Motor Control Outcomes Following Nintendo Wii Use by a Child With Down Syndrome

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Purpose: The purpose of this work was to examine motor outcomes following an 8-week intervention period of family-supported Nintendo Wii use by a child with a diagnosis of Down syndrome (DS). **Summary of Key Points:** A 12-year-old child with a diagnosis of DS and with limited Wii exposure was asked to play Wii games in the home 4 times each week for 20 minutes each session for 8 weeks. Family members were encouraged to participate. The participant chose what games to play and selected 4 different games. Repeatedly practicing the skills involved in these games resulted in improvements in the child's postural stability, limits of stability, and Bruininks-Oseretsky Test of Motor Proficiency, 2nd edition balance, upper-limb coordination, manual dexterity, and running speed and agility standard scores. **Conclusions:** Wii game use by a child with DS may elicit improvements in highly practiced motor skills and postural control. **(Pediatr Phys Ther 2012;24:78–84)**
Key words: child, Down syndrome, male, manual dexterity, motor performance, play, postural balance, video games

INTRODUCTION

Down syndrome (DS), also known as trisomy 21, is a genetic condition caused by an error in cell division that occurs at conception[1] and results in an additional copy of chromosome 21.[2] According to the National Association for Down Syndrome,[1] DS is the most commonly occurring chromosomal disorder, with an incidence of 1 in every 800 live births.

Low muscle tone[1-3] and ligamentous laxity[3] leading to joint hypermobility are characteristic of individuals with DS.[2] These factors influence voluntary muscle control, awareness of the body in space, and movement quality.[2] Compared to their peers, individuals with DS demonstrate reduced muscle strength and endurance,[4] which require increased amounts of energy expenditure during daily activities.[3] Greater energy costs lead to decreased tolerance of physical activity, predisposing individuals with DS to sedentary lifestyles, higher percentages of body fat, diabetes mellitus,[3] decreased cardiovascular fitness, increased risk for osteoporosis, and difficulties performing activities of daily living.[4]

The importance of encouraging physical activity for those with DS cannot be overemphasized. Cowley et al[5] concluded that adults with DS who were more physically fit were better able to perform functional tasks such as walking efficiently, rising from a chair, and negotiating steps. An early commitment to movement and physical activity may mean a more independent life for those with DS. Those with physical disabilities often experience participation restrictions as a consequence of their functional and structural impairments, yet the advantages of participation in physical activities are multifold. Those who participate in such activities, whether organized or not, experience not only the physiological benefits of exertion and skill acquisition but also the psychosocial benefits of exercise and participation, including friendship formation and enhanced game-related competencies (eg, turn-taking, rule

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compliance, and competitive sportsmanship[6]). Children who participate in enjoyable tasks are motivated to engage in these tasks for their intrinsic rewards, and children who are motivated are more likely to experience a greater sense of self-efficacy. Individual decisions regarding participation must be made in light of a child's level of interest, the need for adaptations, and available financial resources and support systems within the context of community opportunity. Unfortunately, potential child, family, and community barriers to inclusion are more generally experienced by children with disabilities such as DS than by those without disabilities.[6] A qualitative study by Menear[7] concluded that parents of children with DS agree that physical activity can have a positive influence on their child's health both now and in the future and that individual sports that do not require their child to match skill levels with teammates or compete with different-ability opponents are important. In addition, parents believed that education regarding home-based activities and community programs are essential. Participation through virtual gaming may offer all of these advantages to children with special needs.

Health professionals with an interest in both prevention and rehabilitation are exploring the potential benefits of virtual reality (VR) in the therapy clinic.[8-11] A recently published systematic review summarized existing evidence surrounding the use of VR systems as rehabilitation agents for children.[12] The authors determined that VR systems are practical and safe and that the devices have potential to serve as adjuncts to both assessment and treatment.[12] Such a report is especially encouraging to those who work in the area of pediatric rehabilitation because children are particularly drawn to these devices and are often intrinsically motivated to compete as avatars in a new and exciting virtual landscape. Virtual gaming may offer children incentives for participation and skill acquisition that cannot be fully experienced through participation in "real world" activities. Children are offered perceptual, sensorimotor, and cognitive feedback regarding their success in negotiating these landscapes and can respond to feedback to improve performance.

