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The effects of balance training intervention on postural control of children with autism spectrum disorder: Role of sensory information

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ABSTRACT

Purpose: The aim of this study was to investigate the effect of balance training intervention in children with autism spectrum disorder (ASD), and to explore the relative role of the sensory systems in such kids.
Methodology: We recruited 20 school children (IQ > 80) diagnosed with ASD, and categorized them in two groups; a 10-member training group (average age: 7.70 ± 1.05) and a 10-member control group (average age: 7.90 ± 1.10). Thus, following a six-week-long balance training intervention in four conditions of bipedal upright stance [compliant (Foam) vs. non-compliant (Hard) with eyes-open (EO) vs. eyes-closed (EC)], we examined measures such as mean velocity (*V*), anteroposterior (AP) and mediolateral (ML) axis displacement, and compared the results to those calculated prior to the initiation of the intervention using MANOVA test.
Results: This study showed that the balance training program efficiently improved the postural control in ASD suffering children, and that removing the visual and plantar proprioceptive information led to increased sway in both groups. The training group performed significantly better than the control group in all conditions.
Conclusion: It is thus concludable that children suffering from ASD can benefit from such balance training programs to improve their balance and postural control.

1. Introduction

Children with autism spectrum disorder (ASD) primarily suffer from impairments in communication and social interaction, though recent literature supports the prevalence of motor impairments (Fournier et al., 2010). The prevalence rate of ASD continues to increase with 1 child in 88 having ASD, with males being 5 times more likely to be diagnosed than females (Centers for Disease Control & Prevention, 2012). ASD is a disorder with a wide range of impairments of body structures and functions, many of which impact postural control. Postural stability is defined as the ability to maintain the projected center of mass (COM) in the base of support (Dusing & Harbourne, 2010). Children with ASD showed higher

Abbreviations: ASD, autism spectrum disorder; COM, center of mass; COP, center of pressure; *V*, velocity; AP, anteroposterior axis; ML, mediolateral axis; TD, typically developing; ADI-R, autism diagnostic inventory-revised; EO, eyes open; EC, eyes-closed; MANOVA, multivariate analysis of variance.

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instability in mediolateral than anteroposterior axis though typically developing (TD) children demonstrated higher sway scores in anteroposterior than mediolateral direction (Memari et al., 2013).

On the other side, the vestibular, somatosensory (including proprioceptive and cutaneous inputs) and visual systems are the afferents involved in the complex process of maintaining upright balance in humans. Any deficit in these systems or in the integration of information from these systems could affect balance. Sensory impairments are common in children with developmental disabilities (Gal, Dyck, & Passmore, 2010), and they are at an increased risk for visual impairments (Creavin & Brown, 2009). Of particular importance are the identified deficits in postural control (Gepner & Mestre, 2002). Previous research on such children has identified deficits in motor development (Provost, Lopez, & Heimerl, 2007), coordination and general motor function (Jansiewicz et al., 2006), and the planning and execution of movement (Rinehart et al., 2006). There is a paucity of research on the use of the somatosensory and postural control for children with ASD. Kohen-Raz, Volkman, and Cohen, 1992 were the only ones to suggest that children with ASD may prefer using the somatosensory system to maintain balance. Also ASD children have been found to have deficits in various motor control areas, including hypotonia and motor apraxia (Ming, Brimacombe, & Wagner, 2007), overall gross motor development, locomotor and object control skills, manual dexterity, ball skills and balance (Green et al., 2009), and a general deficit in manual responses to visual stimuli (Todd, Mills, Wilson, Plumb, & Mon-Williams, 2009).

The efficacy of balance training programs for children is not well understood. Many interventions and exercise programs include balance components, but there are few research studies that focus solely on balance training for children with developmental disabilities. Wang and Chang (1997) specifically studied the effects of a jumping skill program on balance during gait among children with mental retardation and Down syndrome. Shumway-Cook, Hutchinson, Kartin, Msme, and Woollacott (2003) also reported improvements in balance with cerebral palsy following an intervention program. Most of the balance intervention studies involve the elderly population. But there has been no research about possible influences of balance training interventions on postural control in ASD suffering children. In general, there has been little research regarding characteristics of postural control in ASD. It has been assumed that postural control is best achieved when postural sway is held to a minimum. Based on this assumption, researches have shown that balance training can improve postural control in healthy (Kovac, Birmingham, Forwell, & Litchfield, 2004), injured/diseased (Kidgell, Horvath, Jackson, & Seymour, 2007; McKeon et al., 2008), and elderly populations (Nagy et al., 2007).

