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Original article

The effects of a daily, 6-week exergaming curriculum on balance in fourth grade children

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Abstract

Balance is an essential component of movement and is critical in the ability to participate in physical activity. Developing an exergaming curriculum for schools has the potential to improve balance or postural stability in children. In this study, a purposely-built exergaming center in an elementary school was used to test fourth grade students with a specially designed exergaming curriculum oriented toward improving postural stability. The program was implemented over a 6-week period, 34 min per day, 4–5 days per week. Two control groups were used: (1) a physical education (PE) class geared toward agility, balance, and coordination (ABC) improvement, and (2) a typical PE curriculum class. Exergaming students improved their postural stability significantly over a 6-week period compared to those in the typical PE class. Improvements in postural stability were also evident in the ABC class. Postural stability in the girls was better than the boys in all pre- and post-intervention tests. This study demonstrates that exergaming is a practical resource in the PE class to improve postural stability.

Keywords: Balance; Children; Elementary school; Exergaming; Fundamental movement skills

1. Introduction

Balance is one of many fundamental movement skills (FMS) that is critical to the physical development and functional activity level of children.[1–5] The development of balance and other FMS upon which more difficult motor tasks are built is vital to the confidence in the physical skills of a child. Competence and confidence in one's own FMS are essential elements in the intrinsic desire to participate in physical activity (PA) on a regular basis.[6]

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The intricate multidimensional ability to balance is a construct that continues to evolve.[7–10] The World Health Organization considers functional balance in the dimension of activity when classifying disability and health.[11] The difficulty in describing the complicated nature of balance and postural stability is heightened by the lack of agreement in the literature. No single consensus on terminology or definition exists. For the purposes of this research, a practical and simplistic definition is used: Humphriss et al.[12] describe the outcomes of balance (sit, stand, and move) as the body's ability to keep its centre of mass (COM) over its base of support (BOS). Postural stability is defined as the ability to control the COM in relation to the BOS. In other words, balancing is the process by which postural stability is maintained.[1,13]

Commonly, balance is considered in two categories: static and dynamic. The seminal description of static and dynamic balance provided by Bass[7] has essentially remained unaltered: the body's ability to constantly maintain the relationship between COM and BOS whenever it is stationary (static) or

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moving (dynamic) in an upright position. Both voluntary and involuntary movements maintain this equilibrium.

A review of the literature has shown that current research related to balance with school-aged children has taken place primarily in a laboratory setting. The school-based balance studies that do exist often explore the efficacy of physical education (PE) interventions related to health and skill related components of fitness and/or secondary curriculum.[14–18] There is very limited field research on postural stability in an elementary school PE setting.[19] Notwithstanding our previous research, no peer reviewed studies related to exergaming and balance in children have been located.[20]

Exergames are videogames that require participants to engage in physical movement in order to play.[21] Fun and exercise are combined, enabling videogame players to become physically active, thereby thwarting the perception that videogame playing is always sedentary. The trend in youth toward this type of videogame playing makes it an attractive option in the quest to promote a healthy, active lifestyle,[22] including within the school setting. However, strategies related to the use of exergaming in schools are new and research is limited mostly to laboratory settings. Additionally, the research that does exist relates mainly to exergaming and energy expenditure, and not postural stability.[23–27] Research surrounding exergaming and balance improvement is predominantly in the area of university students, people affected by medical conditions (i.e., cerebral palsy, Down syndrome, *etc.*), or adults and seniors for rehabilitation and fall-prevention strategies. An Internet search for exergaming studies focusing on balance improvement in healthy, elementary-aged children came up empty. For these reasons, a study of this kind fills a large gap in the current research.

Gender has been shown to have an effect on a child's balance. Studies in a laboratory setting have revealed that elementary-aged girls demonstrate greater postural stability than boys.[14,15] This study will examine the gender differences in postural stability in a school setting.

