstrating sufficient power for this dependent variable.

Blinding of participants and outcome assessors was attempted in only one study[19] potentially reducing the risk of bias and improving the internal validity of the study. However the nature of the outcome measures used to assess balance are computationally automated and thus threat to bias from lack of outcome assessor bias is limited. In addition the lack of blinding of the intervention (balance exercises) mirrors clinical practice, therefore the results remain highly relevant to practice.

All studies used convenience sampling meaning studies may be influenced by selection bias. Therefore caution is advised when considering whether conclusions can be generalised to the wider population as the included samples may not be representative of the source population.

Discussion

Participants

Sub-Type of Cerebral Palsy

Four of the six studies[15, 16, 19, 29] only involved children with spastic CP, with only 3.3% of the total participants presenting with dyskinetic CP and none with ataxic CP. This is an important consideration as different subtypes are associated with different symptoms and impairments[7] and so interventions may have differing effects between CP subtypes. However, similar results from TUG have been found in participants with spastic CP[15] as well as dyskinetic CP[40] suggesting that perhaps the subtype of CP has little influence on those specific results. This could be explained by the inclusion criteria of grade 1, 2 or 3 GMFCS ensuring participants all had a similar level of mobility pre-intervention. Furthermore, the relevance of under-representing the ataxic subtype is questionable as they account for only 4.3% of the CP population[38] thus this subtype breakdown is typically of the wider population.

Age

The participant age's ranged from five to 18 years across the studies included in this review. Balance maturation is reached between the ages of ten and 12.[17, 23] Prior to this, children rely more upon their visual system as the vestibular system is last to develop.[23] This may explain why Gatica-Rojas et al.[16] found insignificant results in

their eyes closed condition as 80% of participants were younger than ten. Additionally, continually changing biomechanics caused by periods of rapid growth during puberty, forces sensory input systems to constantly recalibrate[8] perhaps affecting balance ability. The average age for pubertal peak height velocity is 11 to12 in females and 13 to 14 in males[31] therefore you may expect that participants of this age perform worse. Furthermore, although the brain remains 'plastic' throughout life, neural plasticity is maximal in the first few years of life, and then continues to decrease, suggesting that younger children may show greater improvements with balance interventions. [22,24] Due to the amalgamation of results across the studies and failure of the studies to report individual data, it is difficult to distinguish the effect of age on improvement within this review. However, when directly comparing mean ages to standing balance outcomes, results do suggest a relationship. Ramstrand and Lygnegard[29] demonstrated no significant improvement in CoP velocity with a mean participant age of 13.4 years, however Gatica-Rojas et al.[16] produced a mean improvement of 40.4% in participants with a mean age of 9.6 years. A similar relationship is not seen across the other balance measures suggesting this is not a universal pattern.

Participant Characteristics

In children with CP, 30-50% have a level of cognitive impairment, [9] 20% have visual disturbances,[5] and there is a high incidence of vestibular disorders.[32]Despite this, Ramstrand and Lygnegard[29] did not include cognitive impairment in their exclusion criteria or those with visual or vestibular disturbances. Therefore, there is a strong possibility that participants within this study would have displayed some of these traits. This may have affected some children's ability to fully engage and thus show improvements, whilst others may not have fully understood the requirements of the intervention or game instructions, perhaps contributing to the insignificant findings reported. In contrast, Jelsma et al.[19] also did not exclude cognitive impairment but demonstrated an improvement post intervention. However, unlike Ramstrand and Lygnegard[29], Jelsma et al.[19] had formally supervised sessions which may help to explain the difference in findings. This could suggest that balance intervention is most beneficial to those without visual or vestibular disorders, as well as suggesting

supervision may be required, especially for those with cognitive impairment in order to achieve an improvement in balance outcomes.

Intervention

Compliance

Only one study within this review included unsupervised intervention sessions.[29] Although this study concluded insignificant results, they were unable to account for compliance or choice of games as participants completed the intervention at home. However, this could be more reflective of clinical practice thereby highlighting supervision as an important factor to consider within intervention programmes.