Interventions incorporating VR systems such as the Nintendo Wii may be beneficial to individuals with sedentary behavior, which children with DS often exhibit.[13] Many authors have reported that playing video games that demand physical activity, such as Wii Sports, elicits significantly greater energy expenditure and movement compared to sedentary behaviors.[13-16] Graves et al,[14] determined that 15 minutes of Wii Sports boxing required an adolescent to exert enough energy (3.2 METS) to exceed the lower limit for moderate physical activity (3-6 METS). Graf et al[13] found that 30 minutes of participation in active video gaming was comparable to moderate-intensity walking of the same duration. The authors reported that Wii boxing elicited a 2- to 3-fold increase and Wii bowling a 2-fold increase in energy expenditure compared to watching television.[13] In sum, current literature suggests that video games that require physical activity are an enjoyable and valuable means of facilitating energy expenditure to promote weight loss and help counter the effects of sedentary behavior.[13-16]

Researchers have found other beneficial outcomes using the Wii. Brumels et al[17] compared the efficacy of video game (Wii FitM) and traditionally based balance programs in improving balance performance measurements and compliance. The Wii FitM group experienced a reduction in average postural sway, unlike the traditional balance program participants. The authors concluded that video game interventions increased patient enjoyment and engagement, which may enhance compliance while also improving selected balance performance measurements.[17]

Deutsch et al[18] investigated the effects of adding Wii Sports active gaming sessions to the regular therapeutic regimen of an adolescent with cerebral palsy to determine whether the Wii would be a feasible and beneficial adjunct. The adolescent showed improvements in visual perceptual processing, postural control, and functional mobility, enabling the authors to suggest Wii use as a feasible method to augment treatment. These authors also evaluated the effects of multiplayer sessions. The addition of new participants led to strategy-sharing, turn-taking, and supportive attitudes between the players. The authors concluded that the Wii can engage and accommodate individuals with many different abilities, including those with cerebral palsy (CP), and may improve therapy delivery efficiency and compliance. The Wii provided representation of real-world environments and activities to a child whose functional limitations may otherwise have prevented the child from experiencing such activities.[18]

PURPOSE

To our knowledge, the efficacy of using the Wii as computerized feedback to augment the development of motor skills in children with DS has not yet been investigated. The purpose of this case report was to examine motor and self-efficacy outcomes following an 8-week intervention period of family-supported Wii use by a child with a diagnosis of DS. We examined outcomes when a child was given the choice of Wii games and parents and family were encouraged to join and support their child in these interactive gaming opportunities. Outcome measures assessing change in activity and body structure and function, self-efficacy, and compliance with a home exercise program were used. Body structure and function measures included strength, agility, coordination, balance, visual perceptual skills, and body composition. We hypothesized that, following the intervention period, use of the Wii would result in positive changes in these measures. A secondary hypothesis proposed that the more time the child spent playing games that heavily relied upon specific motor skills and abilities, the greater the improvement in these specific motor skills.

DESCRIPTION OF CASE

The child was recruited through advertisements delivered by 2 different DS awareness group listservs. Inclusion criteria were the following: a diagnosis of DS, from 7 to 12 years of age, minimal exposure to the Wii gaming system (less than 4 hours a month), able to communicate in English, and access to an adequate size television for gaming purposes. Exclusion criteria were the following: the inability to understand the gaming programs, cognitive impairment affecting the child's ability to complete a questionnaire with assistance and health impairments for which exercise would be contraindicated.

This child was 11 years old when completing preintervention assessments and, within the 8-week intervention period, turned 12 years old. The child was the eldest of 3 children; his siblings and mother accompanied him to the preintervention assessment. The family lived in a community with a population of approximately 150 000 people where he attended public school. The child was capable of completing questionnaires with assistance, eager to participate, able to follow directions, and cooperative during testing sessions.

INSTRUMENTS

Assessment Tools

Questionnaires. Questionnaires were used to gather information about self-efficacy and perceived physical abilities. The Self-Perception Profile for Children (SPPC) Athletic Competence and Physical Appearance subscales were used for this purpose. Granleese and Joseph[19] recommended the SPPC for assessing self-perception in children due to the survey's relatively high internal consistency (Cronbach's alpha coefficients between 0.71 and 0.86).[20] The Perceived Physical Ability Scale (PPA) was developed to assess perception of personal strength, speed, and coordinative abilities in children using a short, 6-item questionnaire.[20] To overcome obstacles with the child's literacy level, a parent read these short questionnaires aloud to the child.