This study was designed to investigate the effect a PE exergaming curriculum on the postural stability of 9- and 10-year-old children in a school setting. Specifically:

1. Does a daily 6-week exergaming experience in a fourth grade PE class improve postural stability (compared to a control group) as measured by the HUR BT4™ (HUR Labs balance software 2.0 Manual; HUR Labs, Kokkola, Finland) balance platform?
2. Does a daily 6-week agility, balance, and coordination (ABC) experience in a fourth grade PE class improve postural stability (compared to a control group) as measured by the HUR BT4™ balance platform?
3. What is the relationship between a 6-week exergaming and an ABC unit in fourth grade children?
4. Does gender have an effect on the postural stability of the children in this study?

The length of the study was established based on the current literature that has shown improvements in adult and adolescent postural stability using a 6-week intervention.[28–31] The results for any shorter period were inconclusive in both adults and children.[32] Our previous research examining third grade students found that curriculum-specific Wii™ (Nintendo corporation, Kyoto, Japan) balance activities can significantly improve balance.[20] The current study expands on that research and examines the effect of daily PA using a variety of exergaming equipment with curriculum-specific balance objectives on fourth grade students.

2. Methods

2.1. Participants

The exergaming study was designed to include all fourth grade students at the participating school ($n = 64$; 28 females, 36 males). There were three classes of grade four students. Two students did not receive parental permission to take part in the data collection; however, they participated in the activities as part of their PE experience. One other student moved during the course of the intervention, therefore the data was excluded. This study was approved by the University of Calgary Biomedical Research Ethics Board. Informed consent was obtained by the parents of participating students. The parents of the children involved in the primary study identified no injuries, chronic balance disorders, or long-term lower body impairments.

The PE teachers were employees of the school and responsible for curriculum design in consultation with the principal investigator (PI) and for teaching the PE classes. The PI was responsible for all pre- and post-test data collection.

2.2. Facility

A 750 ft^2 elementary school stage was converted to an exergaming teaching station in a local public school in Calgary, Alberta, Canada. This living lab is the Canadian Exergaming Research Centre (CERC; www.ucalgary.ca/exergaming). A privacy curtain was installed to eliminate the visual distractions between teaching stations. Only those students participating in the study were allowed access to the exergaming equipment.

2.3. Exergaming equipment

iDance™ (Positive Gaming BV, Hillegom, Netherlands) is a wireless system of $3' \times 3'$ dance platforms (similar to Dance Dance Revolution™ (Konami corporation, Tokyo, Japan)) that requires a user to follow a visual pattern of foot movements in beat with the music. Users achieve a score (rating) based on their ability to strike the prescribed area of the touch pad at precisely the correct moment. iDance™ uses family friendly music and a variety of levels (rated G for all ages) to ensure that each player can participate in the game successfully. The iDance™ activity requires coordination, balance, and agility in addition to reasonable reaction time and a sense of rhythm. There were nine iDance™ pads in the CERC.

The Wii Fit™ Plus (Nintendo, Kyoto, Japan) exergaming platform offers a variety of activities related to strength, flexibility, balance, and dance (each of which has an element of agility and coordination). Personalized feedback based on basic anthropometric measures is one of the unique customization features of this product. There were eight Wii Fit™ stations in the CERC.

The XR-Board™ Dueller System (iTech Fitness, Denver, CO, USA) is a snowboard simulator that requires students to balance on a snowboard-shaped platform and navigate their way through a series of obstacles on a virtual ski hill. This equipment has a significant emphasis on balance and is set up so that a user can play as a sole competitor or with another gamer. There were two XR Board™ Dueller stations with a total of four active snowboards in the CERC. There were also two inactive practice snowboards that were used by students while waiting for their turn to participate on the virtual snowboarding course.

The Lightspace™ Play Wall (Lightspace Corporation, Boston, MA, USA) is made up of 64 individual interactive tiles that can detect the location and force of a participant's hand or implement. The $8' \times 4'$ playing surface is wall mounted and offers a variety games for one or two players. A range of skill levels can be selected to meet the individual needs of the player. The Lightspace™ requires a player to move laterally and vertically and may be used to develop coordination, reaction time, speed, agility, balance, and laterality. The CERC has one Lightspace™ Wall unit.

