THE EFFECT OF AN EXERGAME-BASED INTERVENTION ON BALANCE ABILITY ON DEAF ADOLESCENTS

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Abstract
The purpose of this study was to determine whether there is a difference between an exergame-based and a traditional adapted Physical Education balance training program, in adolescents with deafness. Twenty adolescents with severe hearing loss were randomly divided into two training program groups of 10 students each, a traditional Physical Education group (TPEG) and an exergames group (ExG). The two training program groups performed a specific balance program for 8 weeks, two times per week, and 15 min per session. The ExG used the interactive games Wii-Fit Plus of the Nintendo Wii console, as a training method to improve their balance, while the TPEG used an exercise program with inflatable discs. Before and after the completion of the eight-week balance program, participants completed a single leg static balance assessment (Flamingo Balance Test). Two-way analysis of variance (ANOVA), with repeated measures on the last factor, was conducted to determine effect of training program groups (TPEG, ExG) and measures (pre-test, post-test) on Flamingo Balance Test scores. Analysis of the data illustrated that both groups demonstrated an improvement in balance mean scores. Conclusively, findings support the effectiveness of using the Nintendo Wii gaming console as an intervention for improving the balance ability of adolescents' students with deafness.

Key words: *exergames, balance, deafness, adolescents, physical education.*

Introduction

Both static and dynamic balance play important roles in the development of fundamental motor skills. For example, the ability to climb a ladder, kick a ball, hop on one foot, and skip all require the child to maintain a certain degree of equilibrium (Payne & Isaacs, 2011). In order, for a person to maintain equilibrium, a great deal of information must be gathered and processed by the central nervous system. Data collected by the eyes, skin, proprioceptors in the muscles and joints, and the vestibular apparatus of the ears enter the brain where it is processed. Then, adjustments are made and the individual maintains balance as the situation demands. If any of these components are impaired, balance is likely to be affected until the other components can compensate (Gheysen, Loots & van Waelvelde, 2008; Majlesi, Farahpour, Azadian, & Amini, 2014). When deafness is accompanied by inner ear defects, the vestibular mechanism may be damaged and balance impaired. Although hearing loss does not directly affect the musculoskeletal system, children or adolescents with deafness often have reduced orientation, kinesthetic and rhythm perception ability, the latter impacting the development of various motor abilities that are related to the fundamental physical ability of balance (Gheysen, et al., 2008; Majlesi et al., 2014). Several studies have suggested that the deaf, as a group, are inferior to the hearing in both static and dynamic balance (e.g. Zwierzchowska, Gawlik & Grabara, 2004; Azevedo & Samelli, 2008; Gheysen et al., 2008; Majlesi et al., 2014). The importance of adequate motor development has many implications for the deaf child or adolescent who is often isolated from his environment. Improvement in motor functioning may allow this child to have greater mobility and thus be less dependent. Increased levels of physical fitness can have a direct impact on vocational competence, as well as increase opportunities for social interaction and leisure and recreational activities. It is apparent that a quality physical education program can go a long way towards providing the deaf with some of the tools necessary to adapt and cope effectively in a "hearing world." Exergames are a new generation of videogames, which in contrast to the older generation of static videogames, require whole-body movements and have the potential to help children and adolescents with or without deafness to improve their balance ability.