Some researchers have focused on examining the effects of various constraints (e.g., disease state, restricted vision, and heightened attentional awareness) on postural sway (Roerdink, Hlavckova, & Vuillerme, 2010). Much research has been devoted to improving postural control through exercise programs. However, there is insufficient research investigating the use of balance training programs in the developmental disabilities. On the other hand, based on neurobehavioral studies, children with ASD have structural or functional impairments (Nayate, Bradshaw, & Rinehart, 2005). In the present research, we aimed to examine the effect of progressive balance program on the improvement of postural control in children with ASD, and to measure the relative role of the sensory systems in this regard. We hypothesized that balance program could reduce postural sway in ASD suffering children. We further hypothesized removing the visual and plantar proprioceptive information could lead to increased levels of postural sway.

2. Methods

2.1. Participants

A total number of twenty participants were selected for this study, and were assigned to two groups: control group (average age: 7.90 ± 1.10) and training group (average age: 7.70 ± 1.05). Each group consisted of 10 boys aged 7–10 years old diagnosed with high functioning ASD (IQ > 80). Each child had to meet the criteria of ASD diagnosis on both DSM-IV (Association and DSM-IV, 2000) and the autism diagnostic inventory-revised (ADI-R) (Lord, Rutter, & Le Couteur, 1994) which was examined by a child psychiatrist or psychologist. The participants were included from autism specific schools in Ahvaz. The protocol was approved by the Review Board of Shahid Chamran University prior to participant recruitment, and all participants provided written informed consent before participation in experimental procedures. The study was also approved by the Ethics committee of Shahid Chamran University of Ahvaz.

2.2. Assessment of postural control

Postural sway data were collected using the Bertec force plate (type strain gage, 40×60). Force platform is the instrument that records the ground reaction forces excreted by an individual. The force sensors under the force plate measure the forces in the horizontal and vertical directions. The information is then transferred to a computer by a cable to enable the analysis of the data and the process of information such as position of ground reaction forces in anteroposterior and mediolateral axes. Data were sampled out at 100 Hz and the platform was calibrated before each test.

2.3. Additional assessments

Maintaining upright posture is a complex process involving multiple afferent systems. During the "eyes closed" tasks, subjects were blindfolded and asked to keep their eyes closed under a blindfold. High foam pad with a density of 1 lb/ft3 was

Table 1
Descriptions of the exercises that comprised the balance training intervention.

Balance exercise	Description	Reps/sets	Progression level[a]
Single leg stance	Maintain balance in upright unilateral stance	3 reps of 30 s with each leg	Level 1: Hard surface, (eyes open) Level 2: Hard surface, (eyes closed) Level 3: With Foam (eyes open) Level 4: With Foam (eyes close)
Balance path	Maintain balance while walking forward across a designated path	3 trips (backand forth)	Level 1: linear path; gait Level 2: curved path; gait Level 3: linear path; heel-toe Level 4: curved path; heel-toe
Dynamic balance	Maintaining balance on the non-dominant leg and dominant leg	3 reps of 30 s	Level 1: flexion–extension (Hard surface, eyes open) Level 2: abduction–adduction (Hard surface, eyes closed) Level 3: flexion–extension (With Foam, eyes open) Level 4: flexion–extension (With Foam, eyes close)
Double leg	Maintain balance in stance atop on balance board	3 reps of 30 s	Level 1: with help, eyes open Level 2: with help, eyes closed Level 3: eyes open, without help Level 4: eyes close, without help

[a] Each exercise was advanced through progression levels according to each participant's skilled ability and willingness to be challenged by more difficult forms of an exercise.

placed on top of the force platform, covering the entire 50 cm × 50 cm surface the children were asked to stand as quietly as possible with arms at their sides for 30 s under four different test conditions: eyes open, feet on platform; eyes closed, feet on platform; eyes open, feet on foam; eyes closed, feet on foam.