Programme duration and frequency

Both the duration and frequency of the balance exercise programmes varied across the studies. Significant improvement in balance outcomes have been shown in both a 12 week programme with two sessions per week[40] and a shorter three week programme of 12 sessions.[19] Furthermore, although no statistical significance was shown, Gatica-Rojas et al.[15]
demonstrated a larger improvement in a shorter programme of six weeks with three sessions per week in both SLS compared to Tarakci et al.[40] and TUG compared to Tarakci et al.[39, 40] This could suggest that shorter programmes are sufficient to yield significant improvements in balance, providing the frequency remains high (multiple sessions per week). In addition, no relationship was found when comparing duration per session or total weekly training time in all outcome measures, suggesting that shorter sessions can produce similar results when frequency remains high. By increasing the frequency of sessions, the training stimulus needed to achieve neuroplasticity, as well as physiological and structural changes, is reached more readily, achieving a successful training effect and resulting in performance improvement.[30]This could explain why results suggest a trending between frequency of sessions and improvement in balance outcomes, more so than the duration of the exercise programme.
The same relationship between training frequency and balance improvement was not seen when comparing data between the studies using the static standing balance. Despite the increased training frequency, Ramstrand and Lygnegard[29] failed to show a significant improvement in static standing balance when using 5

sessions a week, however Gatica-Rojas et al's[16] programme of 3 sessions a week showed significant improvements. Ramstrand and Lygnegard's[29] possible compliance issues relating to their intervention may explain these findings. Furthermore, programmes with similar training frequency showed large differences in results when using Functional Forward Reach[39, 40]. However, the inclusion of additional treatments may have influenced these findings, such as Neurodevelopmental treatment (NDT) included within Tarakci et al.[39]

Game selection and level

The games selected for the intervention varied between studies, however according to a game analysis by Deutch et al[11] all selected games within this review trained aspects of balance and therefore suggest that the specific balance games selected is not highly important. In addition, within this review there seems to be no apparent relationship between the games selected and the outcome of the study.

Despite progression being a well-established principle within exercise in order to improve performance, only Tarakci et al.[40] directly stated that the training programme will be updated to higher levels of games every four weeks. No other study stated whether or not progression was considered within their training programmes and therefore it is assumed it was not. This could limit the amount of improvement seen through the intervention as a ceiling effect may prevent further balance improvement.

Outcome measures

The outcome measures used differ between the studies involved in this review, assessing static and dynamic balance. These include using a force plate to measure centre of pressure sway and velocity during static standing,[16 , 29] timed single leg stance,[15, 40] timed up and go,[15 , 39, 40] functional reach,[39 , 40] and Subtest 5 (balance) of the modified Bruininks-Oseretsky test of Motor Proficiency 2nd edition (BOT-2).[19] TUG is a widely used, quick, practical test of dynamic balance, requiring participants to rise from a seat, walk three meters, turn, return to the seat and sit down.[28] It is being increasingly used in paediatrics and has been found to be a reliable measure of dynamic balance in children with CP[18]. Although falls risk is multifaceted with balance being one of numerous factors, a decrease in falls post intervention can be used to determine whether an increase in TUG score is reflective of a functional balance improvement. However, there is currently no evidence supporting the

predictive ability of TUG in children with CP. Literature in adults is inconclusive, with some suggesting that three meters is insufficient for detecting subtle balance deficits,[5] whilst others concluding it can predict risk of falls in the elderly.[7, 36, 45] However, due to the functional nature of TUG, it could be suggested that an improvement in TUG score is applicable to a functional balance improvement in children with CP.

The FRT assesses dynamic standing balance,[14] by measuring the distance one can reach forwards whilst maintaining a fixed base of support in standing.[39] Some evidence concludes the FRT to be a valid and reliable measure of dynamic balance in children with CP[15] whereas others conclude it a weak measure, suggesting the need to consider compensatory mechanisms such as trunk movement.[20] Modifications to include sideways reaching also are suggested, which have demonstrated good validity and reliability[4] and were included within Tarakci et al.[39] Therefore it could be suggested that FRT is a good test of dynamic standing balance, however it is important to consider the effect of compensatory mechanisms upon this outcome measure.