2.4. Research design

A multi-factor, multi-variable repeated measures design with convenience sampling was chosen for this school-based research. The non-equivalent pre−post control group study resulted in minimal impact on student scheduling and the least amount of disruption for the school. Students in the fourth grade participated as part of their regularly scheduled daily PE classes. This study used the exclusion criteria established by Emery and colleagues.[28] Since the PA in this study was part of the required school day, these conditions did not exclude a student from participating, but rather only from the data collection.

2.4.1. Experimental conditions

The three pre-existing fourth grade classes were randomly assigned to the exergaming intervention, the ABC intervention, or the control group. The ABC group was included in the design to allow for a comparison of the exergaming results to a unit with similarly desired outcomes. Both intervention group results were compared against the control group. All groups received 34 min of PE, 4−5 days per week over the 6-week study period.

2.4.2. Control group

Activities included those generally found in a typical PE curriculum, such as paddle sports, low organized games, badminton, and fitness Friday circuits. There were 12 boys and nine girls in this group.

2.4.3. Exergaming group

Students participated in a structured exergaming experience using a variety of exergaming equipment. The class was divided into three subgroups that rotated to a different station each day. Subgrouping allowed for an equal rotation among three stations; iDance™, XR Board™/Lightspace™, and Wii Fit™ Plus. Students at the iDance™ station all started at the basic levels of challenge but by the third week were able to select their own level of difficulty to match their skill level. The Lightspace™ and XR Board™ were combined into a single station due to the difficulty of virtual snowboarding; after two downhill races a student would switch to the Lightspace™ to give their legs a rest and play the games that require arm activity. This group consisted of 10 boys and 11 girls.

2.4.4. ABC group

Students were instructed by a PE specialist using a variety of custom designed lessons focusing on ABC. Dance, gymnastics, and obstacle course activities were included in this unit. A variety of innovative equipment was introduced including duck walkers, jump bands, balance pads, reaction balls, agility ladders, BOSU® balls (BOSU corporation, Ashland, OH, USA), and yoga mats. Eleven boys and eight girls participated in this group.

2.5. Procedures

The pre-testing of postural stability was completed in week 1 of the study. Anthropometric measures and the assessment of postural stability were recorded by the PI. Balance testing was done on the HUR BT4™ platform, a sophisticated portable assessment device designed for advanced testing of postural stability. Postural stability is measured using trace length, which is how far the participant shifts from the center of pressure over a 20-s period while performing balance tasks. The sum of the successive straight length segments separated in time by one-fifth of a second provides a measure of postural stability in millimeters (mm). The sampling frequency was set to 50 Hz, which was recommended by the manufacturer to balance consistent data acquisition and manageable data size. The HUR BT4™ platform has a sensitivity of 2,V/V $\pm$ 0.25% and an acceptable combined error maximum of 0.03%.

All balance testing was done in the elementary school gymnasium with varying levels of noise and distraction (Fig. 1). Students were tested in groups of two or three at a time. The PI randomly selected which student to test while the others watched. Testing took approximately 4−5-min per student. A complete description of the balance trials can be found in our previous work.[2] Briefly, postural stability was tested six ways: single-leg and tandem stance each with either eyes open or eyes closed on a hard surface and each stance with eyes open on a foam surface. The non-dominant foot was used to balance on during any single leg trial (Fig. 2). During the tandem

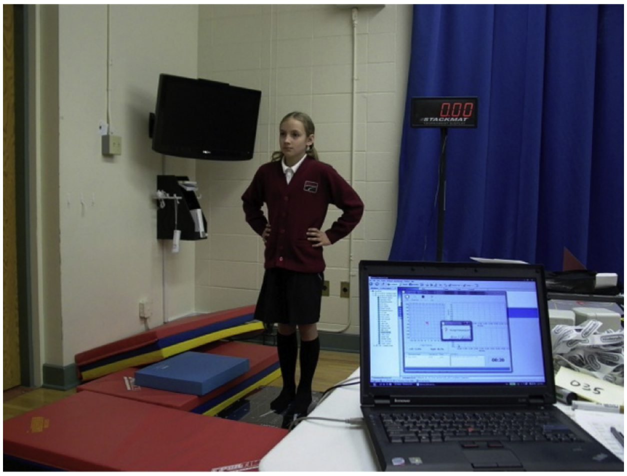

Fig. 1. CERC balance testing area.