2.4. Procedure

All experiments were conducted in the same room and under the same conditions. The computer used for recording data was kept outside the room. During the testing procedure, each subject stood quietly on the force platform with bare feet, with heels placed together and feet positioned at a 30° angle. Upon arriving to the first experimental session, each participant underwent initial testing to establish baseline postural control performance. This session consisted of eight counterbalanced trials of four different stance conditions (two trials per condition). The conditions consisted of bipedal stance on a compliant and high foam pad surface with eyes open (EO) and eyes-closed (EC). For each trial, participants were asked to stand on force plate 'as still as possible' with feet placed approximately shoulder's width apart and arms crossed over the chest. While in this position, COP was recorded in the AP and ML directions at a sampling rate of 100 Hz for trials of 30 s. Foot placements were marked on the force platform hard surface and foam pad surface prior to recording any trial to ensure similar stance widths within and between testing sessions. Finally, during all EO trials participants were asked to direct their visual attention toward a 5 cm × 5 cm piece of blue cardboard attached to a movable tripod and positioned at eye level 1 m directly in front of each participant. Upon returning to the lab on the day following baseline testing, each participant began the balance training intervention. For the intervention, participants attended three balance training sessions (Adam, Haworth, Hieronymus, Walsh, Smart, 2011) per week for eighteen sessions. Each session lasted approximately 45 min and was supervised by either a licensed and certified athletic trainer or another senior member of the research staff (graduate student or faculty advisor). During each session, participants performed a set of four balance training exercises (Table 1).

Each exercise had four progression levels through which participants could advance. Finally, within no more than 2 days of completing the intervention, all participants returned to the lab for a posttest session that was identical to baseline testing.

2.5. Statistical analysis

Prior to analysis with any postural sway measure, the first and last 2 s of all AP and ML COP time-series were cropped (leaving 26 s, or 2600 data points per time-series). This was done to limit the influence of movement adjustments participants might have made at the beginning of a trial while getting situated, or by anticipating the end of a trial. The Kolmogrov Smirnov test and leven test were used for secure normal distribution and equality of variance assumptions respectively. To test for groups (Training and Control), visual conditions (Closed and Open) and surface (Hard and With Foam) difference on dependent variable in the pre-test and post-test phases, multivariate analysis of variance were utilized. Upon observation of a significant F test, post hoc univariate test were conducted to identify the source of any significant main effects in the displacement of AP, ML axis, and velocity of COP. The calculated variables were inserted to SPSS16 in order to data analysis. The level of significance was set at $P < 0.05$ for all statistical tests.

3. Results

The participants' characteristics are presented in Table 2. Means (±SD) COP measures in different sensory conditions in pre-test and post-test for children with ASD are listed in Table 3. The significant difference between the pre- and post-test results are

Table 2
Characteristics of the participants (mean ± SD), training ($n = 10$) and control ($n = 10$).

Subject characteristic	Mean and SD[a]	
	Training	Control
Age (years)	7.70 ± 1.05	7.90 ± 1.10
Weight (kg)	33.50 ± 4.57	32.70 ± 1.01
Height (cm)	132.0 ± 4.05	131.10 ± 1.03

[a] (SD) standard deviation.

Table 3
Distribution of mean and standard deviation of COP displacement in the AP axis, ML axis, and velocity of COP children with autism in different sensory condition in pre-test and post-test.

Variable	Group	Stance surface	Vision	Pretest	Posttest
Direction anteroposterior	Control	Hard	Open	2.007 ± 0.150	1.387 ± 0.272
			Closed	2.183 ± 0.320	1.457 ± 0.368
		Foam	Open	2.158 ± 0.345	1.570 ± 0.395
			Closed	2.299 ± 0.445	1.632 ± 0.444
	Training	Hard	Open	1.946 ± 0.201	1.246 ± 0.162
			Closed	1.989 ± 0.178	1.314 ± 0.168
		Foam	Open	1.938 ± 0.183	1.220 ± 0.171
			Closed	2.015 ± 0.251	1.274 ± 0.243
Direction mediolateral	Control	Hard	Open	2.271 ± 0.215	1.621 ± 0.215
			Closed	3.153 ± 2.762	2.503 ± 2.762
		Foam	Open	2.367 ± 0.286	1.717 ± 0.286
			Closed	2.461 ± 0.333	1.954 ± 0.320
	Training	Hard	Open	2.206 ± 0.071	1.324 ± 0.503
			Closed	2.209 ± 0.074	1.342 ± 0.083
		Foam	Open	2.392 ± 0.407	1.538 ± 0.401
			Closed	2.319 ± 0.178	1.490 ± 0.255
Mean velocity	Control	Hard	Open	5.136 ± 0.734	4.983 ± 0.711
			Closed	5.601 ± 0.934	1.387 ± 0.874
		Foam	Open	5.241 ± 0.972	1.457 ± 1.349
			Closed	5.961 ± 1.255	1.570 ± 1.443
	Training	Hard	Open	5.158 ± 0.538	1.632 ± 0.538
			Closed	5.443 ± 0.582	1.246 ± 0.735
		Foam	Open	5.382 ± 0.679	1.314 ± 0.679
			Closed	5.546 ± 0.530	1.220 ± 0.775

