Effects of Taekwondo intervention on balance in children with autism spectrum disorder

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The purpose of this study was to investigate the effects of an 8-week Taekwondo (TKD) intervention on balance in children with autism spectrum disorder (ASD). A total of 14 children with ASD participated in this study. Eight children (eight males; mean age, 10.25 ± 2.38 yr) completed TKD intervention (50 min/2 times/8 week), and six children received no intervention serving as controls (five males, one female; mean age, 10.00 ± 2.83 yr). A computed posturography system with a long force-plate (NeuroCom Balance Master) was used to evaluate static (double and single leg stance with various test conditions) and functional balance (step-quick-turn). Balance was measured before and after the intervention. A mixed-model analysis of variance showed a significant group by time interaction in single leg stance balance. After the intervention, the TKD group displayed a greater improvement in single leg stance balance with eyes closed condition than the control group ($P = 0.046$). Within-group analysis showed that the TKD group significantly improved single leg stance balance with eyes open condition ($P = 0.014$). In addition, TKD group displayed trends of improvements in double leg stance balance with unstable surface under eyes closed condition (ES = 0.83) and step-quick-turn (Cohen d [ES] = 0.70). The control group did not show any significant changes in balance outcomes. In conclusion, TKD training can help children with ASD improve their balance. Children with ASD also showed a high rate of adherence (92%) to the TKD training. Our findings suggest that TKD can be a fun, feasible, and effective therapeutic option for balance improvement of children with ASD.

Keywords: Autism spectrum disorder, Developmental disability, Balance, Taekwondo, Martial art

INTRODUCTION

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by deficits in social communication and interaction, restricted interests, and repetitive behaviors (American Psychiatric Association, 2013). Children with ASD often experience difficulties performing fundamental motor skills, such as walking, running, and jumping (Green et al., 2009; Jasmin et al., 2009; Provost et al., 2007; Staples and Reid, 2010). Adequate balance is critical to perform proficient fundamental motor skills and participate in various forms of physical activity (Jasmin et al., 2009). Children with balance impairments may have increased risk of falling during performance, experience limited opportunities for learning advanced sport skills, and have difficulty engaging in physical activities in inclusive or community settings. Moreover, physical

limitations associated with disability are often accompanied by physical inactivity, which may lead to obesity and sedentary lifestyles (Hwang et al., 2014; Must et al., 2014). High levels of inactivity may hinder physiological, neurological, and psychosocial development in children (Rimmer et al., 2012; Stodden et al., 2008).

Several researchers investigated differences in balance development between children with and without ASD. Most of them agreed upon that children with ASD exhibit decreased postural stability and increased postural sway compared to their peers without disability (Fournier et al., 2010; Graham et al., 2015; Kohen-Raz et al., 1992; Memari et al., 2013; Minshew et al., 2004; Molloy et al., 2003). In addition, no significant association between balance improvement and age was found in children with ASD (Fournier et al., 2010; Memari et al., 2013; Minshew et al., 2004). Minshew et al. (2004) stated that balance does not begin to im-

prove until the age of 12 and rarely achieves adult level in children with ASD. These results indicate that balance deficits are apparent from early childhood and may persist throughout the lifespan.

To mitigate the balance deficits, previous studies have examined the effects of rehabilitation exercise programs on balance in children with ASD. Recreational activities, such as horseback riding and swimming, have been proposed as alternative therapeutic options. Two intervention studies involving horseback riding have found increases in the duration of single leg balance and balance-related motor skills using the Bruininks-Oseretsky Test of Motor Proficiency, the Pediatric Balance Scale, and the Activities Scale for Kid Performance (Silkwood-Sherer et al., 2012; Wuang et al., 2010). In addition, Yilmaz et al. (2004) reported swimming to be an effective therapeutic option for children with ASD and found significant improvements in the duration of standing balance under various sensory conditions and other components of fitness such as flexibility, muscular strength, and running speed. These studies provide evidence that participation in recreational activities can be effective therapeutic exercise options for children with ASD.

The effects of Taekwondo (TKD), a traditional form of Korean martial arts, have been studied to improve balance in people with and without disabilities. TKD generally involves punching, kicking, sparring, breaking, practicing self-defense techniques and Poomse, a combination of offensive and defensive movement sequences (Fong and Ng, 2011). Two studies have reported improvements in the duration of single leg balance and functional balance following TKD training in the elderly population (Brudnak et al., 2002; Cromwell et al., 2007). In addition, Pons van Dijk et al. (2013) found decreases in postural sway using a forceplate and increases in single leg stance duration and one leg hop distance in healthy adults. The effects of TKD training on balance have also been investigated in children with developmental coordination disorder (DCD), who demonstrate similar motor delays and balance deficits as children with ASD. The researchers found that following TKD intervention, children with DCD decreased postural sway during single leg stance compared to the control group who did not participate in the training (Fong et al., 2012; Fong et al., 2013). Overall, there is a consensus in the literature that TKD training has been effective in improving balance during single leg stance performance.