Standardized Tests. The Bruininks-Oseretsky Test of Motor Proficiency, second edition (BOT-2) is a norm-referenced standardized assessment used to measure gross and fine motor skills in children aged 4 to 21 years old.[27] The BOT-2 consists of 4 motor areas. The subject was assessed in 3 of the 4 motor areas, including manual coordination, body coordination, and strength and agility. Wuang and Su[28] reported a Cronbach's alpha coefficient of 0.92 and an intraclass coefficient for test-retest reliability of 0.99. Validity of the BOT-2, as reported by Bruininks and Bruininks,[29] was considered good on the basis of test content, group differences, and relations to other motor tests.[29]

The Test of Visual Perceptual Skills, Third Edition (TVPS-3) is a nonmotor assessment of visual perception designed for children between 4 and 12 years of age.[24] The TVPS-3 evaluates 7 visual perceptual skills on subtests. Three of these 7 subtests were administered for the purposes of this report: (1) visual-spatial relationships, (2) visual form constancy, and (3) visual figure-ground.[25] Although McFall et al[26] found that TVPS-3 scores on the total test show adequate test-retest reliability for use in clinical settings, scores on the subtests should be used with caution, as test-retest reliability estimates were low.[26]

Equipment. The Biodex BioSway Balance System[21] (0.81, ICC, test-retest reliability[22]) was used to examine the subject's change in center of mass in both stable and unstable conditions. This portable device features an adjustable, computerized platform that can be adjusted to provide varying degrees of stability. Measures from this system included sway in anterior-posterior and medial-lateral directions. An overall stability score was calculated by the system software.

The BodyStat QuadScan 4000 was used to measure body fat, lean mass, and dry lean mass using a body composition equation for children 6 years and older.[23]

Motor Control Analysis Tool

A tool determining the weighted contribution of motor control skills and abilities to particular Wii games was developed from information gathered from students and practitioners well-informed about concepts of motor control. These skills and abilities were linked to BOT-2 subscales for analysis purposes. Details about the development of this analysis tool and its BOT-2 alignment are available from the authors.

DESCRIPTION OF INTERVENTION

Procedures

This work was approved by the university's Institutional Review Board. Informed consent and child assent forms were signed by both the child and his parent prior to assessment, training, and intervention.

Three physical therapist students were trained to administer specific subsections of the BOT-2; all subsections were administered by the same student at week 0 and week 8. The TVPS-3 was administered by an individual with experience in the administration of the test. Physical therapist students participated under the direct supervision of an experienced physical therapist with a background in pediatrics.

Intervention and Assessment

A Wii gaming device with games was loaned to the child for the 8-week intervention period. The child was assessed at baseline (week 0) and immediately after the intervention period (week 8). The subject was assessed in the following areas: visual perception (TVPS-3), self-efficacy (SPPC), and self-perception (PPA); manual coordination (BOT-2), body coordination (BOT-2), strength and agility (BOT-2), balance (Biodex BioSway Balance System), body composition (BodyStat Quadscan 4000).

Following the initial assessment and prior to intervention, the authors taught both the child and parent to use the Wii gaming system. The child then used the device at home during the subsequent 8-week period. The child was asked to use the Wii at least 4 times each week for at least 20 minutes each session.

The frequency and duration of Wii sessions were selected by the authors as reasonable enough to encourage compliance yet not so intensive that it would interfere with typical physical activity and to discourage overutilization of the device at the expense of typical lifestyle activities. Parents were asked to keep a log describing the date, game used, and amount of time spent by the child playing the game each session. The subject was encouraged to play games that held his interest, and the child's parents and siblings were encouraged to participate, as well.

One of the authors contacted the parents by phone or e-mail every 2 weeks to assess compliance and address questions from the family. At the end of the 8-week intervention period, the child and parent returned to the test site for postintervention assessment. All preintervention tests were readministered at the postintervention session. In addition, the child's parent participated in an interview about the child's experience during the intervention period.

The family received their child's pre- and postintervention assessment results in report format after the final assessment.