Both Gatica-Rojas et al.[16] and Ramstrand and Lygnegard[29] measured posturography by recording CoP velocity to determine a participant's static balance pre and post intervention. Posturography has been shown to be sensitive to small changes,[42] effective at measuring therapeutic efficiency[25] and able to predict falls risk.[27] Participants were asked to stand still for 20 or 30 seconds in Gatica-Rojas et al.[16] and Ramstrand and Lygnegard[29].However, a literature review investigating the reliability of CoP measures suggests that a minimum of 90 seconds with three to five repetitions is required to achieve reliable data[33] inferring that both studies may have failed to comply with such recommendations questioning the reliability of the data.

The SLS or timed one leg stand (TOLS) is a common balance measure used to assess static balance and postural stability.[40] Participants are timed how long they are able to stand on one leg.[13] Gatica-Rojas et al.[15] demonstrated an average increase of 28.0%, the equivalent of 6.2 seconds, although results were not deemed statistically significant. Conversely, Tarakci et al.[40] demonstrated a significant improvement in SLS. Although Shimada et al.[35] consider the SLS potentially useful for predicting functional improvement, there is very limited evidence investigating the reliability and validity of SLS for measuring static balance in any population, including children with CP. Therefore it is questionable whether changes seen in

SLS within the included studies would accurately represent a functional improvement.

Jelsma et al.[19] used a modified version of subtest-5 of the BOT-2, which focuses on balance, including tasks such as standing heel-toe on a balance beam.[10] The BOT-2 as a whole has shown moderate to high reliability in healthy children[10] as well as in those with learning difficulties,[44] however children with CP were excluded from this study. No other studies have evaluated the use of BOT-2 in children with CP, like those in Jelsma et al.[19] Furthermore, when specifically looking at 'body coordination', which includes subtest-5, highly variable reliability coefficients have been found[10] further suggesting that results from Jelsma et al.[19] may be unreliable. Although all but one participant showed an improvement in their scores post-intervention, due to being tested a total of 12 times, it can be questioned whether these results are due to a practice effect which has been found to be prevalent within this balance subtest.[10] Therefore due to its questionable reliability and possible practice effect, Jelsma et al.[19] results may not truly represent balance improvement post-intervention.

It is important to consider the validity and reliability of each outcome measure as well as evidence supporting its use within the target population. Evidence supports the use of TUG and FRT in children with CP, both of which found significant improvement post-intervention across the studies, suggesting a positive relationship between Nintendo Wii-Fit Balance Board intervention and an improvement in dynamic balance. Results from measures of static balance, such as SLS and TOLS, may be more variable. Furthermore, due to the lack of evidence to support the use of these outcome measures in children with CP, it can be questioned as to whether these results can be relied upon as a true representation of balance improvement.

Only Jelsma et al[19] completed post-intervention follow up, demonstrating a significant improvement in the BOT-2 Subtest 5 (Balance) after intervention, and two months post-intervention. However, as no other study investigated the retention of the balance skills developed, it is not possible to draw conclusions of whether the balance improvement is retained after intervention as stopped.

Conclusion

Overall, there is moderate evidence to suggest a Nintendo Wii-Fit Balance Board intervention can improve balance in children with CP. However, when applying these results to clinical practice, there are many factors to consider. There is a lack of evidence within this review to include ataxic or dyskinetic CP, and so conclusions applied to these subtypes must be done with caution. Results regarding the impact of age upon balance improvement are inconclusive, however it can be suggested that older children, or those undergoing a pubescent growth spurt may show less improvement. Children with cognitive, visual or vestibular impairments may also show less improvement. It appears that a 6 week programme is sufficient to show balance improvement, however training frequency should remain high. Only one study within this review investigated the long term effects of balance intervention and so further research is needed in this area. The game selection from the balance range on the Nintendo Wii-Fit software appears to have no impact on results although it was not clear whether regularly increasing game levels would influence improvement. Results suggest greater improvements in balance outcomes when sessions are supervised, ensuring good compliance to the programme. Intervention appears more beneficial for dynamic balance than static balance, with evidence suggesting TUG and FRT are more appropriate outcome measures to use in children with CP than SLS and static balance.

Limitations

As grey literature was not included within this search, as well as non-English-language studies being excluded there is possible publication bias resulting in the risk of quality evidence being missed from this review.[2] None of the articles within this review included participants from all three sub-types of CP, possibly limiting the generalisability of the results to the entire population of children diagnosed with CP.