The purpose of this study was to investigate the effects of TKD intervention on balance in children with ASD. Previous intervention studies used various standardized motor assessments to examine the duration of standing balance and proficiency of balance-related tasks. The results of previous studies on balance in children

with ASD have been difficult to compare due to the methodological differences. This study provided more precise quantitative measure of balance using a forceplate, which will enable the results to be compared to previous studies using similar technology. It was hypothesized that there would be biomechanical differences on balance between the TKD and control groups following an 8-week TKD intervention. First, the TKD group would decrease postural sway during static balance tasks following an 8-week TKD training program. Second, the TKD group would reduce the time spent to complete functional balance tasks.

MATERIALS AND METHODS

Participants

A total of 14 children with ASD, between the ages of eight and 14 yr, participated in this study. Eight children with ASD (eight males; mean age, 10.25 ± 2.38 yr) completed the TKD intervention twice per week for eight weeks (50 min per session). Six children with ASD received no intervention and served as the control group (five males, one female; mean age, 10.00 ± 2.83 yr). The inclusion criteria consisted of (a) a formal diagnosis of ASD confirmed by a physician, (b) age of 6 to 15 yr old, (c) the ability to follow verbal instructions, and (d) the ability to participate a 50-min exercise sessions twice a week for 8 weeks. Prior to data collection, parent consent forms, child assent form, and medical release form from were obtained from each participant. The protocols of this study were approved by an Institutional Review Board.

Experimental procedures

All tests were performed in a balance analysis laboratory at a university-based therapeutic exercise facility. Participants were asked to wear comfortable exercise clothing and to be barefoot during the data collection procedure. Before balance tests, basic anthropometric data were obtained, including height and weight. Participants' demographic information is summarized in the Table 1. All assessments were completed before and after the intervention. The NeuroCom Balance Master (Neurocom International, Clackamas, OR, USA, 2010) was used to evaluate static (double and single leg stance) and functional balance (step-quick-turn, SQT). For static balance tests, the participants were instructed to stand still and place their hands on the hips. During the static balance eyes open trials, participants were asked to look straight ahead at a marker on a screen, which was adjusted to their eye level. Based on each participant's age and height, the NeuroCom Balance Master software generated foot positions and normative

Table 1. Participants' demographic information (n=14)

Variable	TKD (n=8)	Non-TKD (n=6)
Age (yr)	10.25±2.38	10.00±2.83
Sex, male:female	8:00	5:01
Height (cm)	121.31±0.60	138.68±14.02
Weight (kg)	97.19±44.65	87.55±30.20

Values are presented as mean±standard deviation.
TKD, Taekwondo.

data. The foot position was marked on the force plate with tapes to ensure that there was no variation between trials. If participants lost their balance during the test trial, the trial was discarded and repeated. If challenging behaviors, stereotypical ASD movements, or foot displacement occurred during a trial, the trial was replaced by an additional trial. For the functional balance test, the participants watched a video demonstration, provided by the NeuroCom software, for uniformed instruction. Participants performed practice trials for both sides. If participants were unable to follow the test protocol (e.g., turning to the opposite direction), the trials were replaced. Participants were given 1-min rest intervals between each test were provided. During the assessment, active spotters were positioned around the participants for safety.

Variables

Static balance tests

The double leg stance test measured sway velocity (degrees per second) under four sensory conditions – eyes open and closed on a firm stable surface, and eyes open and closed on a foam unstable surface. The surface condition was modified using a foam mat (medium density, 15 cm thick). The single leg stance test measured sway velocity (deg/sec) under four different conditions while participants were standing on one leg at a time – eyes open and closed with left leg, and eyes open and closed with right leg. Three 10-sec trials were measured for each condition, and the average sway from the three trials was recorded.

Functional balance test

The SQT test assessed turning performance by time (sec). The participants were instructed to take two steps forward (with a designated lead leg first), turn 180 degrees quickly in the direction of lead leg, and return to the starting point. Three trials were performed for both left and right side of turning, and the average time from the three trials were recorded for each side.

Intervention program

Participants in the TKD intervention group performed 50 min

Table 2. Intervention program

Program	Static activity	Dynamic activity	Time (min)
Warm-up	Stretching, jogging, & strengthening (sit-up & push-up)		10
Blocks & body punch			10
Upper			
Down	Wide stance	Walking forward/backward	
Inside			
Outside			
Kicking			10
Front	Fighting stance	Walking forward/backward	
Round house		Jumping	
Side			
Poomse	#1 (motion 1–8)	#1 (motion 10–16)	10
Cool down	Stretching, group game		10

of various martial art techniques twice per week for eight weeks. The intervention was held at a private martial arts studio. The TKD intervention program consisted of 10 min of warm-up, 20 min of block, punching, and kicking, 10 min of Poomse, and 10 min of cool-down. A sample of TKD intervention regimen is provided in Table 2. The TKD intervention was led by qualified TKD instructors including the primary researcher.