RESULTS

During the 8-week period, the participant played the Wii gaming device for a total of 547 minutes (an average of 68 minutes per week) and chose to play 4 different games: Wii Sports bowling, baseball, rhythm boxing and a snowboarding game (Table 1).

The participant demonstrated improvements in the BOT-2 manual dexterity, upper-limb coordination, balance, and running speed and agility scaled scores. However, according to Wuang and Su,[28] the upper-limb coordination mean change score (week 8 − week 0 = 1) did not exceed the minimum importance difference (minimum important difference [MID] = 1.61) for this subtest. Table 2 provides information about MID and minimum detectable change as they compare to this child's test results. His strength scaled score did not change, and his bilateral coordination scaled score decreased (Table 2 and Table 3).

TABLE 1
Minutes Spent Playing Specific Wii Games During 8 Weeks

Game (% of Total Time)	Time (min)
Bowling (56%)	310
Baseball (22%)	122
Rhythm boxing (14%)	80
Wii Fit Balance (snowboard) (8%)	35
Total	547

The subject demonstrated no changes in the visual spatial relations and form constancy subtests of the TVPS-3. There was a small improvement in the figure-ground subtest scores (pretest scaled score: 0, posttest scaled score: 2).

Both the postural stability tests and limits of stability tests indicate improvements in postural control. The postural stability test showed a decrease in anterior/posterior sway and an increase in medial/lateral sway; the overall stability index showed improvement (Table 4). The limits of stability test indicated that the child demonstrated better dynamic control in all directions, except backward and backward/right (Table 5). These results were confirmed by improvements in the BOT-2 balance subsection scores.

Anthropometric measures revealed that during the 8-week intervention period, the child grew an inch (week 0 = 61 in; week 8 = 62 in) while his weight remained relatively stable (week 0 = 108.0 pounds; week 8 = 108.6 pounds; typical weight for a child of similar height = 119-130 pounds). The child's hip circumferential measurement increased (week 0 = 33 in; week 8 = 34 in) while his waist circumferential measurement decreased (week 0 = 30 in; week 8 = 27 in), resulting in a decreased waist/hip circumferential measurement ratio (week 0 = .92; week 8 = .79). His body fat increased (week 0 = 2.0%; week 8 = 3.9%); however, this child was very lean even after gaining body fat (a healthy body fat range for a child of similar height and weight is between 12% and 18%).

DISCUSSION

The purpose of this case report was to examine motor outcomes following an 8-week intervention period of family-supported Wii use by a child with a diagnosis of DS. One of our original purposes, to examine self-efficacy changes, was discarded because of questionable response reliability.

This child was selected for the case report because he demonstrated the minimum attention requirements and cognition needed to complete the intervention and most of the outcome measures. He exhibited good listening skills and attentiveness during the assessments and instructions for playing the Wii device. He also had minimal exposure to playing the Wii device and was motivated and enthusiastic prior to the study about receiving a gaming device to take home. We determined the results of the self-efficacy and self-perception questionnaires may have been affected by parent influence and the survey results were excluded from analysis. It was determined that the child demonstrated sufficient cognition to follow through with the intervention and other assessments, justifying his continued participation in the intervention activities.

The child spent an average of 68 minutes per week playing the Wii gaming device, which did not meet the minimum suggested program of four 20-minute sessions (80 minutes total) throughout the week. The subject was encouraged to play the games that held his interest, and he chose to play only 4 games.

TABLE 2

Results of the Bruininks-Oseretsky Test of Motor Proficiency, 2nd edition (BOT-2)

BOT-2 Subtest Scaled Scores	Scaled Scores Mean = 15, SD = 5		Mean Change		
	Week 0 (z Score)	Week 8 (z Score)	(Week 8 − Week 0)	MDC[b]	MID[b]
Manual dexterity[a,c,d]	4 (−2.2)	6 (−1.8)	2	1.19	1.47
Upper-limb coordination[a]	9 (−1.2)	10 (−1.0)	1	1.70	1.61
Bilateral coordination[c,d]	15 (0)	9 (−1.2)	−6	1.52	1.11
Balance[a,d]	5 (−2.0)	6 (−1.8)	1	1.14	.57
Running speed and agility[a,d]	7 (−1.6)	8 (−1.4)	1	1.14	.59
Strength	7 (−1.6)	7 (−1.6)	0	1.47	1.73
	Standard Scores Mean = 50, SD = 10		Mean Change		
BOT-2 Composite Standard Scores	Week 0 (z Score)	Week 8 (z Score)	(Week 8 − Week 0)	MDC[b]	MID[b]
Manual coordination[a,c,d]	33 (−1.7)	35 (−1.5)	2	1.54	2.55
Body coordination[c,d]	36 (−1.4)	33 (−1.7)	−3	1.87	1.65
Strength and agility[a]	35 (−1.5)	36 (−1.4)	1	1.87	1.39