Many research studies on the effectiveness of therapeutic programs based on exergames environments have reported positive findings in individuals with balance disorders(e.g. Yang, Tsai, Chuang, Sung & Wang, 2008; Vernadakis, Derri, Tsitskari, & Antoniou, 2014). De Bruin, Schoene, Pichierri & Smith, (2010) point out that physical exercise based on exergames is more effective than conventional balance training. According to the authors, physical exercise using exergames is beneficial because settings and therapy protocols can be tailored to each individual's therapeutic requirements and interests, enabling gains in balance and motor coordination. Ribas, Alves da Silva, Corrêa, Teive & Valderramas, (2017) analyzed the effectiveness of exergaming in improving functional balance, fatigue, functional exercise capacity and quality of life in Parkinson's disease. The study population consisted of 20 patients aged 61 ± 9.11 years allocated into two groups: an exergaming group and a conventional exercise group. Results showed that exergaming was effective in enhancing balance and reducing fatigue in Parkinson's disease patients after 12 weeks of treatment, but this benefit was not sustained in the long-term. In another study, Bonney, Jelsma, Ferguson & Smits-Engelsman, (2017) investigated whether exergames training delivered under variable practice led to better learning and transfer than repetitive practice. One hundred and eleven children aged 6–10 years with no active exergaming experience were randomized to receive exergames training delivered under variable or repetitive practice schedule. Both groups participated in two 20 min sessions per week for 5 weeks. Results indicated that children with and without developmental coordination disorder learn balance skills quite well when exposed to exergames. Gains in learning and transfer are similar regardless of the form of practice schedule employed. Finally, in a study examining the usability of Wii Fit Plus games in the rehabilitation of middle-aged individuals with balance impairments, the participants reported more motivation and enjoyment than in traditional physiotherapy (Meldrum, Glennon, Herdman, Murray & McConn-Walsh, 2012).

Exergaming research has focused mainly on rehabilitation and promotion of physical activity. In rehabilitation, exergaming has been used as a tool to improve balance and functional movement in a variety of populations (Taylor, Shawis, Impson, Ewins, McCormick & Griffin, 2012; Mhatre et al., 2013). One of the main reasons for employing exergames is the ability to increase motivation and produce a distraction from mundane and boring training and/or painful treatments (Kato, 2010). It is interesting to note that when an earlier review of exergaming was published there were no studies carried out in people with deafness even though it is possible that the reported benefits of exergaming in balance and mobility in other populations will have a positive impact on people with deafness. Thus, the research study presented in this paper appears to be the first of its kind exploring the development of balance ability through exergames in people with deafness. Specifically, the aim of this study was to determine whether there is a difference between an exergame-based and a traditional adapted Physical Education balance training program, in adolescents with deafness.

Methods

Participants

Twenty adolescent students (10 boys and 10 girls)aged 17 to 19 years (M=18.3, SD=0.7) with severe hearing loss were randomly divided into two training program groups of 10 adolescent students each, a traditional Physical Education group and an exergames group. Prior to group assignments, adolescent students expressing interest were screened to ensure they were willing to participate after being informed of the full study responsibilities. The criteria applied for inclusion were: presence of bilateral profound sensorineural hearing loss (audiometric threshold greater than 70 dB constitutes a profound hearing loss); aged between 17 and 19 years; possessing the same nutritional and socioeconomic status; and did not have any previous exposure to exergaming, such as Nintendo Wii, perceived to affect balance. Exclusion criteria were: presence of any other associated disabilities (neurological, visual, or mental); classified as overweight or obese; presence of musculoskeletal problems; or using medication affecting the central nervous system. Informed consent was obtained from each adolescent student prior to his voluntary participation in the study.

Balance instrument

The flamingo balance test was used to determine the development of balance ability in adolescent students with deafness. The test was demonstrated to all participants and the adolescent students could practice three times to avoid all possible errors. Test was practiced with eyes open without shoes for the dominant leg. To administer the flamingo test, the subject was asked to stand on the wooden beam (50 cm long, 5 cm high, 3 cm wide) with shoes removed on the tested leg and bend the free leg at the knee, and the foot of this leg was held close to the buttocks with both hands on the iliac crests, standing like a Flamingo. Participants were instructed to maintain this position as long as they can. Stopwatch was used to note each time the person loses balance either by falling off the beam or letting go of the foot being held or hands removed off the body. Every adolescent student was made to perform three attempts and the average was recorded for statistical analysis of this study.