Statistical analysis

A 2×2 mixed model analysis of variance was used to analyze the overall effect of the TKD intervention between the TKD and control group (group by time effect). When a significant group interaction was found, a paired t-test was used to examine pre- and postintervention differences. All statistical analyses were performed using IBM SPSS Statistics ver. 22.0 (IBM Co., Armonk, NY, USA) with the significance level at 0.05. Cohen d (ES) was reported for mean differences with small (0.2 to 0.49), moderate (0.5 to 0.79), and large effect (≥0.8). After the eight-week TKD intervention, mean adherence rate (percentage) was reported when participants completed more than 80% (40 min) of each session. Adherence was defined as the percentage of total sessions (128) that were completed. A session was considered completed when participants achieved greater than 40 min of the total 50-min exercise session.

RESULTS

All participants completed the intervention and balance assessments in this study without any falls or injuries and were included in the final data analysis. The TKD group attended 118 sessions out of the 128 total, achieving a 92% adherence rate.

Table 3. Between- (group by time interaction) and within-group (time effects) difference after 8-week Taekwondo training

Variable	Group	Pre	Post	P(G×T)	P(T)	Cohen d
Double leg stance						
Stable EO	TKD	0.63±0.20	0.59±0.13	0.423	0.417	0.2
	Control	0.61±0.23	0.78±0.30			
Stable EC	TKD	0.88±0.35	0.80±0.18	0.865	0.574	0.3
	Control	0.87±0.37	0.85±0.22			
Unstable EO	TKD	1.21±0.44	1.08±0.26	0.49	0.335	0.4
	Control	1.31±0.44	1.26±0.55			
Unstable EC	TKD	2.17±0.79	1.61±0.56	0.364	0.055	0.8
	Control	2.32±0.62	2.00±0.35			
Single leg stance						
Right EO	TKD	4.50±4.16	2.14±1.28	0.436	0.147	0.9
	Control	5.09±4.39	4.61±3.99			
Right EC	TKD	10.03±2.36	8.26±4.09	0.046*	0.223	0.5
	Control	12.00±0.00	11.47±1.31			
Left EO	TKD	4.56±3.52	2.49±2.47	0.204	0.014*	0.7
	Control	6.39±4.66	5.73±4.10			
Left EC	TKD	9.29±2.56	8.14±3.63	0.226	0.316	0.4
	Control	11.49±1.25	9.51±3.90			
Step-quick-turn						
Right turn	TKD	2.10±1.02	1.52±0.59	0.893	0.073	0.7
	Control	2.10±1.27	1.64±0.70			
Left turn	TKD	1.71±0.70	1.68±0.77	0.498	0.827	0.1
	Control	2.20±1.35	1.86±0.99			

Values are presented as mean±standard deviation.
G×T, groups (Taekwondo and control) by time (pre and post) interaction; T, time effects; EO, eyes open; EC, eyes closed; TKD, Taekwondo.
*P<0.05.

Following the 8-week TKD intervention, group by time interaction was found in the single leg stance. The TKD group showed a greater decrease of sway velocity during right single leg stance under eyes closed condition (P = 0.046) compared to the control group. Within-group difference between pre- and postintervention in TKD group was also found in the single leg stance test. The TKD group displayed a significant decreases of sway velocity during left single leg stance under eyes open condition (P = 0.014). after the intervention compared to their baseline. The control group showed no significant difference before and after the intervention (Table 3).

There were no statistically significant differences of sway velocity before and after the intervention in the double leg stance test and SQT test. However, the TKD group showed a trend of reduction in sway velocity, particularly during double leg stance under unstable surface with eyes closed condition (P = 0.055; ES = 0.8). The TKD group also displayed a trend of reduction in turning time on the right side only (P = 0.073; ES = 0.07) (Table 3).

DISCUSSION

This study aimed to examine the effects of an 8-week TKD in-

tervention on balance in children with ASD. Following the TKD intervention, children with ASD showed balance improvement during right single leg stance under eyes closed condition compared to those who did not participate in the intervention. Children with ASD in the TKD group also improved their balance during left single leg stance under eyes open condition compared to their baseline performance. Children with ASD in the control group also showed a slight balance improvement under the same condition; however the differences were negligible. In addition, children in the TKD group displayed trends of balance improvement in the double leg stance under unstable surface with eyes closed condition and the SQT on the right side. The projected study outcomes were that the TKD group would decrease postural sway during double and single leg stance tasks and complete the turning tasks quicker following an 8-week TKD training program.