[a]Improvement.
[b]Wuang and Su.[28] The MDC (minimum detectable change) indicates the smallest difference or change that would be statistically significant when comparing different samples. The MID (minimum important difference) establishes when the difference between 2 scores constitutes a clinically significant difference.
[c]Mean change score exceeds MDC.
[d]Mean change score exceeds MID.

TABLE 3

Analysis BOT-2 or Biodex BioSway Measure Score Changes

Most Frequently Played Games (% of Total Time Played)	BOT-2 Subtest or Biodex BioSway Measure
Wii sport: Bowling (56%)	• Upper-limb coordination[a] (*)
	• Bilateral coordination[a] (−)
Wii sport: Baseball (22%)	• Upper-limb coordination[a] (*)
	• Balance[a] (+)
	• Bilateral coordination[a] (−)
	• Manual dexterity[a] (+)
	• Postural stability[b] (see Table 5)
	• Limits of stability[b] (see Table 6)
Wii Fit (aerobic): Rhythm boxing (14%)	• Upper-limb coordination[a] (*)
	• Bilateral coordination[a] (−)
	• Manual dexterity[a] (+)
	• Balance[a] (+)
	• Postural stability[b] (see Table 5)
	• Limits of stability[b] (see Table 6)
	• Untested: stamina
Wii Fit (balance): Snowboard (8%)	• Balance[a] (+)
	• Postural stability[b] (see Table 5)
	• Limits of stability[b] (see Table 6)
	• Running speed and agility[a] (+)
	• Upper-limb coordination[a] (*)
	• Bilateral coordination[a] (−)

[a]BOT-2 subtest.
[b]Biodex BioSway Measure.
"+" indicates improved performance score; "*" indicates improved performance score not exceeding the minimum important difference (MID) according to Wuang and Su[28]; "−" indicates decrease in performance score. The MID establishes when the difference between 2 scores constitutes a clinically significant difference.

TABLE 4

Results of the Biodex Portable BioSway Postural Stability Test

Direction	Degree of Sway[a]	
	Week 0	Week 8
Overall Stability Index	1.39	1.00[b]
Anterior/Posterior Index	1.39	0.64[b]
Medial/Lateral Index	0.53	0.94

[a]Referred to by Biodex Portable BioSway equipment data as "Standard Deviation" in direction; a measure of position sway with lower values indicative of less sway.
[b]Improvement.

TABLE 5

Results of the Biodex BioSway Limits of Stability Test

Directional Control	Control (%)	
	Week 0	Week 8
Overall	24	31[a]
Forward	14	47[a]
Backward	56	31
Right	34	54[a]
Left	43	59[a]
Forward/Right	41	45[a]
Forward/Left	37	52[a]
Backward/Right	37	19
Backward/Left	22	28[a]

[a]Improvement (higher level of dynamic control).

The motor control analysis that we conducted prior to the study weighted Wii Sports bowling, baseball, and rhythm boxing (Table 2) as heavily reliant upon motor abilities requiring control precision, speed of arm movement, rate control (timing), and manual dexterity. Improvements in BOT-2 test areas—upper-limb coordination (although changes did not exceed the MID), manual dexterity, balance, and running speed and agility (Table 3)—may be related to those motor control variables.

The child showed no improvement in his BOT-2 bilateral coordination scaled score as predicted, nor were improvements noted in the child's BOT-2 strength scaled score; however, strength gains were not expected because the child did not spend time practicing Wii games that challenged this motor ability. It is quite likely, given the drastic drop in this child's bilateral coordination score, that the child was experiencing greater difficulty with the complex synchronous and asynchronous patterns required of the bilateral coordination test for reasons other than skill level or ability. The child was more easily distracted at postintervention assessment, was reluctant to return the Wii, and was not accompanied by his siblings, as he was at the preintervention assessment. It is also possible that bilateral coordination was not truly challenged during the games as predicted from our motor control analysis of the games.