Procedure

Participants were randomly divided into two training program groups of 10adolescentstudents each, a control group (TPEG) and an experimental group (ExG). The two training program groups performed a specific balance program for 8 weeks, two times per week, and 15 min per session. Before the intervention started, the experimental group was given a 120-minute introductory session on how to use the Nintendo Wii-Fit Plus games and its tools. The ExG used the interactive games Wii-Fit Plus of the Nintendo Wii console, as a training method to improve their balance. The games varied each week starting with the easiest and ending with the most difficult. At the beginning and at the end of each session the participants performed a series of yoga exercises (a. yoga tree pose, b. standing knee pose and c. king of the dance pose) for a total duration of 5 minutes. In the meantime, they had to deal with Nintendo Wii-Fit Plus interactive balance games for 10 minutes. After each exercise – game there was a 20 second break. Those exercises had also been used in prior studies (e.g. Vernadakis, Gioftsidou, Antoniou, Ioannidis & Giannousi, 2012; Roopchand-Martin, McLean, Gordon & Nelson, 2015) and were as follows: a. Bubble Balance, b. Lotus Focus, c. Penguin Slide, d. Ski Jump, e. Ski Slalom, f. Snowboard Slalom, g. Soccer Heading, h. Table Tilt, and i. Tightrope Walk. The TPEG used an exercise program with inflatable discs to improve their balance. Those exercises had similar characteristics as the ExG exercises, had also been used in prior studies (e.g. Gioftsidou, Malliou, Pafis, Beneka, Godolias & Maganaris 2006; Malliou, Gioftsidou, Pafis, Beneka & Godolias, 2004; Willardson, 2007) and were as follows: a. Walking 'tiptoes-heel' on the walking line for 2 min and 30 sec. b. Balance on one foot on the ground, alternating right and left leg, the bent leg touching the knee of the other leg, for 1 min and 30 secs on each leg and an interval of 10 sec between sets. c. Inflated flat balance disk 1: balance on one leg on the soft surface of the disk, alternating right and left leg, the bent leg touching the knee of the other leg, for 1 min and 30 secs on each leg and an interval of 10 sec between sets. d. Inflated flat balance disk 2: balance on one leg on the soft surface of the disk, alternating right and left leg, the bent leg touching the knee of the other leg and the hands touching the waist, for 1 min and 30 secs on each leg and an interval of 10 sec between sets. e. Inflated flat balance disk 3: balance on one leg on the soft surface of the disk, alternating right and left leg, the bent leg touching the knee of the other leg and the student trying to catch a ball thrown to him/her in different directions while maintaining his/her balance, for 1 min and 30 secs on each leg and an interval of 10 sec between sets. Before and after the completion of the eight-week balance program, participants completed a single leg static balance assessment (Flamingo Balance Test).

Data analysis

The experimental design in this study was a pre-test/post-test control group design, where participants were randomly assigned to the groups. Random assignment was accomplished by computerized generation of random student numbers and assignment of the students to groups based on those numbers. Prior to analysis, data were screened for violations of statistical assumptions, and no violations were detected (Green, & Salkind, 2013). A two-way analysis of variance (ANOVA) with repeated measures was conducted to evaluate the effect of training programs and measurements across time on FBT performance. The dependent variable was FBT scores. The within-individuals' factors were training program groups with two levels (ExG, TPEG) and time with two levels (pre-test, post-test).

The Training programs x Time interaction effect, as well as the Training programs and Time main effect were tested using the multivariate criterion of Wilks's lambda (Λ). Significant differences between the means across time were tested at the 0.05 alpha level. An effect size was computed for each analysis using the eta-squared statistic (η2) to assess the practical significance of findings. Cohen's guidelines were used to interpret η2 effect size: 0.01=small, 0.06=medium and 0.14=large (Cohen & Manion, 1994). The hypotheses of this study were:

H1. Both groups of adolescent students (ExG and TPEG) will not differ significantly on measure of FBT at pre-test.

H2. Both groups of adolescent students (ExG and TPEG) would improve their FBT scores.