Our findings of decreased postural sway during the single leg stance test after the TKD intervention are consistent with previous studies. Previous studies have identified that participation in TKD training can enhance single leg stance balance in healthy individuals (Brudnak et al., 2002; Cromwell et al., 2007; Pons van Dijk et al., 2013). In particular, Pons van Dijk et al. (2013) used

biomechanical measure of sway path and sway area during double and single leg balance and found significant decreases of postural sway after the TKD intervention. Researchers have also reported the benefits of TKD intervention in children with DCD (Fong et al., 2012, 2013). After three months of TKD intervention, children with DCD significantly decreased postural sway during the single leg stance compared to those who did not receive TKD intervention (Fong et al., 2012, 2013).

The general assumption behind this method is that the kicking practice of TKD can be an excellent way to develop balance since it provides an opportunity to practice single leg stance while maintaining a stable body posture (Brudnak et al., 2002; Fong et al., 2012, 2013). The improvement in single leg stance sway found in our results may be explained by kicking practices in TKD. Kicking is a primary component of TKD and requires stable balance on one leg. Repeated practice of kicking while standing on one leg may improve the ability to maintain balance during the single leg stance. Therefore, children who practice TKD may develop better postural control and body alignment while single leg standing. Kicking practice also develops strength in the lower extremities and core, which may result in improved balance (Fong et al., 2013). An improvement in knee extensor (quadriceps) strength was found after three months of TKD practice in children with DCD (Fong et al., 2013). The authors explained that the positive change found in the single leg stance may be related to the improved isokinetic knee extensor muscle strength obtained during TKD intervention.

Although there was no statistically significant difference, children with ASD in the TKD group showed a trend of balance improvement during the double leg stance. Children with ASD performed the double leg stance test under various sensory conditions with eyes open and closed on stable and unstable surface. Interestingly, the greatest balance improvement was observed when the test was the most challenging of the four different conditions; standing on an unstable surface with eyes closed. There was little to no change in balance under the other three conditions. It may be that the most difficult balancing task had the most room for improvement between the beginning and the end of the TKD intervention. The majority of the participants (five out of eight children with ASD) improved their postural control in this condition after the TKD intervention, while three participants showed no improvement. Also, children with ASD who had poorer balance at the baseline showed greater improvement after the TKD intervention. The length of the TKD intervention may have been too short for gains by all participants. Many TKD intervention stud-

ies report intervention periods of three months or longer and this may add to their effectiveness.

There was no statistical significance for both right and left turning performance during the SQT. Yet children with ASD in the TKD group demonstrated a trend of balance improvement, with a large degree of variation. Five out of eight children with ASD performed right turn faster compared to their baseline performance. Turning ability to the left side did not appear to change before and after the intervention. This variation may be associated with different limb dominance of participants. Although the TKD program was designed to practice both legs equally, the participants appeared to be more comfortable standing on their supporting leg compared to their dominant leg (kicking leg) during training. Based upon the limb used to kick a ball (Seeley et al., 2008), we classified seven children with ASD as right side dominant and one child as left side dominant. This may explain why postural control on the left leg improved during the static balance task. While performing the right side kick in TKD, the left leg is forced to support one's body weight and repeatedly perform a single leg stance. On the other hand, while standing on the left leg, the right foot consistently practiced various forms of kicks moving in different planes of motion (e.g., Sagittal plane with front kick, transverse plane with roundhouse kick, frontal plane of side kick), which may have led to the trends of improvement observed in the SQT.

A few limitations should be taken into account when interpreting the results from this study. First, the sample size of this study is small so our findings cannot be generalized to the entire population with ASD. Second, test protocols such as the 10-sec double leg standing in less challenging conditions may not have been sensitive enough to detect differences before and after the TKD intervention. Many postural sway assessments use time of 20 to 30 sec. Lastly, the short intervention time may have limited the amount of improvement. This may be one reason that trends of improvement were apparent for several variables but findings were not statistically significant. Therefore, it is suggested that future studies use a larger sample size and increase the duration of the TKD intervention. Additionally, it is recommended that future studies explore the relationship between severity of ASD and the effectiveness of TKD. The participants who had poorer postural control in the beginning showed more improvement after the intervention; however, we did not have any clinical measures of symptom severity of ASD.

In conclusion, children with ASD experienced improvements of postural control following participation in eight weeks of TKD

intervention. Moreover, the participants showed high adherence to the TKD sessions (92.3%) and both the participants and their parents reported enjoying the sessions and being involved in the activity. Based on the findings of this study, TKD may provide an effective and enjoyable therapeutic option for children with ASD. This study outcome will aid clinicians and researchers, when developing a therapeutic intervention for children with ASD.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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