The participant spent 8% of his time playing the Wii snowboard game, which we proposed to be reliant on motor control abilities requiring postural discrimination, response integration, and gross body equilibrium. The time spent repeatedly practicing these skills may have led to improvements in the child's BOT-2 balance standard score, overall stability (measured by the Postural Stability test), and overall directional control (measured by Limits of Stability test). The Postural Stability test improvements (Table 4) may reflect the participant's enhanced ability to control his center of mass within his base of support while demonstrating less sway.

The Limits of Stability test improvements depict the participant's enhanced ability to control his center of gravity, as it shifts beyond his base of support. The participant demonstrated less sway in all directions, except backward and backward/right (Table 5). Improvements in these balance tests could be the result of more refined and precise integration of sensory and motor control aspects of postural maintenance.

In summary, as we hypothesized, this child showed gains in those motor control areas he practiced the most. The suggestion that high levels of intense practice will result in skill acquisition and mastery is grounded in concepts of neural plasticity and the principles of motor learning.[30] Neural plasticity allows continuous growth and reorganization of the nervous system as a product of practice, experience, and interactions with environmental stimuli. Wii games provided the child with visual, auditory, and haptic biofeedback, possibly promoting enhancement of motor and postural control skills needed to successfully play the games.

The authors also expected that self-efficacy for participating in motor skill challenges would be enhanced by giving the child complete control of which Wii games were played and also incorporating multiplayer/family sessions to maintain interest and improve compliance. Whereas these expectations cannot be confirmed the child played the Wii with his parents and typically developing siblings, who likely modeled strategies for improvement of motor skills and postural control.

The subject's mother stated that the child was very enthusiastic during the beginning of the intervention, but he showed a decline in interest over the 8-week period. However, he increased time playing the Wii device once again toward the end of the period when he knew that the gaming device needed to be returned and would no longer be available. The child's mother also stated that her son and their family enjoyed playing Wii games, and they were planning to buy their own personal system so they could continue to play. Although the results of this report are encouraging, the authors stress the importance of viewing Wii use as only one of many means toward achieving improved function and participation in the real world.

CONCLUSION

In this case, repeated practice of Wii bowling, baseball, rhythm boxing, and snowboarding by a child with DS were accompanied by improvements in upper-limb coordination, manual dexterity, balance, postural stability, and limits of stability control. Allowing the child to choose the games and incorporating multiplayer/family sessions can help maintain interest and enthusiasm for an activity that can ameliorate activity limitations and body structure and function impairments characteristic of a child with DS. Use of the Wii gaming device may be a beneficial home tool to improve motor skills and abilities for a child with DS while it serves as a fun and social form of physical activity for the whole family.

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REFERENCES

1. Facts about Down syndrome. National Association for Down Syndrome Web site. http://www.nads.org/pages_new/facts.html. Updated 2009. Accessed August 17, 2010.
2. Tsimaras VK, Fotiadou EG. Effect of training on the muscle strength and dynamic balance ability of adults with Down Syndrome. *J Strength Cond Res*. 2004;18(2):343-347.
3. Lewis CL, Fragala-Pinkham MA. Effects of aerobic conditioning and strength training on a child with Down Syndrome: a case study. *Pediatr Phys Ther*. 2005;17(1):30-36.
4. Shields N, Taylor NF, Dodd KJ. Effects of a community-based progressive resistance training program on muscle performance and physical function in adults with Down Syndrome: a randomized controlled trial. *Arch Phys Med Rehabil*. 2008;89:1215-1220.