Results

Table 1 show students' demographic and somatometric data (which were measured prior intervention) as well as means and standard deviation for the ExG and the TPEG in pre-test and post-test.

Table 1. Descriptive statistics of students' demographic/somatometric data and pre-test/post-test FBT scores.

	ExG (n=10)	TPEG(n=10)
Age (years)	18.1	18.4
Height (m)	1.73	1.72
Weight (Kg)	70.7	74.5
BMI (Kg/m^2)	23.42	24.93
FBT pre-test	9.21 (0.71)	9.09 (0.74)
FBT post-test	7.33 (1.48)	7.04 (1.67)

Note: Values are mean (standard deviation).

Balance comparison

An independent sample t-test analysis was conducted to evaluate Hypothesis I (that the two groups of participants would not differ significantly on measure of FBT at pre-test). Indeed, there were no significant initial differences between the two groups in the mean FBT scores, $t(2, 18) = .159$, $p = .867$. Two-way analysis of variance (ANOVA) with repeated measures was conducted to evaluate the Hypothesis II (that participants in both the ExG and the TPEG groups would improve their FBT scores). As demonstrated in what follows, this hypothesis was supported.A significant main effect was noted for Time, $\Lambda=0.088$, $F(1, 18)=186.706$, $p<0.001$, partial $\eta^2=0.912$, while the Training programs x Time interaction effect was not significant, $\Lambda=0.978$, $F(1, 18)=0.295$, $p=0.654$, partial $\eta^2=0.014$. The univariate test associated with the Group's main effect was not significant as well, $\Lambda=0.432$, $F(1, 18)=0.171$, $p=0.708$, partial $\eta^2=0.009$. Pairwise comparisons using t-test with a Bonferroni adjustment revealed significant mean differences in FBT scores between pre-test and post-test (MD=1.62; 95% CI: 1.06 to 2.17, $p<0.001$) in the ExG group. Similarly, significant mean differences in FBT scores were found between pre-test and post-test (MD=1.81; 95% CI: 1.25 to 2.36, $p<0.001$) in the TPEG group. As shown in Figure 1, the post-test FBT scores were remarkably higher than pre-test FBT scores for both experimental groups (ExG, TPEG).

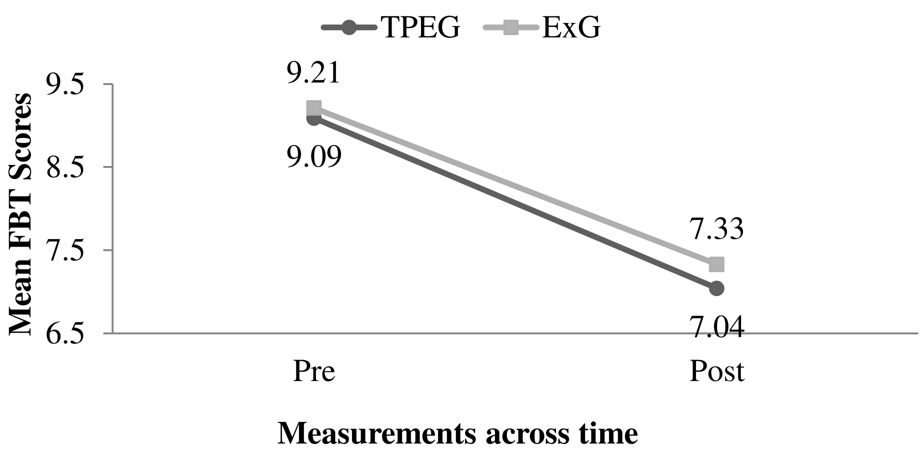

Figure 1. FBT performance of the two groups on all measurements across time.