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Table 1 – Search Terms

Key Concept	**Combinations**
Cerebral Palsy	Cerebral Palsy
Nintendo Wii	Nintendo Wii
Balance	Balanc*
Children	child* or adolescent* or youth* or teen* or p*diatric*

Table 2 – Detailed Search Strategy using MySearch

Key Concept	Combinations
Cerebral Palsy	Search 1 – Cerebral Palsy **= 56,354**
Nintendo Wii	Search 2 – Cerebral Palsy AND Nintendo Wii **= 54**
Balance	Search 3 – Cerebral Palsy AND Nintendo Wii AND Balanc* **= 29**
Children	Search 4 – Cerebral Palsy AND Nintendo Wii AND Balanc* AND child* or adolescent* or youth* or teen* or p*diatric* **= 41**

Figure 1 - PRISMA Flow diagram of search

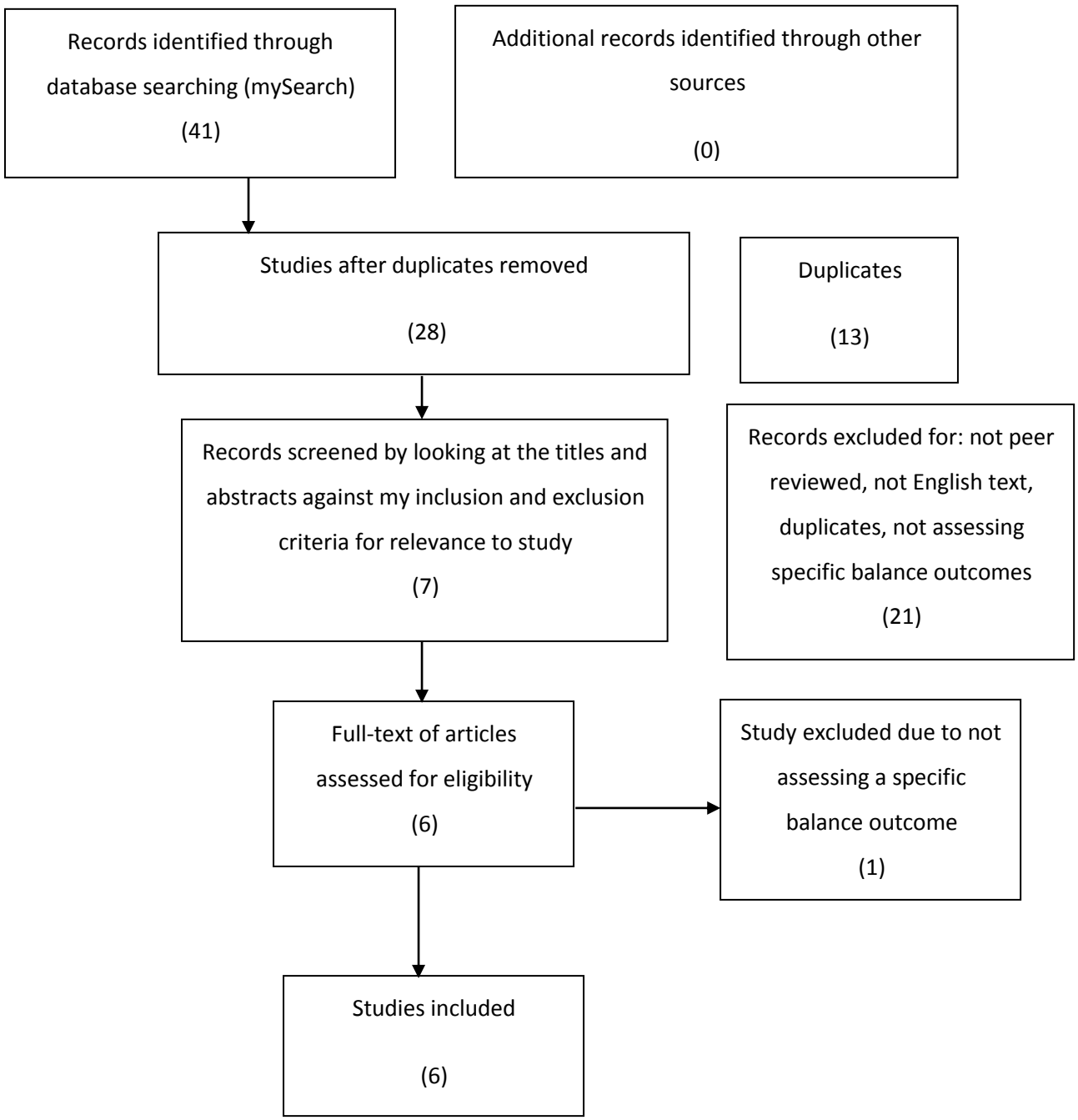

Table 3 – Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
▪ Diagnosis of any subtype of cerebral palsy ▪ Grade 1, 2 or 3 on the Gross Motor Function Classification System (GMFCS) or Expanded and Revised Gross Motor Function Classification System (GMFCS-ER) ▪ Intervention using a Nintendo Wii-Fit Balance Board with the Nintendo Wii-Fit software ▪ Balance as a specific outcome measure	▪ Aged <5 or >18 years ▪ Intervention using other interactive games other than the Nintendo Wii-Fit Balance Board ▪ Balance not a specific outcome measure

Table 4 – Modified Downs and Black Checklist

Question	Gatica-Rojas et al (2016b)	Taraki et al (2016)	Taraki et al (2013)	Jelsma et al (2013)	Gatica-Rojas et al (2016a)	Ramastrand and Lyngnegard (2012)
1	1	1	1	1	1	1
2	1	1	1	1	1	1
3	1	1	1	1	1	1
4	1	1	1	1	1	1
5	1	1	1	1	1	1
6	1	1	1	1	1	1
7	1	1	1	1	1	1
8	1	0	0	1	0	0
9	1	1	1	1	1	1
10	1	1	0	1	0	1
11	UTD	UTD	1	UTD	UTD	UTD
12	UTD	UTD	1	1	UTD	UTD
13	1	1	1	1	1	1
14	0	0	0	0	0	0
15	0	0	0	1	0	0
16	1	1	1	1	1	1
17	1	1	UTD	1	1	1
18	1	1	1	1	1	1
19	1	1	1	1	1	0
20	1	1	1	1	1	1
21	UTD	1	1	UTD	1	0
22	UTD	1	1	1	UTD	UTD