5. Cowley PM, Ploutz-Snyder LL, et al. Physical fitness predicts functional tasks in individuals with Down syndrome. *Med Sci Sports Exerc*. 2010;40(2):388-393.
6. Murphy NA, Carbone PS Council on Children with Disabilities. Promoting the participation of children with disabilities in sports, recreation, and physical activities. *Pediatrics*. 2008;121(5):1057-1061.
7. Menear KS. Parents' perceptions of health and physical activity needs of children with Down syndrome. *Down Syndr Res Pract*. 2007;12(1):60-68.
8. Newton V. The Wii: a new approach in rehab. *Nurs Spectrum (NY NJ)*. 2008;20(14):12-13.
9. Leach B. Rehab facilities finding many uses for Wii Fit. *The Press of Atlantic City*. http://www.pressofatlanticcity.com. Published December 1, 2008. Accessed December 9, 2008.
10. Coyne C. Video "games" in the clinic: PTs report early results. *PT Mag Phys Ther*. 2008;16(5):22-28.
11. Therapy Times staff. A heavy price to pay: the growing epidemic of pediatric obesity. Therapy Times Web site. http://www.therapytimes.com/110408PediatricObesity. Published November 3, 2008. Accessed August 17, 2010.
12. Laufer Y, Weiss PL. Virtual Reality in the assessment and treatment of children with motor impairment: a systematic review. *J Phys Ther Ed*. 2011;25(1):59-71.
13. Graff DL, Pratt LV, Hester CN, Short KR. Playing active video games increases energy expenditure in children. *Pediatrics*. 2009;124:534-540.
14. Graves LEF, Ridgers ND, Stratton G. The contribution of upper limb and total body movement to adolescents' energy expenditure whilst playing Nintendo Wii. *Eur J Appl Physiol*. 2008;104:617-623.
15. Graves L, Stratton G, Ridgers ND, Cable NT. Comparison of energy expenditure in adolescents when playing new generation and sedentary computer games: cross sectional study. *BMJ*. 2007;335:1282-1284.
16. Lanningham-Foster L, Foster RC, McCrady SK, Jensen TB, Mitre N, Levine JA. Activity-promoting video games and increased energy expenditure. *J Pediatr*. 2009;154:819-823.
17. Brumels Ka, Blasius T, Cortright T, Oumedian D, Solberg B. Comparison of efficacy between traditional and video game based balance programs. *Clin Kinesiol J Am Kinesiother Assoc*. 2008;62(4):26-31.
18. Deutsch JE, Borbely M, Filler J, Huhn K, Guarrera-Bowlby P. Use of a low-cost, commercially available gaming console (Wii) for rehabilitation of an adolescent with cerebral palsy. *Phys Ther*. 2008;88(10):1196-1207.
19. Granleese J, Joseph S. Reliability of the Harter's Self-Perception Profile for Children and predictors of global self-worth. *J Genet Psychol*. 1994;155(4):487-492.
20. Colella D, Morano M, Bortoli L, Robazza C. A physical self-efficacy scale for children. *Soc Behav Pers*. 2008;36(6):841-848.
21. *BioSway Portable Balance System [Apparatus and software]*. Shirley, NY: Biodex Medical Systems, Inc.
22. Hinman MR. Factors affecting reliability of the Biodex Balance System: a summary of four studies. *J Sport Rehab*. 2000;9(3):240-252.
23. Bodystat Quadscan 4000. Bodystat: changing attitudes to health. http://www.bodystat.com/products/quadscan_4000.php. Updated 2009. Accessed December 17, 2009.
24. Brown GT, Rodger S, Davis A. Test of Visual Perceptual Skills—revised: an overview and critique. *Scand J Occup Ther*. 2003;10:3-15.
25. Gardner MF. *Test of Visual-Perceptual Skills (Non-Motor)*. San Francisco, CA: Psychological and Educational Publications; 1982.
26. McFall SA, Deitz JC, Crowe TK. Test-retest reliability of the Test of Visual Perceptual Skills with children with learning disabilities. *Am J Occup Ther*. 1993;47(9):819-824.
27. Deitz JC, Kartin D, Kopp K. Review of the Bruininks-Oseretsky Test of Motor Proficiency, second edition. *Phys Occup Ther Pediatr*. 2007;27(4):87-102.
28. Wuang YP, Su CY. Reliability and responsiveness of the Bruininks-Oseretsky Test of Motor Proficiency-Second Edition in children with intellectual disability. *Res Dev Disabil*. 2009;30(5):847-855.
29. Bruininks RH, Bruininks BD. *Bruininks-Oseretsky Test of Motor Proficiency*. 2nd ed. Manual. Circle Pines, MN: American Guidance Service; 2005.
30. Shumway-Cook A, Woollacott MH. *Motor Control: Translating Research into Clinical Practice*. 3rd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2007.