Discussion and conclusion

Although balance impaired in people with deafness are well established, no study has explored the development of balance ability through exergames in people with deafness. Therefore, the purpose of this study was to determine whether there is a difference between an exergame-based and a traditional adapted Physical Education balance training program, in adolescents with deafness. The first research hypothesis, that both experimental groups of participants would not have significant differences on measure of FBT scores at pre-test was supported. Perhaps these similarities were due, in part, to the fact that the schools were within the same district, used the same curriculum guidelines, and the compensatory adolescent programs had identical selection criteria. However, students in both groups achieve low scores in balance ability as measured by FBT.

Although this study did not examine why these low FTB scores occurred, it might be hypothesized that a variety of organic factors such as vestibular or neurological dysfunction and sensory deprivation of hearing might lead to the balance deficit in combination with emotional factors such as lacking confidence because of overprotection or parental neglect (Gheysen, et al., 2008; Majlesi et al., 2014). The second research hypothesis, that participants in both the ExG and the TPEG groups would improve their balance skills was also supported. As derived from the results of quantitative analyses, both programs yielded an improvement in students' balance ability as measured by FBT. This finding seems to agree with the findings of other studies in various samples with and without disability, which have shown a significant improvement in participants' balance ability after an exergame-based intervention (Bonney et al., 2017; Ribas et al., 2017; Roopchand-Martinet al., 2015; Vernadakis et al., 2012; Vernadakis et al., 2014). The post-test results were not surprising, as research has documented that adapted exercise programs are particularly important for the improvement of proprioception, namely the individual's ability to recognize the position of body in space and to control movements of adolescent students (Valovich McLeon, 2008; Di Stefano, Clark & Padua, 2009). It seems, that both balance interventions were developmentally and instructionally appropriate. Activities were designed to be modified, therefore meeting the needs of the variety of participants. Considering the fact that the adolescent students were already familiar with traditional balance exercises from their prior school years, whereas exergame balance training was completely new for them, it appears that the use of the Nintendo Wii gaming console allowed ExG students to become active participants in the training process. Specifically, Nintendo Wii-Fit Plus software allowed balance development to take place through the use of its interactive balance games, supporting learners to become discoverers and examiners of the balance-based activities.

Moreover, the specificity and frequency of the feedback provided to the ExG adolescent students by the system regarding both the knowledge of their performance and the knowledge of the results of their actions contributed to their balance development. This study had certain limitations, which should be mentioned. First, the results apply to adolescents with deafness aged 17 to 19 years and cannot be generalized to other populations. Second, the sample was small. However, given the small number and the specificity of the population studied, obtaining a greater sample was very difficult. Third, findings concern the specific exergames used (Nintendo Wii Fit Plus balance exergames). The results may have been different, if other exergames were used.

In conclusion, findings support the effectiveness of using the Nintendo Wii gaming console as an intervention for adolescent students with deafness, and specifically, its effects on physical function related to balance competence. However, future studies are needed to investigate the effectiveness of this mode of balance training to multiple settings and populations.

References

Azevedo, M.G., & Samelli, A.G. (2008). Comparative study of balance on deaf and hearing children. *Revista CEFAC, 11*(1), 85-91.

Bonney, E., Jelsma, D., Ferguson, G., & Smits-Engelsman, B. (2017). Variable training does not lead to better motor learning compared to repetitive training in children with and without DCD when exposed to active video games. *Research in Developmental Disabilities, 62*, 124-136.

Cohen, L., & Manion, L. (1994). *Research methods in education.* London: Routledge.

de Bruin, E.D., Schoene, D., Pichierri, G., Smith, S.T. (2010). Use of virtual reality technique for the training of motor control in the elderly-Some theoretical considerations, *Zeitschriftfür Gerontologie und Geriatrie, 43*, 229-234.

Di Stefano, L.J., Clark, M.A., & Padua, D.A. (2009). Evidence supporting balance training in healthy individuals: A systemic review. *Journal of Strength and Conditioning Research, 23*(9), 2718-2731.

Gheysen, F., Loots G., & van Waelvelde, H. (2008). Motor development of deaf children with and without cochlear implants. *Journal of Deaf Studies and Deaf Education, 13*(2), 215-224.