stance, students were asked to stand heel to toe with their feet as close as possible without touching with the non-dominant foot behind the dominant foot. Hands had to be kept on the hips for all tests. Students with long hair were asked to ensure their eyes were visible during testing. A focal point was placed at eye-level on the wall. Some balance tests required the use of a foam pad (Fig. 3). A new rectangle high density (50 kg/m^3) closed-cell Airex Balance Pad (47 cm × 39 cm × 6 cm, 0.7 kg) was used for all tests requiring a foam surface. That balance pad was rotated 180° after each test to ensure even wear. Subjects were given a 10−15 s opportunity to get used to the foam pad prior to the first trial of balance testing with the foam. Gymnastic mats were placed around the subject for safety and to decrease the impression that a subject was elevated when testing on a foam pad.

Students who lost their balance were instructed to make any necessary adjustments and return to the testing position as quickly as possible. Only one trial was permitted per stance.

Fig. 2. Single leg balance test using the HUR BT4™ balance platform.

Fig. 3. Tandem balance test using the HUR BT4™ balance platform and foam pad.

The maximum time between tests was 20 s. In most cases the only break was the time that it took to explain the next test and to add or remove the foam pad.

The study ran over the course of 8 weeks. The pre-test of postural stability was completed in 3.5 days during week 1. The intervention period took place during weeks 2−7. There were a total of 26 PE classes involved in this research over a 6-week period. Post-testing of postural stability occurred during week 8. Students were post-tested in the same order as the pre-test.

2.6. Data analysis

Data were analyzed using SPSS for Windows version 17.0 (SPSS Inc., Chicago, IL, USA). A two-way analysis of variance with one repeated measure was conducted to explore the interaction effect for Time by Group and Time by Gender. Simple effect testing was conducted to determine the specific relationship between groups and time. A pairwise comparison was used to evaluate the mean composite score between each subgroup after the balance pre-testing. This investigation was done to determine the uniformity between research groupings at the start of the intervention. An additional pairwise comparison of the pre- and post-test mean composite scores determined the significance of change in postural stability for each group. $p < 0.05$ is considered to be statistically significant.

3. Results

Descriptive results from postural stability pre- and post-testing are presented in Table 1. A decrease in trace length as measured by the HUR BT4™ represents an improvement in postural stability. A pairwise comparison was used to evaluate the mean composite score between each subgroup after the balance pre-testing. This investigation was done to determine

Table 1
Postural stability scores (mm, mean ± SD).

Group	n		Pre-test	Post-test	Overall range
	Male	Female			
Control	12	9	6742 ± 2075	6543 ± 1904	3351−12,384
Exergaming	10	11	7688 ± 1828	5454 ± 1054*	4829−11,114
ABC	11	8	8567 ± 2484	6170 ± 1729*	4465−13,529
Total ($n = 61$)	33	28	7636 ± 2226	6052 ± 1640	3351−13,529

*$p < 0.001$, compared with control group. Abbreviation: ABC = agility, balance, and coordination.

the uniformity between research groupings at the start of the intervention. The evaluation of the pre-test means indicated that there was a significant difference in the starting point between the control and ABC groups ($p = 0.027$). There was no statistical difference in the pre-test means of the control and exergaming groups (Table 2).

Since there was a significant difference in pre-test results, an analysis of covariance (ANCOVA) with pre-test as the covariate was used to control the discrepancy from the pre-test. This process computes the residual-adjusted gain score between pre- and post-test as the dependent variable. Table 3 presents the results of the ANCOVA. There was a significant covariate effect and a significant main effect difference between groups on the residual-adjusted gain score. Table 4 shows the pairwise comparisons indicating a significant difference between the exergaming and control and the ABC and control.