23	0	1	0	1	0	1
24	0	UTD	0	UTD	0	UTD
25	0	0	0	0	0	0
26	1	1	1	1	1	1
27	0	0	0	0	0	0
TOTAL	**17**	**19**	**18**	**21**	**16**	**16**

Table 5 – Date Extraction Table

Authors and Design	Subjects	Exclusion criteria	Intervention	Results	D& B Score	Comments
Gatica-Rojas et al (2016b) Pilot Study	10 participants 6-17 yrs 2 female 8 male Spastic CP Hemiplegic, diplegic or monoplegic CP Level 1 or 2 on GMFCS	Cognitive impairment Epilepsy Grade 3 or more on MMAS in ankle plantar flexor muscles. Previous surgeries in LL over the last 2 years Botox in LL in last 10 months Uncorrected visual or vestibular impairment	18 sessions over 6 weeks 3 x a week 25mins each PT supervised/supported patients Snowboard, Penguin slide and Super Hula Hoop and Yoga game.	Improved static standing balance; Significantly reduced the Centre of Pressure (CoP) Sway by mean of 2.18, eyes open condition – (40.370% decrease) Insignificantly reduced CoP by mean of 0.69 eyes closed condition – (13.45% decrease)	18	Only spastic subtype included Mean age; 9.61 years
Tarakci et al (2013) Pilot Study	14 participants 5-17 yrs 3 female 11 males Spastic/ Dyskinetic CP Hemiplegic or Diplegic CP Level 1, 2 or 3 on GMFMCS-ER Normal-mild level	Epilepsy Grade 3 or more on MAS in lower extremities -Inability to cooperate with exercise or measurement	24 sessions over 12 weeks 2 x a week Approx. 40 minutes each PT supervised/supported the patients Ski Slalom, Soccer Heading, Tilt Table and Walking a tight rope.	One leg standing test significantly improved; Mean Right increase 0.4s (6.06% increase) Mean Left increase 3.09 (57.12% increase) Mean Timed up and Go significantly decreased by 3.69s (20.21% decrease) Mean Functional reach test significantly increased by 1.72cm (8.28% increase)	19	Includes spastic and dyskinetic type CP Mean age; 12.07 years