Gioftsidou, A., Malliou, P., Pafis, G., Beneka, A., Godolias, G., &Maganaris, C. (2006). The effects of soccer training and timing of balance training on balance ability. *European Journal of Applied Physiology, 96,* 659-664.

Green, B.S., & Salkind, J.N. (2013). *Using SPSS for Windows and Macintosh: Analyzing and understanding data.* New Jersey: Prentice Hall.

Kato, P.M. (2010). Video games in health care: closing the gap. *Review of General Psychology, 14*, 113-121.

Majlesi, M., Farahpour, N., Azadian, E., &Amini, M. (2014). The effect of interventional proprioceptive training on static balance and gait in deaf children. *Research in Developmental Disabilities, 35*, 3562-3567.

Malliou, P., Gioftsidou, A., Pafis, G., Beneka, A., & Godolias, G. (2004). Proprioceptive training (balance exercises) reduces lower extremity injuries in young soccer players. *Journal of Back and Musculoskeletal Rehabilitation, 17*, 101-104.

Meldrum, D., Glennon, A., Herdman, S., Murray, D., & McConn-Walsh, R. (2012). Virtual reality rehabilitation of balance: Assessment of the usability of the Nintendo Wii Fit Plus. *Disability and Rehabilitation: Assistive Technology, 7*(3), 205-210.

Mhatre, P.V., Vilares, I., Stibb, S.M., Albert, M.V., Pickering, L., Marciniak, C.M., et al. (2013). Wii Fit balance board playing improves balance and gait in Parkinson disease. *PM&R, 5,* 769-777.

Payne, V. G., & Isaacs, L. D. (2011). *Human motor development: A lifespan approach.* Boston, MA: McGraw-Hill.

Ribas, C.G., Alves da Silva, L., Corrêa, M.R., Teive, H.G., & Valderramas, S. (2017). Effectiveness of exergaming in improving functional balance, fatigue and quality of life in parkinson's disease: A pilot randomized controlled trial. *Parkinsonism and Related Disorders, 38*, 13-18.

Roopchand-Martin, S., McLean, R., Gordon, C., & Nelson, G. (2015). Balance Training with Wii Fit Plus for Community-Dwelling Persons 60 Years and Older. *Games for Health Journal, 4*(3), 247-252

Taylor, M.J.D., Shawis, T., Impson, R., Ewins, K., McCormick, D., & Griffin, M. (2012). Nintendo Wii As a Training Tool in Falls Prevention Rehabilitation: Case Studies. *Journal of the American Geriatrics Society, 60*, 1781-1783.

Valovich McLeon, T.C. (2008). The effectiveness of balance training programs on reducing the incidence of ankle sprains in adolescent athletes. *Journal of Sport Rehabilitation, 17*, 316-323.

Vernadakis, N., Derri, V., Tsitskari, E. & Antoniou, P. (2014). The effect of Xbox Kinect intervention on balance ability for previous injured young competitive male athletes: a preliminary study. *Physical Therapy in Sport, 15*, 148-155.

Vernadakis, N., Gioftsidou, A., Antoniou, P., Ioannidis, D., & Giannousi, M. (2012). The impact of Nintendo Wii to physical education students' balance compared to the traditional approaches. *Computers and Education, 59*(2), 196-205.

Willardson, M.J. (2007). Core stability training: Applications to sports conditioning programs. *Journal of Strength & Conditioning Research, 21*(3), 979-985.

Yang, Y.R., Tsai, M.P., Chuang, T.Y., Sung, W.H., & Wang, R.Y. (2008). Virtual reality-based training improves community ambulation in individuals with stroke: A randomized controlled trial. *Gait & Posture, 28*(2), 201-206.

Zwierzchowska, A., Gawlik, K., & Grabara, M. (2004). Energetic and coordination abilities of deaf children. *Journal of Human Kinetics, 11*, 83-16.

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