Daily exergaming for 6 weeks resulted in a 29% improvement in postural stability. The ABC group had a 28% improvement in postural stability. Both intervention group improvements were significant. The control group had no significant difference in their postural stability (3%; Fig. 4). The pre- and post-test composite mean score of each gender was compared (Table 5). A two-way between-groups analysis of variance was conducted to explore the impact of gender by time (Table 6). There was no statistically significant interaction effect for gender by time ($p = 0.371$), however, the girls had significantly better postural stability than the boys ($p = 0.049$).

4. Discussion

At the core of FMS proficiency is the development of balance and coordination. Finding a method of teaching balance and coordination in a way that engages students is essential to a successful PE curriculum. The use of exergaming in schools is a novel approach to embedding the training of balance, coordination, and many different FMS in a way in which children can relate. To understand the use of exergaming for balance improvement in elementary-aged children to the fullest, three groups of fourth grade children were studied: an exergaming group, an enhanced agility, balance and coordination training group (ABC) and a typical PE curriculum group which provided a control. The control group post-test assessment of postural stability using the HUR BT4™ platform showed little improvement in balance scores and the pairwise comparison indicated that the change in the control group over time was not significant. The exergaming and ABC intervention groups showed substantially improved balance (29% and 28%, respectively). As a result of the little change in the postural stability of the control group, a significant interaction effect occurred among the groups over time.

Data from this study indicate that the daily use of a variety of exergaming equipment over a 6-week period in a PE class was equivalent to the ABC training offered for the same amount of time. Students in both groups participated in a structured class that had similar outcomes, demonstrating that using technology in the PE classroom can be an effective tool in the quest to improve balance in fourth grade children. Improvements in both groups also indicate the importance of focusing on the introductory skills of ABC in order to improve postural stability.

Catering to the individual needs of a child in a large classroom setting can be a challenge. One way of ensuring that all children participate is by offering a variety of settings in which to take part. Children in the ABC group performed their activities in front of each other and could observe each other's successes and failures. In the exergaming cohort, students were in very small groups based on the amount of equipment; however, they worked independently and monitored their own performance. Providing both arenas for participation allows those who perform better in one situation over another to find a venue for activity that they enjoy.

Table 2
Pairwise comparison of pre-test means by group.

Group (I)	Group (J)	Mean difference (I−J)	SE	p
Control	Exergaming	945.772	658.596	0.469
Exergaming	ABC	878.703	675.706	0.596
ABC	Control	1824.475	675.706	0.027

Abbreviation: ABC = agility, balance, and coordination.

Table 3
Analysis of covariance with dependent variable HUR post-test trace score and covariate HUR pre-test trace score.

Source	Type III sum of squares	df	Mean square	F	p
Corrected model	1.116×10^8	3	37,196,095.696	42.605	0.001
HUR pre-balance	98,756,681.193	1	98,756,681.193	113.116	0.001
Group	32,143,020.501	2	16,071,510.251	18.408	0.001
Error	49,764,050.627	57	873,053.520		
Total	2.396×10^9	61			
Corrected total	1.614×10^8	60			

Note: $R^2 = 0.692$; Adjusted $R^2 = 0.675$.

Table 4
Pairwise comparisons of HUR post-test trace scores.

Group (I)	Group (J)	Mean difference (I−J)	SE	p
Control	Exergaming	1667.177	293.435	0.001
	ABC	1489.148	313.888	0.001
Exergaming	Control	−1667.177	293.435	0.001
	ABC	−178.029	300.127	0.555
ABC	Control	−1489.148	313.888	0.001
	Exergaming	178.029	300.127	0.555

Abbreviation: ABC = agility, balance, and coordination.

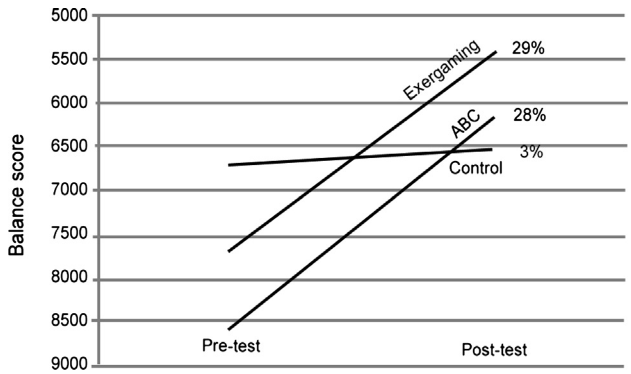

Fig. 4. Percentage of balance improvement (by group): grade 4 HUR BT4. ABC = agility, balance, and coordination.