indicative of improvement. Multivariate analysis of variance (MANOVA) indicated no significant differences between groups ($F_{(70, 3)} = 0.443$ $P > 0.05$), visual condition ($F_{(70, 3)} = 1.852$ $P > 0.05$) and ($F_{(70, 3)} = 1.874$ $P > 0.05$) in pre-test phase. Post-tests were conducted after eighteen sessions of training intervention (balance training program). Multivariate analysis of variance was used to determine the significance of the differences observed amongst different groups (Training and Control), visual conditions (Closed and Open), and surface (Hard and With Foam) in the post-tests. MANOVA indicated significant differences between groups ($F_{(70, 3)} = 7.047$ $P > 0.05$), visual conditions ($F_{(70, 3)} = 5.453$ $P > 0.05$), surface ($F_{(70, 3)} = 3.529$ $P > 0.05$) (Table 4).

After observation of a significant F test, post hoc univariate test were conducted to identify the source of any significant main effects. The results demonstrated significant difference between the training group and the control group in anteroposterior displacement ($P = 0.001$) and mediolateral displacement of COP ($P = 0.041$). Furthermore, results of the univariate tests revealed that for different surface conditions (Hard and With Foam), significant differences are only observed in the mediolateral displacement of COP ($P = 0.007$). In addition, on findings study revealed that in visual conditions (eyes open and closed), significant difference is observed in the velocity of COP ($P = 0.009$). Moreover, compared to the

Table 4
Results of multivariate analysis of variance under sensory different conditions.

Effect	Test	Value	F	Hypothesis df	Error df	Sig
Group		0.768	7.047	3	70	0.001*
Surface		0.899	3.529	3	70	0.048
Visual		0.869	3.529	3	70	0.019*
Surface * group	Wilks Lambda	0.975	0.593	3	70	0.622
Visual * group		0.980	0.465	3	70	0.707
Visual * surface		0.983	0.399	3	70	0.754
Visual * surface * group		0.990	0.241	3	70	0.06

* Significant difference.

control group, Lower sway in postural control and more stability was found for the training group in all postural control parameters (anteroposterior displacement, mediolateral displacement, and velocity of COP) and in all visual and surface conditions.

4. Discussion

The review of literature indicates poor postural control in children with ASD. No research has been dedicated to the improvement of the aforementioned shortcoming so far. Therefore, the present study aimed to investigate the effect of balance training on postural control in children with ASD to come over a solution for these deficiencies. Furthermore, we aimed to examine the role of sensory information. Results of the present study suggested that balance training resulted in the improvement of postural control in children with ASD. Moreover, the manipulation of sensory information was observed to increase the postural sways even after balance training intervention. Studies have shown that the amount of postural sway often increases during upright stance when vision is restricted (or impaired), as well as when stance is performed atop a compliant surface (Cornilleau-Peres et al., 2005; Stins, Michielsen, Roerdink, & Beek, 2009). Evidence from empirical studies supported that high rates of postural sway in children ASD were partially due to poor integration of vestibular, somatosensory, and visual inputs (Kohen-Raz et al., 1992; Minshew, Sung, Jones, & Furman, 2004; Molloy, Dietrich, & Bhattacharya, 2003). This deficit could arise difficulties in keeping body upright (Molloy et al., 2003). In addition, neurobehavioral studies demonstrated that cerebellum and basal ganglia with an established role in postural control (Bastian, 2006; Takakusaki, Saitoh, Harada, & Kashiwayanagi, 2004; Visser & Bloem, 2005) have structural or functional impairments in these children (Allen & Courchesne, 2003; Nayate et al., 2005; Rinehart et al., 2006). Taking these findings in to consideration, we have provided ASD suffering children with a balance training program comprised of progressive balance training with different sensory conditions involved in them. It should be noted that all the children studied were educable. After 18 training sessions, group training could easily implement balance programs. During the 18th session, children learned to perform the stance blindfolded or on the surface of a foam pad, an activity against which they resisted in the pre-tests. Furthermore, they managed to perform the stance more professionally in the last session. This is suggestive of improved postural control and possibly the improvement of functional deficits in the cerebellum and basal.