	intellectual disability					
Ramstrand and Lyngnegard (2012) Randomised cross-over design	18 participants 10 females 8 males 8-17rs Hemiplegic or diplegic Level 1 or 2 on GMFCS Able to walk unaided for 10 minutes Not previously used NWBB		25 sessions over 5 weeks 5 x a week Minimum of 30 minutes each Played at home without PT supervision. Diary to record playing time Soccer Heading, Ski Slalom, Ski Jump, Table Tilt, Tightrope walk and Balance Bubble.	Standing balance (using the modified sensory organization test (mSOT)) found no significant difference in any condition. Reactive balance evaluated by investigating the latency response in the lower leg musculature following an external perturbation; found no significant difference (equipment failure)	15	Only spastic CP included Mean age; 13.41 years No exclusion criteria; Doesn't take into account main confounding variables including epilepsy, spasticity, and cognitive impairment, visual or vestibular disorders. Wii intervention within participants home and not supervised – reliable? Equipment failure during reactive balance testing
Gatica-Rojas et al (2016a) Pilot Case Series	4 males 8-16yrs Spastic CP Hemiplegic or diplegic CP Level 1 or 2 in GMFCS and GMFCS-ER	Cognitive impairment Epilepsy Previous surgeries in the LL over the last 2 years Uncorrected visual or vestibular impairment	18 sessions over 6 weeks 3 x a week 25 minutes per session PT supervise/supported patients Snowboard, Penguin Slide and Super Hula Hoop, Yoga game	Mean Timed up and Go significantly decreased by 2.81s (22.50% decrease) Mean Timed one leg standing showed no significant improvement increasing by 6.22s (27.96% increase) however the average post-training time was higher than the average pre-training time.	**17**	Only spastic CP included Mean age; 12 years
Jelsma et al (2013)	14 participants	Epilepsy	12 sessions over 3	Significant difference in BOT-2 Subtest 5	**22**	

	7-14yrs	Visual or hearing	weeks	(balance) after intervention, and after 2		Only spastic CP included
AB, Single subject	Spastic CP	impairments	4 x a week	months		Unable to determine mean
	Hemiplegic	Undergoing	25mins each			age
	Level 1 or 2	orthopaedic surgery	Research Assistant			Not taking into account
	on the	for serial plastering	recorded game score,			cognitive impairments
	GMFCS	at the time of date	time, rest breaks and			Tested 9 times – training
		collection	absenteeism.			effect?
		Access to Wii Fit at	Snowboarding, Skiing,			
		home	Penguin Game, Soccer,			
			Bubble Game and Hula-hoop.			
Taraki et al (2016)	30 children	Epilepsy	12 weeks	Significant increase in mean forward reach	**20**	Spastic and dyskinetic
	11 female	Botulinum toxin A	2 x a week	increased by 4.27cm (21.00% increase)		type CP included
Randomised control	19 male	treatment for the	50 min session	Significant increase in mean leftward reach		Mean age; 10.46 years
trial	5-18yrs	lower extremities in	30 mins of	increased by 3.2cm (20.96% increase)		NDT and Nintendo Wii-Fit
	Diagnosis of	the previous 6	Neurodevelopment	Insignificant increase in the mean rightward		Balance Board
	spastic of	months	treatment (NDT)	reach, increased by 3.6cm (22.42%)		programme well defined
	dyskinetic type	- excessive	approach plus 20 mins	Significant decrease found in mean Timed		
	CP	spasticity in any joint	of Wii or conventional	up and Go, decreased by 2.34s (18.05%		
	Diplegic or	(score > 2 on the	balance programme	decrease)		
	hemiplegic CP	Modified Ashworth	PT			
	Level 1, 2 or 3	Scale	supervised/supported			
	of GMFCS		the patients			
	Confirmed		Slalom skiing, Walking			
	mental ability		on a rope, Tilt Table and			
	to be able to		Heading the ball			
	adapt to					
	exercise					

KEY: CP, Cerebral Palsy; LL, Lower limb; MMAS, Modified Modified Ashworth Scale; BOT-2, Modified Bruininks-Oseretsky test of Motor Proficiency 2nd edition; NDT, Neurodevelopmental treatment; GMFCS, Gross motor function classification system.