A similar exergaming study of third grade students found the same significant differences in postural stability between boys and girls.[20] Gender results from this and the third grade exergaming studies are consistent with the findings of similar research with 7–12-year-old children.[14,33] A possible explanation of this gender difference is that neurological, visual, vestibular and proprioceptive systems, which are all used for balance, mature earlier in girls than boys.[14]

The overall goal of PE is to expose children to a variety of options with the intent to find a way to develop a positive attitude toward PA. As fewer children participate in PA outside of the PE classroom and engage more in sedentary behaviors such as watching TV and playing videogames, bringing a format that children understand into PE could provide educators, health providers, and parents with a means to connect with children and reverse the trend of inactivity. Using the balance-specific equipment in the gymnasium provided the same benefits that the exergaming equipment did, however, in the home environment children have greater access to exergaming consoles than duck walkers, jump bands, balance pads, reaction balls, agility ladders, BOSU™ balls, and yoga mats. Since the goal of educators is to encourage children to take the knowledge that they learn in school and apply it elsewhere, using exergaming in schools could lead to children wanting to use video consoles at home for active, rather than sedentary gaming.

ABC are at the core of FMS and are the groundwork that other more complex motor skills rely on.[34–39] Improving balance can translate to greater confidence and an increased likelihood of participation in PA.[40] It is the competence to perform basic motor tasks coupled with the confidence to try new activities that could encourage children to embrace a positive attitude about being active for life. The results presented here demonstrate that using exergaming as a tool for improving postural stability is a viable option for specific ABC training in a fourth grade PE class. Physical educators can join in the exergaming trend exhibited by students as a means to connect students to PA.

Table 5
Postural stability score by gender (mean ± SD).

Gender	Time	Mean ± SD
Male	Pre-test	8133.97 ± 2144.11
	Post-test	6381.42 ± 1703.86
Female	Pre-test	7050.06 ± 2215.51
	Post-test	5664.33 ± 1499.26

Table 6
2 × 2 ANOVA of postural stability (time × gender).

Source	*df*	Mean square	*F*	*p*
Time	1	74,610,000	58.973	0.001
Gender	1	24,540,000	4.037	0.049
Time × gender	1	1,027,323	0.812	0.371
Error (time)	59	1,265,228	–	–
Residual error	59	6,077,665	–	–

Some limitations presented during the course of this research that may hinder the generalizability of the conclusions. One is the challenge of conducting scientific research in a functioning school environment. The testing environment cannot be considered clinical as conditions changed on a regular basis (i.e., noise levels). Costs to purchase and maintain the equipment may be a limiting factor in the widespread uptake of exergaming in schools. Moreover, there is limited technical support available in Canada; however, the students themselves are often helpful at troubleshooting and resolving matters related to the set up and playing of games.

5. Conclusion

Pedagokinetics is the art and science of teaching FMS, and is becoming a key consideration in the evolution of PE curriculum for both practitioners and researchers.[41] Innovative methods that embed the development of FMS into activities that children enjoy are being introduced in schools (i.e., BOSU® balls, yoga mats, and duck walkers). The exergaming movement is another such practice that is being studied as an alternative method of increasing PA levels, however without regard for the potential as a tool to develop FMS.[24,25,42] The evidence provided in this paper suggests that balance is one motor skill that can be improved by the strategic and intentional use of exergames. Parents, teachers, and recreational leaders can confidently know that based on the results of this study there is a measureable benefit to balance development when using certain exergames.

Future research should include determining teacher and student impressions of integrating exergaming into the school curriculum. Subsequent studies should expand investigation about the potential use of exergaming to develop other FMS such as laterality, coordination, and agility. Simple methods of assessing those skills in PE classes may also be a topic for future consideration. Additionally, researchers may want to consider the effects of home-based exergaming on FMS development.

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