On the other hand, children with ASD are bound to have number of impairments in motor skill development (such as balance and coordination) as well as lower motor experiences compared to their normal peers (Pan & Frey, 2006). It is conveyed that people with higher motor experience (Lamoth, van Lummel, & Beek, 2009) or physically active life (Shumway-Cook et al., 2003) show lower postural sway scores compared with those without enough motor proficiencies. As was observed during training, participation of these children in practices led to the development of their motor skills and physical activity. Thus, providing balance training can improve children's motor skills and compensate their motor deficits, and eventually result in the improvement of their postural control. Studies have also indicated that children with ASD show different pattern of postural sway in mediolateral (ML) vs. anteroposterior (AP) direction compared to normal children. These children were more unstable in ML axis than AP axis. This might be related to postural immaturity in children with ASD (Fournier et al., 2010; Kohen-Raz et al., 1992; Minshew et al., 2004). These children show delay, stop or deficits in postural control mechanisms (Provost et al., 2007). Hence, it could be considered that children with ASD acquire "muscle balance" later than their normal peers, and there is an asynchrony between AP and ML stabilizing muscles in earlier years among children with ASD. Therefore, providing these children with balance training such as balance boards can improve the posture control mechanisms in AP and ML axes. Furthermore, balance training can led to the improvement of postural muscle balance as well as the strength of the lower extremities (Heitkamp, Horstmann, Mayer, Weller, & Dickhuth, 2001). On the other hand, studies have demonstrated that ASD symptom severity is correlated with the amount of sway. Severity of ASD symptoms may impact a wide range of cognitive and physical skills (Gotham, Pickles, & Lord, 2009; Matson & Rivet, 2008; Matson, Wilkins, & Macken, 2008) such as attention (Happé, 1999), practice (Dziuk et al., 2007) and presumably postural control. Higher rates of ASD symptom severity have per found potential to influence the amount of effort required to stand properly (Hauer et al., 2003). Since the children studied have an IQ higher than 80, the severity of their ASD symptoms is almost modified. Balance training is likely to create conditions similar to the game conditions and physical activities that can improve their cognitive and motor skills. The amount of force required to stand correctly will thus decrease following this improvement which will eventually lead to their overall postural control. In addition, it is possible that higher amount of sway in these children is due to the anxiety experienced because of the social and cognitive disabilities such as communication impairments and social awkwardness (MacNeil, Lopes, & Minnes, 2009; Matson, Neal, Fodstad, & Hess, 2010). Therefore, their participation in eighteen sessions of balance training and also continuous interaction and communication with both Subgroups and their trainers, it can alleviate the experienced anxiety, their shortcomings in communication and social conditions, and consequently, the amount of postural sway.

4.1. Limitations and future directions

The effects of changes in postural control must be explored. Further research is required to determine the effects of balance programs on postural sway. Scholars need to further identify the roles of balance training in motor cortex limitations or cerebellum of ASD. Intervention programs also need to be investigated. Future research needs to focus on more functional and long-term outcomes. Scholars need to measure the effectiveness of intervention programs for children with autism in bigger populations and various age ranges.

4.2. Implications

This study provides a context for clinicians to focus on balance training to improve postural control in children with ASD in different sensory conditions.

4.3. Conclusion

Since the children with autism have developmental delay or problems in the central nervous system as well as clinical features associated with autism spectrum disorders, they experience greater levels of postural sway. Thus, based on the results of the current study, balance training can improve postural sway in different sensory conditions in children with ASD. Therefore, this training intervention can be used as a rehabilitation program to improve balance in ASD suffering children.

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